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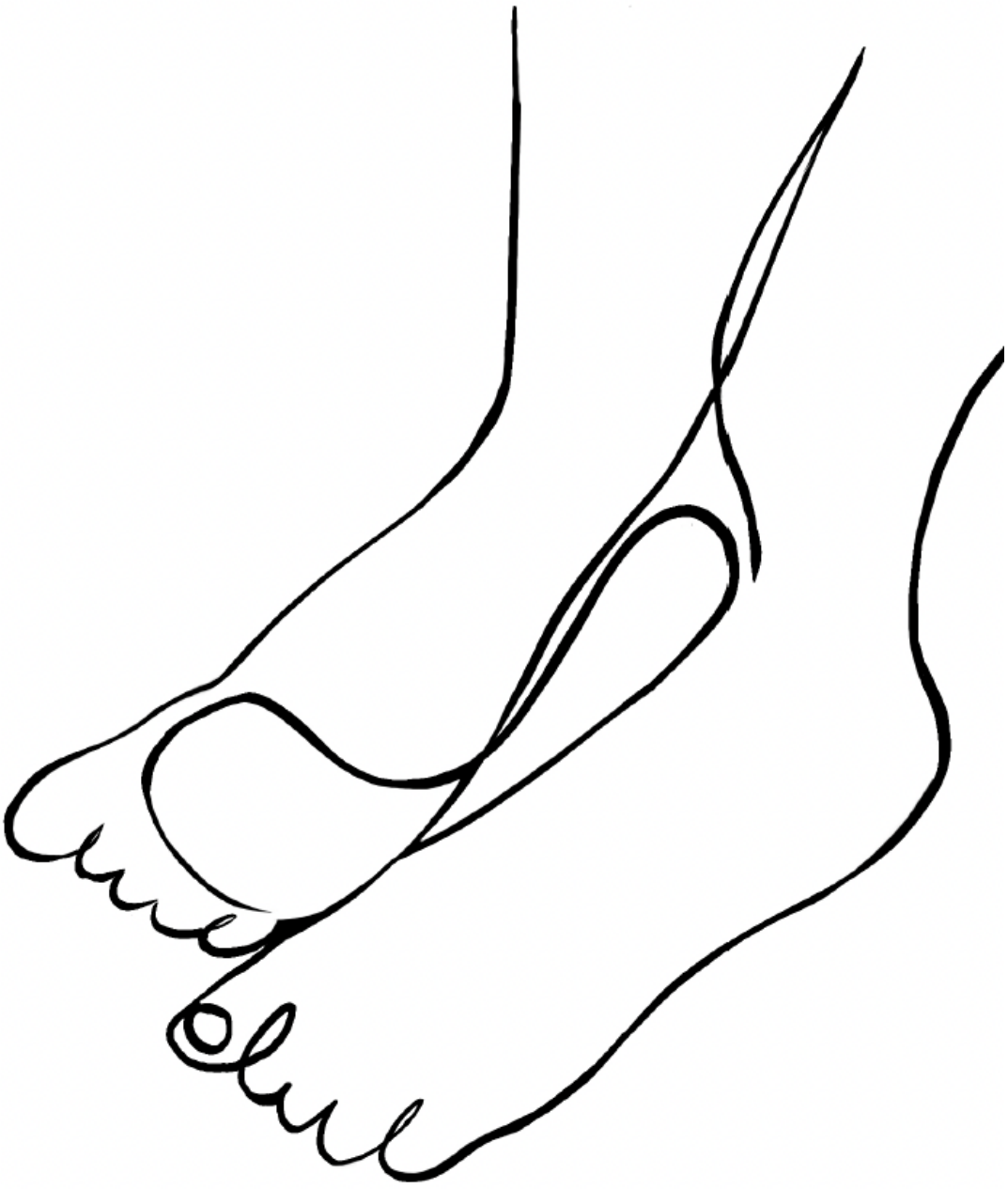

NATIONAL FOOT & ANKLE REVIEW

2022–2023
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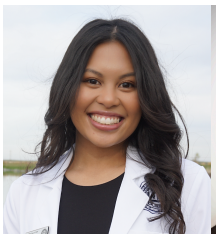
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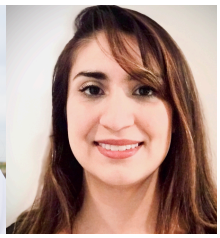
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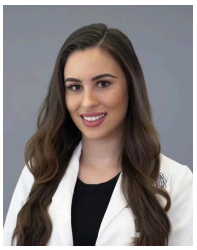
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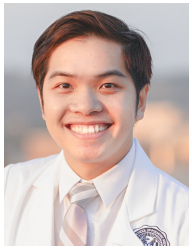
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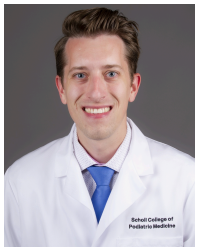
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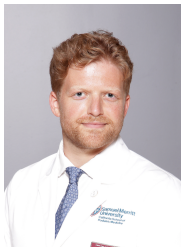
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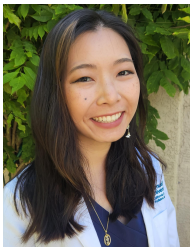
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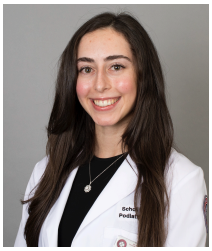
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A NOTE FROM THE EDITORIAL STAFF:

Welcome to the 25th volume of the *National Foot and Ankle Review (NFAR),* an academic journal produced by students at the Samuel Merritt University College of Podiatric Medicine (SMU-CPM). Each article is written by student authors and is peer-reviewed by student editors throughout the course of the academic school year. This year's journal is unique as it is the first time we have had student editors from an additional podiatry school, Scholl College of Podiatric Medicine (SCPM).

As an editorial team, we thank all the student authors who submitted manuscripts for review. We wish our fellow students' success in their future endeavors and a rewarding lifetime of learning. It was a pleasure working with you all.

Next, the editorial staff would like to gratefully acknowledge our faculty advisor, Dr. Eric D. Stamps, for his invaluable guidance and keen editorial eye. We also thank Dr. Albert Burns, the founder of this journal, for his many years of dedication.

We dedicate this 25th volume of the National Foot and Ankle Review to Dr. Chia-Ding (JD) Shih, who motivates students to actively engage in research and cultivate compassion as future physicians. Dr. Shih exemplifies unwavering commitment to the fields of podiatry, public health, community service, and academia. We extend our heartfelt gratitude for his invaluable contributions to teaching at Samuel Merritt University College of Podiatric Medicine and extend our sincerest well-wishes as he embarks on his journey at the Keck School of Medicine at the University of Southern California.

Finally, thank you for your support and readership of the *National Foot and Ankle Review*. We are proud to present the final product of our work this year.

CONTENTS

National Foot & Ankle Review

KENT STATE UNIVERSITY
College of Podiatric Medicine

Association between Gout and Osteoarthritis: A Literature Review

Sudharshana Priya Kanduri, B.S., Pankti Patel, B.S., MCF

ABSTRACT

Gout is an inflammatory disorder resulting from elevated uric acid; osteoarthritis (OA) is a non-inflammatory disorder that involves cartilage destruction occurring at the joint spaces. Evidence states that they both commonly affect the 1st metatarsophalangeal joint (MPJ); however, the association between both joint disorders has been less commonly studied. In this literature review, studies that identified any correlation between gout and OA were investigated and their results were summarized. Seven relevant articles were analyzed from the PubMed database. As a result, certain biological markers, such as NALP3 inflammasome, IL-1β, prostaglandin E2, and Il-18, were identified to explain the association between gout and OA. Additionally, certain characteristics of gout were identified as contributing factors in the development of OA as a secondary condition. By understanding these connections, new pharmacological therapies can be created to prevent the development of these diseases in high-risk patients.

INTRODUCTION

Gouty arthritis, the most common form of inflammatory arthritis among adults, results from chronic elevation of uric acid levels which then deposit as monosodium urate crystals in the joints.[1] Uric acid is generated through the breakdown of purines, and elevated levels typically result from either overproduction or underexcretion of uric acid. Gout commonly attacks one joint at a time. A qualitative synthesis showed that eleven studies involving 2,325 patients had a prevalence of 73% acute 1st metatarsophalangeal joint (1st MPJ) arthritis.[2] Less common sites include midfoot joints, ankles, knees, wrists, heels, fingers, and elbows. Risk factors include male sex, increased age, hypertension, postmenopausal females, obesity, congestive heart failure, metabolic syndrome, diabetes, insulin resistance and/or impaired kidney function.[1] Taking diuretics, consuming alcohol, and eating or drinking foods with high fructose and purine enriches can also contribute to uric acid elevation. The distribution of gout is uneven across the world, with the highest prevalence in South Pacific Ocean countries. Developed countries have greater prevalence when compared to developing countries. Demographic factors such as age, sex, and ethnicity influence the prevalence of gout. For instance, ethnic-related differences in diet, genetics, and comorbidities may increase the chances of developing gout, and this may explain the greater prevalence in developed countries.[2] Acute gouty arthritis is currently treated with colchicine, nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroids, or a combination of both.[1]

Osteoarthritis (OA) on the other hand, is the most common form of arthritis in humans, affecting 3.3 to 3.6% of the population worldwide.[3] It is associated with impaired structure and integrity of articular cartilage which causes changes in the underlying bone and the joint margins. Anatomical factors, increased age, obesity, female sex, muscle weakness, and joint injury from increased activity are risk factors for developing OA. The two types of OA are primary and secondary. Primary OA is the most common subset and is diagnosed when there is no predisposing trauma or disease, whereas secondary OA occurs when there have been pre-existing joint abnormalities such as trauma, congenital joint disorders, or inflammatory arthritis. Commonly affected sites include the 1st MPJ, sesamoids, the medial column of foot, knee, hip, finger proximal interphalangeal joints, and distal interphalangeal joints.[3] Unlike gout, the ankle joint is less commonly affected in OA. Pharmacological treatments include topical creams (capsaicin), oral medications (NSAIDs), acetaminophen, tramadol, glucosamine, chondroitin, and intra-articular injections like corticosteroids and hyaluronic acid derivatives.[3]

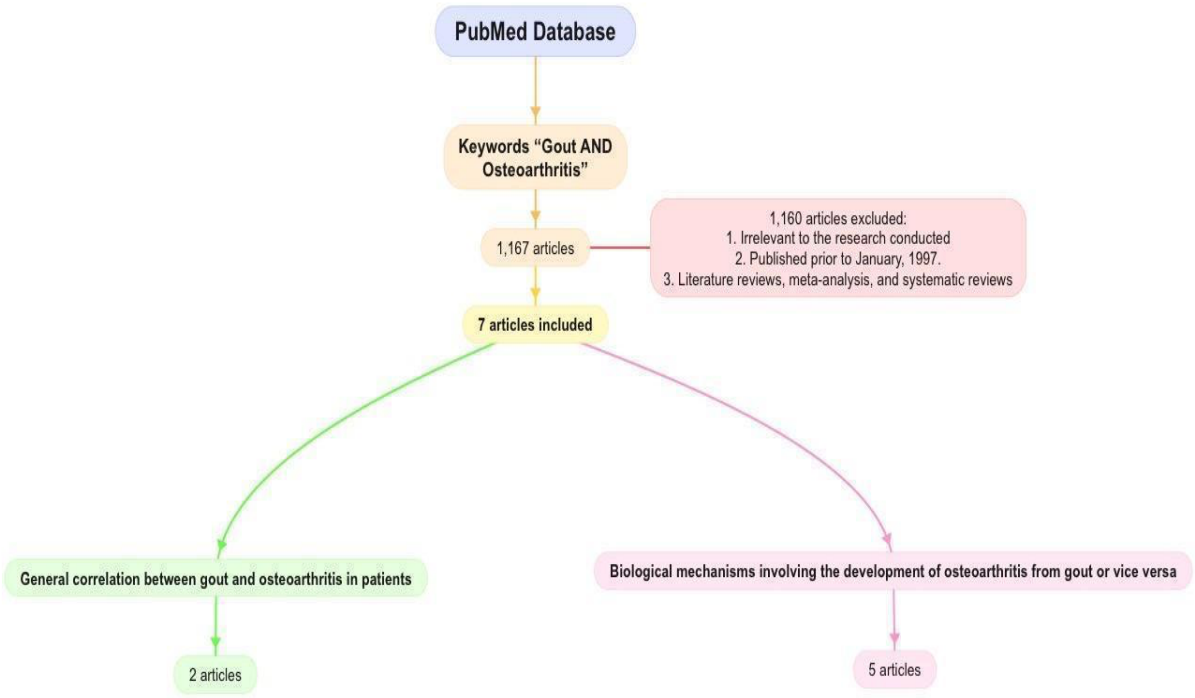
The link between gout and OA has long been recognized because they both affect the 1st MPJ and include similar risk factors. In large, controlled studies, joints that have been affected by acute gouty attacks were more likely to display radiological features of OA than joints that had not been the sites of a previous gouty attack.[4] The mechanism of how this relationship occurs is unclear. In this literature review, we investigate

the association between gout and OA to identify possible mechanisms that link the two conditions.

METHODS

A PubMed database search with keywords "Gout and Osteoarthritis" yielded 1,167 results, published between the years 1937 and 2022. Literature reviews, meta-analyses, and systematic reviews were excluded because they use observational designs and qualitative methodology that may have already compared and summarized the results of individual studies on this topic. Case studies were excluded from our study as the data usually derives from a single individual and therefore cannot be generalized. For relevancy, only studies published after January 1997 were included. For this literature search, the studies were divided into two categories: studies that examined the general correlation between gout and OA and studies that examined the possible mechanisms of the development of OA from gout or vice versa. A total of seven articles were identified.

Figure 1: Inclusion and Exclusion Criteria



DISCUSSION

General Correlation Between Gout and OA In Recent Studies

Roddy et. al suggested that acute gout attacks are associated with OA at different joints.[5] The researchers used a two-phase method to conduct the study: a questionnaire administered via mail and a clinical assessment. The questionnaire asked patients whether they had a previous history of gout and suffered from a painful acute gouty attack. A past medical history questionnaire and a clinical assessment were obtained for each subject. The study found that the presence of gout was most common at the 1st MPJ as well as the knee, mid-foot, and ankle. A high correlation between the sites of acute attacks of gout and the appearance of OA was found with a confidence interval of 95%. In 164 subjects with gout, a significant presence of OA at the 1st MTP joint, DIP joints, mid-foot, and knee was observed. It should be noted that one limitation of this methodology was a low questionnaire response rate. Another limitation was misidentification of gout, for example, calcium pyrophosphate crystals being mistaken for tophus or crystals on aspirates from the synovial fluid.

Bevis et al. hypothesized that there is an association between gout and OA because of an evident correlation between common risk factors.[6] A cross-sectional method was used along with radiographic OA scores to examine subjects over 50 years of age. A statistical analysis was done to determine the association using odd ratios and confidence intervals. There were 53 subjects identified with gout. The limitations of this study included a type II statistical error as well as a sample population that may differ from the

generalized population, which could mask the correlation between gout and OA. After adjusting for confounding factors and conducting univariable analysis, the researchers concluded that there was no significant association between gout and radiographic foot OA. However, they found that the patients with gout were four times more likely to have more than three foot joints affected with radiographic OA.
Both the Roddy and Bevis studies demonstrated a greater chance of foot joint OA after a gout attack.

Possible Mechanisms Involving The Development of OA From Gout or Vice Versa Through Specific Cell Signals/Markers

A possible explanation for the development of OA in joints with gout is inflammation induced by uric acid deposits. Shi et al. tested to see whether uric acid has any adjuvant activity that contributes to increased T cell activity in mice.[7] They used a pool of low molecular weight (LMW) fractions that had adjuvant activity, which markedly increased the induction of cytotoxic T-lymphocytes (CTL) responses. They compared the generation of CTL responses with highly purified uric acid. They found that the uric acid-enhanced CTL priming was very similar to those levels achieved by the LMW fraction. Moreover, they determined that the LMW fractions themselves contained uric acid, as their adjuvant activity was significantly reduced when uricase was introduced. In general, endogenous adjuvant activity markedly increases during cellular injury. Shi et al. observed that uric acid in the mouse cells increased significantly after treatment with heat shock, cycloheximide, and/or emetine. They also observed a fourfold increase in uric acid when cells were treated with ultraviolet radiation. Apart from this, uric acid was also found to be released from dying cells to stimulate dendritic cells to mature and augment the priming of CD8+ T cell responses to cross-presented antigens in mice. The evidence supports that uric acid is a physiologic warning signal which promotes cell-mediated immunity.

Martinon et al.'s research provides insight into the markers involved in uric acid-induced inflammation, which can be used to build on the evidence presented in Shi et al.'s research.[8] Peritoneal macrophages were taken from mice that lacked different key proteins of the inflammasome complex and were analyzed by the researchers. IL-1β, an endogenous pyrogen, has been identified as an important cytokine involved in triggering autoinflammation, and it is also found to be involved in pathways that allow for cartilage destruction. IL-1β works through the stimulation of various cytokines, nitric oxide, prostaglandin E2, and chemokines (IL-6, IL-8, and TNF-alpha) involved in joint inflammation. This results in the decreased synthesis of type II collagen and induces matrix metalloproteinase (MMP) and aggrecanase activity. Its production and maturation are initiated by the caspase-1-activating complex known as the inflammasome. This complex is important for sensing stress or endogenous danger signals generated by cellular injury or pathogens. When Martinon et al. compared the known activators of the inflammasome, such as lipopolysaccharide of the bacterial cell wall and extracellular ATP to monosodium urate crystals (MSU) in gout, they discovered that MSU had a larger role in activating inflammasome. This means that MSU crystals further feed into the IL-1β activation pathway leading to more inflammation through the inflammasome. Moreover, they observed that MSU crystals also induced the production of tumor necrosis factors. Although their research does not show how MSU crystals contribute to cartilage destruction leading to OA, it revealed a significant marker in the potential mechanism.

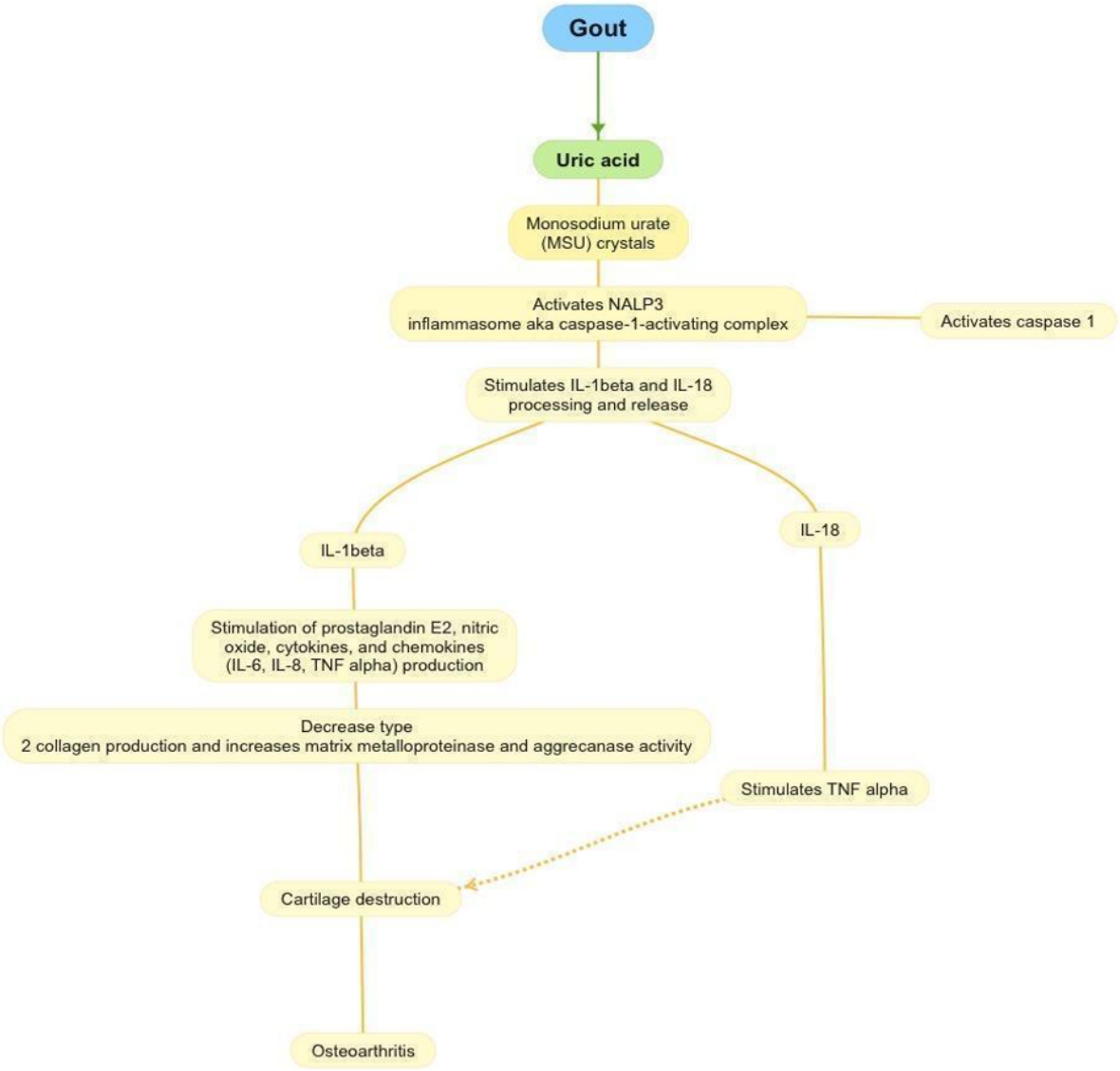
Smith et al. investigated the role of inflammatory cytokines in the development of early OA.[9] Synovial membrane samples were analyzed from 63 patients with knee pain during arthroscopy or during joint replacement. Biotin-labeled riboprobes and immunohistochemistry were used to observe the production of IL-1β, IL-1α, IL-1 receptor antagonist at the mRNA, and tumor necrosis factor-alpha in 20 of those patients. The researchers found the presence of tumor necrosis factor-alpha, IL-1α, and IL-1β cytokines in all patients with OA regardless of their status in the disease progression. With increasing grades of OA, there was a decrease in the ratio of these cytokines. This shows that inflammatory markers like tumor necrosis factor, IL-1α, and IL-1β may be involved in the earlier stages of OA. With Martinon et al. 's research, we observed that the inflammasome complex, stimulated by monosodium urate crystals in gout, activates the maturation of IL-1β leading to inflammation.[8] Smith et al.'s investigation adds to this and shows the possibility of IL-1β to cause the cartilage destruction seen in OA, allowing us to view the link between both diseases.[9] Smith et al.'s work, although substantial, has a very small sample size making it difficult to generalize the findings to a larger population.

Denoble et al.'s study in 2011 focused on the role of the inflammasome in gout-induced OA.[10] As seen in many studies, uric acid is present in normal cells with levels below 6.8 mg/dL and is known for its role in gout. When these levels are exceeded, NALP3 inflammasome is activated and it enhances the synthesis of IL-18 and IL-1β. The study further explores uric acid concentration in synovial fluid and its association with radiographic and scintigraphic OA. The synovial fluid was analyzed in 69 subjects. A P value of less than 0.0001 was seen with serum uric acid and synovial fluid uric acid, making these two variables strongly correlated with each other. On the other hand, synovial fluid uric acid and IL-18 also strongly

correlated with each other as the P value was less than 0.0001. Moreover, r2 = 0.176 and P < 0.0001 that show a statistically significant correlation were seen between serum-synovial fluid uric acid gradient and synovial fluid IL-18 and synovial fluid IL-1β. Therefore, a strong correlation was found between serum and synovial fluid uric levels as well as uric acid, IL-18, IL-1β, and TNF-alpha but only synovial fluid uric acid was strongly correlated with the severity of OA both radiographically and scintigraphically. Hence, it demonstrated that uric acid plays a significant role in the severity and pathology of OA. It was determined that the concentration of IL-18 and detectable levels of IL-1β correlated with the severity of OA. MSU crystals were unable to be assessed in joints, which led to a limitation in this study. There was no correlation between synovial fluid chondroitin sulfate and calcium pyrophosphate dihydrate, hence no correlation with the inflammasome cascade. Uric acid found in synovial fluid, IL-18, and IL-1β were correlated with the severity of knee OA. This leads to the involvement of the innate immune system in the pathophysiology of OA.

As mentioned previously, OA results from the degradation of articular cartilage in joints due to the inability to maintain long standing stress and pressure, and this may be a result of aging in general. The articular cartilage in joints is made up of chondrocytes which produce a matrix of collagen, proteoglycans, and non-collagenous proteins that maintain homeostasis in joints and help withstand any stress. Chhana et al. analyzed the implications for the development of cartilage damage through chondrocytes in gout which

Figure 2: Summary - Possible mechanism in the development of OA from gout:



could contribute to OA.[11] They found that MSU crystals reduced human chondrocyte viability. However, this effect on viability was only seen with the crystalline form of urate but not with soluble uric acid, which is interesting to see. This means that high serum uric acid levels do not necessarily contribute to cartilage loss and OA, but MSU crystals like those formed in gouty arthritis may play a role in developing OA. Moreover, human chondrocytes cultured with MSU crystals for 16 hours significantly increased the mRNA expression of aggrecanases, which are enzymes that lead to cartilage destruction in OA. However, there was no substantial change in the relative mRNA expression levels of matrix metalloprotease-13, an enzyme that also plays an important role in the breakdown of cartilage in osteoarthritic joints. MSU crystals also decreased the expression of the matrix proteins like collagen type 2α1, versican, and aggrecan. Aggrecan is a protein that provides a hydrated gel structure that allows the cartilage to have load-bearing properties; versican is a protein that plays a role in wound healing and inflammation; and collagen type 2α1 is needed for mechanical integrity in the extracellular matrix in the cartilage. When these matrix proteins are decreased, it paves a way for OA in joints. Morphologically, researchers observed cartilage near the MSU crystals was highly disorganized with a loss of normal hyaline cartilage architecture, empty chondrocyte lacunae, and surface discontinuity. This could also explain the pathogenesis of OA induced from gout. It is important to note that human chondrocytes and cartilage used in this study were taken from osteoarthritic joints, which accounts as a limitation in the study.

CONCLUSION

Various biological markers like NALP3 inflammasome, IL-1β, prostaglandin E2, and Il-18 were identified, which explain the positive association between gout and OA observed in recent studies. In this literature review, there is significant evidence of the association between OA and joint sites affected by gout. Whereas gout may attack joints with underlying OA, the development of OA may also be secondary to the inflammation induced by uric acid. In the latter instance, uric acid appears to activate the NALP3 inflammasome. Thus, enhancing the production of IL-1β and IL-18 and triggering innate immunity causing severe OA. These studies provided a basis for substantial pathways between gout and OA. Further illumination of these pathways can foster the development of effective prophylactic pharmacological therapies for high-risk patients. For example, OA is the most common form of arthritis in the elderly, and the burden has been increasing worldwide in the last two decades.[12] It is also a very disabling condition and may interfere with activities of daily living if left untreated. Therefore, if a substantial correlation is found between gout and OA, the presence of gout can act as a signal to a potential OA in the elderly and appropriate treatment measures for gout may prevent the induction of OA in joints. Moreover, the common pathways may allow researchers to find drug-therapies targeting specific biological markers that contribute to the development of either disease in joints.

ACKNOWLEDGMENTS

Dr. Jill S. Kawalec is the Research Director, Professor and Division Head for the Division of Pre-Clinical Sciences at the Kent State University College of Podiatric Medicine (KSUCPM). Dr. Lawrence S. Osher is the Professor of Radiology in the Division of Podiatric & General Medicine at the Kent State University College of Podiatric Medicine. Dr. Kawalec and Dr. Osher reviewed and identified any discrepancies or logical errors within the paper.

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National Foot & Ankle Review

TEMPLE UNIVERSITY
School of Podiatric Medicine

A Literature Review on The Correlation Between Adverse Childhood Experience Score and the Development of Diabetes Mellitus and Poor Diabetic Outcomes

Temitope Adebayo, B.S., Sharon Dei-Tumi, MPH

ABSTRACT

Adverse Childhood Experiences (ACEs) have been said to impact one's health in adulthood and can be used to assess associations between childhood trauma and chronic diseases. ACEs include traumatic experiences such as physical abuse, emotional abuse, sexual abuse, and incarceration. Chronic conditions associated with ACEs include obesity, diabetes mellitus, and cardiovascular disease. ACE scores are typically self-reported, with a higher score associated with a higher risk of developing several negative health outcomes. While associations between ACEs and diabetes mellitus have been reported, there have not been reports of a relationship between ACEs and diabetic sequelae. This literature review attempts to determine the correlation between ACEs and the development of diabetes mellitus and poor diabetic outcomes. Identifying and acting on this correlation could help the healthcare team deliver the best care for individuals with poor diabetes outcomes. The review identified a correlation between higher ACE scores and the development of diabetes, but there was no research on the correlation between ACEs and diabetic neuropathic foot ulceration and amputations. It is suspected that there may be a correlation between ACEs and diabetic foot ulceration and non-traumatic amputation, but more research is needed.

INTRODUCTION

Adverse childhood experiences (ACEs) refer to a broad concept that includes any form of household dysfunction that results in abuse, neglect, domestic violence, or imprisonment, particularly occurring before the age of 18.[1-5] In the original ACE study conducted by the Center for Disease Control (CDC) and Kaiser Permanente from 1995 to 1997, over 17,000 adults were asked if they had an ACE and almost two-thirds of them admitted to at least one.[6] This research highlighted the correlation between a high number of ACEs and the development of chronic health illness such as diabetes mellitus, cardiac disease, obesity, autoimmune disease, and even premature death. In 2019, a CDC Press Release reported an association of ACEs with at least five of the top 10 causes of death in the U.S.[7] This report included ACE data from the Behavior Risk Factor Surveillance System (BRFSS) in over 20 states from 2015 to 2017.

Globally, diabetes mellitus is a major driver for non-traumatic amputation.[7-11] This is because these patients have a higher likelihood of developing peripheral neuropathy resulting in an insensate foot. As a result, repeated injury or more common activities such as cutting one's nails may result in an ulceration.[7] In addition to neuropathy, many patients with diabetes mellitus also develop peripheral arterial diseases (PAD).[7,10] The presence of PAD decrease ulceration healing potential which results in a greater likelihood of infections and ultimately amputations. Once an ulceration develops in a diabetic patient, the risk for recurrence is as high as 65% in the first three years after initial closure.[7]

ACEs affect health through toxic stress. Although some levels of stress is normal, repetitive stress has negative effects, especially in children. In the early, developmental years of life, if stress accumulates, there is a disruption in the development of healthy hormonal systems and neural tissue.[15] Prolonged exposure to ACEs means more toxic stress which affects the endocrine, nervous, and immune systems, and these effects may last a lifetime. This literature review examines the correlation between ACEs and the development of not only diabetes mellitus but also poor diabetic outcomes, specifically diabetic neuropathic foot ulceration and amputation.

METHODS

The PubMed and Google Scholar databases were searched for studies reporting on the key terms "adverse childhood experience," "diabetes," "diabetic ulcers," and "non-traumatic amputations." In PubMed, studies were included that were clinical trials, meta-analyses, randomized controlled trials, reviews and systematic reviews – books and documents were excluded. Articles were selected if they were published after 2015,

had a free full article online and addressed the pertinent references. 50 articles, with at least level two evidence, were identified with this method, seven of which were selected. Additional articles were obtained from the reference list and by performing targeted searches – the original ACE study published in 1998 was identified by targeted research. 15 articles were selected and used in this literature review.

Diabetes and adverse childhood experience – 3/33
Non-traumatic amputation and diabetes – 4/17
Diabetic ulcers and adverse childhood experience – 0
Targeted search – 4
Extraction from references – 4

RESULTS

Of the articles retrieved, 33 were related to diabetes mellitus and ACE, of which three were selected. 17 articles related to non-traumatic amputation and diabetes mellitus were identified with four meeting the selection criteria. Of the 10 articles used in this review, four reported on ACEs and diabetes mellitus ACEs, obesity, and health-related behavior, and another on lower extremity amputations and diabetic neuropathic ulceration. No literature was identified referencing ACEs and diabetic foot ulcers and/or amputation.

DISCUSSION

ACEs, Age Distribution and Diabetes

Subramiam et al.[13] found an increased odds risk of type 1 and type 2 diabetes mellitus among children exposed to divorce or death of a parent. This study used the World Health Organization (WHO) International Questionnaire – ACE Iqs – to establish the prevalence of ACEs. The WHO ACE-Iqs is designed for individuals 18 years and older, as a global measure of ACEs, and their association with risk behaviors in later life.[14] The authors also found an association between ACEs and physiological changes among younger patients.[13] These changes included an elevation of inflammatory markers, free fatty acids, triglycerides, and blood glucose. Interestingly, in individuals above the age of 50, the authors noted a protective association and delayed onset of diabetes mellitus.[13] This association was identified among subjects who lived with someone with mental illness and emotional abuse, after controlling for demographic factors and health risk behaviors. [13] The authors concluded that while age is important in assessing the risk for diabetes mellitus, ACEs remain a more significant factor, especially among younger individuals.

A literature review by Hughes et al.[3] found that having to care for a child with diabetes mellitus may strain a marriage or translate into neglect of the child or both. This neglect worsened the control of diabetes mellitus. In addition, childhood trauma may also leave lasting neurological impressions that may interfere with child's self-confidence and social development. This interference could manifest as late onset type 1 diabetes mellitus or as lifestyle habits that may result in type 2 diabetes mellitus.[3] In adults, the authors reported an association between uncontrolled type 2 diabetes mellitus (adults on a combination of insulin and oral medication therapy) and increased ACEs.[3] They also identified an association between ACEs and a cluster of cardio-metabolic risk markers referred to as metabolic syndrome as well as systemic inflammation.[3]

ACEs, health-related behaviors, and diabetes

Stea et al.[5] observed an association between ACEs, health related behaviors in adulthood, and an increased risk of obesity. Their findings found a significant association among adults who recounted a difficult childhood, low physical activity, low consumption of fruits and fish, high consumption of sugar-sweetened beverages, and either low weight or obesity as a child. The authors also found a protective association between higher education and obesity, as compared to adults with no more than a primary education. Additionally, individuals with household dysfunction including abuse, neglect, or a prevalence of obesity had increased risk of chronic disease and psychiatric problems. These comorbidities inadvertently prevented individuals from engaging in healthy habits.[5]

Similarly, Hughes et al.[3] suggested that exposure to trauma was associated with increased risky behavior or unhealthy habits with additional factor such as use of cigarettes, low physical activity, and smokeless tobacco cited as potential mediators.[5] However indicated that survival bias could skew the association between ACEs and diabetes and recommended the need for trauma-informed methods of screening and treating childhood trauma.[5]

Diabetes, diabetic foot ulcers and amputation

According to Rathnayake et al., the global prevalence of diabetes by 2030 is expected to be over 10%.[10] Numerous studies have established a strong association between diabetes mellitus, foot ulcerations, infections and amputations.[7-11] Among diabetic complications and outcomes, foot ulceration of the diabetic foot is one of the most prevalent.[11] This is primarily from the natural progression of diabetes mellitus resulting in the development of distal peripheral neuropathy and peripheral arterial disease.[7,10] Diabetic foot ulcers (DFUs) as well as diabetic foot infections (DFIs) result in more dire consequences when compared to ulcerations in non-diabetic patients. On their own, DFUs and DFIs are associated with an increased mortality rate.[10] Additionally, most patients with DFUs or DFIs end up with lower extremity amputation either major or minor.[10]

A major amputation is an amputation above the knee. These are associated with severe physical impairment. [8] For patients who avoid amputation, Vuorlaakso et al.,[8] report a mortality rate of about 20% during the first year after a DFI related hospitalization. To put things into perspective, the authors included that the 5-year mortality rate after a DFI was greater than the rates for a patient undergoing hemodialysis, a post stroke patient, and a patient with STEMI without perfusion. After a 5-year follow-up, only one of 12 patients (8.3%) survived.[8] This data underscores the need to prevent the development of DFUs and DFIs.

Diabetes mellitus is a key factor in the development of ulceration and non-traumatic amputation. Diabetes mellitus in turn has been shown to be associated with ACEs which suggests that there might be a correlation between ACEs and poor diabetic outcomes

CONCLUSION

The relationship between ACEs and diabetes mellitus is clear although more data are needed to determine if ACEs have a higher correlation with type 1 or type 2 diabetes mellitus. Little data exists on the impact of ACEs on the etiology of diabetic neuropathic ulceration. There is, however, evidence demonstrating a relationship between diabetes mellitus, development of ulceration or amputation or both.[4] These markers are significant in creating an inflammatory state which delays healing.

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National Foot & Ankle Review

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Correlations Between BPH and Increased Likelihood of Gout: A Literature Review

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ABSTRACT

Uric acid is derived from purine catabolism, and overproduction of this byproduct can lead to detrimental effects, including uric acid calcification in the urinary tract and synovial crystal precipitation or gout. Gout is less commonly associated with benign prostate hyperplasia (BPH) as the pathophysiology of BPH is not typically thought to be related to gout; currently, there is minimal evidence to link BPH to gout. To identify relevant literature, the PubMed database was searched using the keywords "benign prostate hyperplasia AND gout." Eight articles on this topic were identified. The results linked the incidence of gout to BPH and revealed how drugs used to treat gout, like allopurinol, are also effective in treating BPH. However, no studies were conducted that correlated gout to BPH.

INTRODUCTION

Benign prostate hyperplasia

Approximately 50% of men over the age of 50 are likely to have BPH, and more than 80% are likely to have it as they approach the age of 80.[1] Benign prostate hyperplasia (BPH) is a common disease affecting elderly men and is often associated with lower urinary tract symptoms (LUTS). This condition causes various degrees of bladder outlet obstruction, which can harm patients.[2,3] According to Adedeji et al., BPH is a metabolic syndrome.[4] There are potential direct and indirect influences of several micronutrients and macronutrients that increase the risk of developing BPH. Their study found a weak correlation between BPH and several supplements, including lycopene, zinc, and vitamin D.[1] The trial also found that a diet with high levels of fat and red meat, in addition to low consumption of vegetables, was associated with an increased risk of BPH.

Gout caused by excess production of uric acid

Gout, a common inflammatory arthritis, affects males more often than females. In 2015 and 2016, the incidence of gout was 2.7% in women and 5.2% in men in the USA.[5] Its occurrence increases linearly and plateaus at the age of 80. The condition is often seen in high-income countries in the West, which has earned it the nickname "the rich man's disease." Diets high in purines, such as those that involve excess seafood, meats, fructose, and alcohol, are associated with this condition. A clinical manifestation of gout is crystalline monosodium urate deposition in synovial tissue. Gout typically manifests as acute monoarthritis of the first metatarsophalangeal joint.[6] While hyperuricemia contributes to gout, not everyone with hyperuricemia will develop gout.[7]

Uric acid

Uric acid is a waste product of purine catabolism, generated from the oxidation of DNA or RNA by xanthine oxidase, an enzyme found in the peroxisomes of cells.[8] The production of uric acid is part of the normal turnover of nucleic acids. However, high uric acid levels are often associated with gout, renal disease, metabolic syndrome, diabetes mellitus, and hypertension.[8] The increase of serum uric acid in humans is thought to be secondary to an ancient mutation where we lost uricase, the enzyme that converts uric acid to water-soluble allantoin.[9]Gout and hyperuricemia have been reported to be associated with chronic inflammation and oxidative stress.[10] It is also suggested that this may be a contributing factor of BPH. Gout patients have also been reported to have a higher incidence of prostate cancer.[10]

METHODS

A search was conducted on the PubMed database using the following keywords "Benign prostate hyperplasia AND gout." From this search, five articles were identified that were published within the past five years that were studied in humans. A second search using the keywords: "BPH and hyperuricemia" was used to find articles on the correlation between BPH and hyperuricemia, a cause of gout. From this search, two articles published within the past five years were found that were studied in humans. A third PubMed search used the keywords "gout AND diet" to find articles that showed how diet affects gout. From this search, two hundred sixty-nine articles were published on humans within the last five years. It was then narrowed down to twenty-seven using the filters on Pumbmed and only selecting review articles. A fourth PubMed search with the keywords "BPH and diet"

was conducted to identify studies that correlated diet and BPH. Fourteen articles were identified that were published within the past five years, the search was filtered using the PubMed filters to have articles written in English and studied in humans and to be review articles.

RESULTS

Kukko et al. examined 9,015 men who were either taking allopurinol or probenecid, of the 9,015 subjects, 67 of them took probenecid. Two groups were analyzed, one group received anti-hyperuricemic drugs, and a second group served as the control with no intervention. The authors found no risk difference for BPH between probenecid users and non-users. However, the observed BPH risk decreased with allopurinol. The lag time analysis of two years showed a decreased risk for the three BPH endpoints including BPH medication, BPH diagnosis, and BPH-related surgery. This decreased risk of BPH endpoint was not observed following two years of treatment with anti-hyperuricemic medication.[10] After two years, the decreased risk of BPH disappeared, it is only seen in men with a BMI above 27.3 kg/m2.[10]

Sangkop et al., examined the extent of the effect of urate on prostate cancer.[9] The study investigated the effect probenecid had on androgen-sensitive human prostate adenocarcinoma cells through inhibition of a urate transporter. The study found that changes in urate level, either in the plasma or intracellularly, impacted prostate cancer cell growth. Probenecid decreased the growth of the prostate cells by 37 % when compared to the control. The mechanism of how probenecid decreases cellular growth was not tested, however, it is thought to inhibit growth or promote apoptosis.[9]

DISCUSSION

Kukko et al., the risk for BPH was lower in men who received allopurinol compared to non-users.[10] Allopurinol, an anti-hyperuricemic drug, has antioxidant effects and lowers uric acid levels.[10] The efficacy of allopurinol was higher in men with high BMI. Allopurinol's mechanism of action includes decreasing the oxidative stress and chronic inflammation caused by obesity; therefore, it may reduce the risk of BPH in overweight men.[10] Allopurinol inhibits the enzyme xanthine oxidoreductase, which catalyzes hypoxanthine to xanthine and xanthine to uric acid, the last two steps of the urea cycle. Allopurinol inhibition decreases the production of uric acid; therefore, it reduces the uric acid level. High levels of uric acid are associated with oxidative stress-related conditions, including heart disease, gout, and BPH.[10] Allopurinol inhibits xanthine oxidase, which can lead to beneficial effects against BPH.

Activin A and B are known inhibitors of prostate cell activation and growth. Their function is known to be restored by uric acid-lowering drugs such as probenecid.[9] Such drugs are currently only indicated to treat gout. Sangkop et al demonstrated how not only does probenecid decrease uric acid levels, but also restores activin A and B, thus inhibiting the growth of LNCaP cells found in the human prostate by way of two mechanisms.[9] It stands to reason that if uric acid-lowering drugs such as probenecid prevent the growth of prostate cells in prostate cancer, the same would be achieved in BPH cells. Thus, patients being treated for gout would undergo comparatively more prostate cell inhibition than those not treated for gout and therefore would be less likely to develop BPH.

CONCLUSION

There is a high incidence of both gout and BPH occurring in elderly males. Probenecid and allopurinol have traditionally been used over the years to reduce hyperuricemia in order to treat gout. The studies also found that probenecid and allopurinol can also be used to help treat BPH. Further studies need to be conducted to determine if gout correlates to a higher incidence of BPH.

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National Foot & Ankle Review

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A Comparative Review of Hyperbaric Oxygen Therapy versus Ozone Therapy for Treating Chronic Non-Healing Diabetic Foot Ulceration

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ABSTRACT

Managing chronic non-healing diabetic foot ulcers (DFUs) is a common challenge faced by podiatric physicians. Non-invasive adjuvant therapies, such as hyperbaric oxygen therapy (HBOT) and ozone therapy, effectively promote oxygenation and growth factor-dependent wound healing in chronic non-healing DFUs. However, current literature lacks validated studies comparing these two treatment modalities. This comparative review aims to analyze and highlight the similarities and differences in the routes of application, mechanism of wound healing, treatment outcomes, cost, and adverse effects between HBOT and ozone therapy.

Study design: Qualitative systematic review of literature comparing two treatment modalities.

Methods: In October 2022, a literature search was performed in PubMed, Cochrane Library, and Google Scholar. A total of 33 articles were selected to identify the similarities and differences between the two adjunctive treatments, with 25 articles on HBOT and 8 articles on ozone therapy.

Keywords: HBOT, hyperbaric oxygen therapy, Ozone therapy, diabetic foot ulcers, chronic non-healing diabetic foot ulcers, adjuvant therapies.

INTRODUCTION: Currently, 9.26 million diabetic patients worldwide suffer from diabetic foot ulceration (DFUs). Initially, DFUs are treated with debridement, antibiotic therapy, dressing changes, and off-loading.[1] During regular visits to the clinic, wound characteristics, such as size and drainage changes, are monitored to assess wound healing status.[2,3] The healing state of a DFU is further impacted by various polymicrobial agents infecting the wound. As a chronic DFU persists, there is an increase in the probability of developing antibiotic resistance and a decrease in response to treatment such as mechanical or surgical wound debridement paired with frequent dressing changes.[2] Over time, with continued non-healing, advanced treatment modalities such as the use of growth factors, skin grafting, negative pressure wound therapy, and revascularization procedures may need to be considered.[4] In addition, studies have shown that non-invasive adjuvant therapies, including hyperbaric oxygen therapy (HBOT) and ozone therapy, effectively promote oxygenation and growth factor-dependent wound healing in chronic non-healing DFUs and may be employed to reduce healing time and ultimately diminish the risk of amputation.[5,6]

HBOT and ozone therapy are two non-invasive, gas-based adjuvant therapies available to patients. HBOT is an adjuvant treatment that increases oxygenation and requires patients to breathe 100% oxygen in a pressure chamber. [5] HBOT increases oxygen delivery to tissues and promotes wound healing by stimulating angiogenesis, increasing cell turnover, and by decreasing the risk of tissue necrosis.[7]

Similarly, ozone therapy is a gas-based therapy using olefin, a synthetic polypropylene or polyethylene fabric, treated with gaseous ozone, forming ozonized oils applied directly to the wound in the form of a patch or circulated in a sterile plastic bag isolated to the affected limb.[8] Ozone therapy has bactericidal effects, stimulates the release of wound healing growth factors, and increases fibroblast proliferation which enhances peri-wound healing.[6,9] This comparative review will examine the targets of wound healing for both therapies, treatment outcomes, and the potential adverse effects of each therapy.

METHODS: In October 2022, a literature search was performed in PubMed, Cochrane Library, and Google Scholar, and 33 articles were selected, with 25 articles on HBOT and eight articles on ozone therapy to identify the similarities between and variations in both adjunctive treatment options. Studies published between 2012

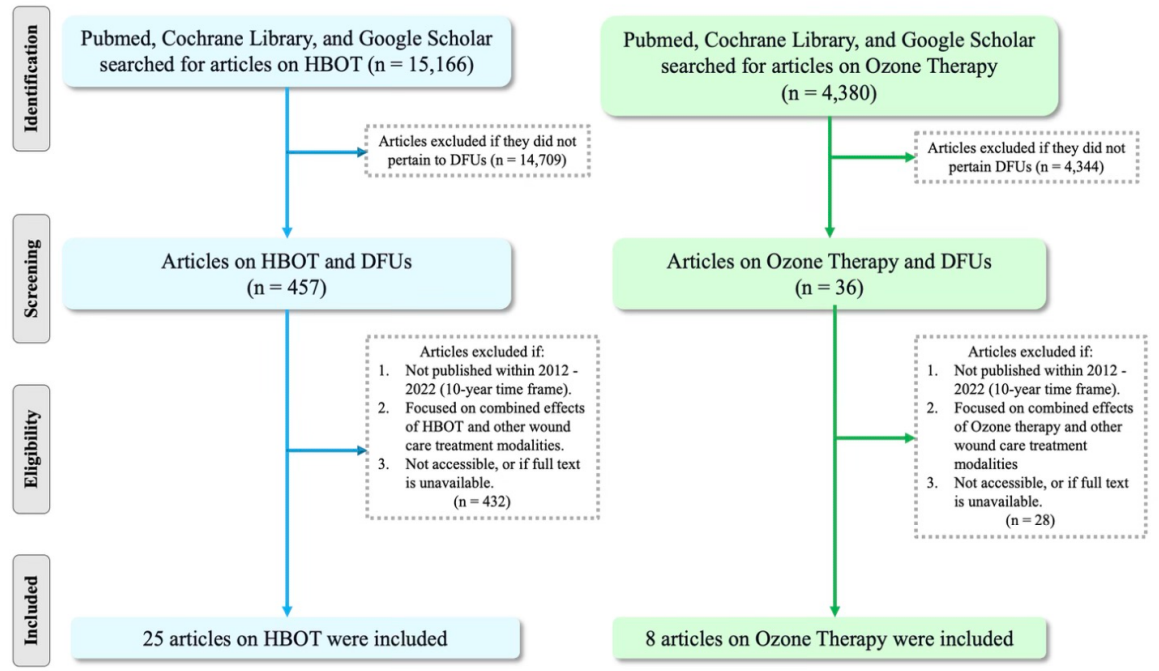

Figure 1. Article Section for HBOT vs. Ozone Therapy Comparative Review

– 2022 were included in this comparative review. Studies were excluded if they focused on the combined effects of HBOT and other wound care treatment modalities and if full text is unavailable. (Figure 1)

DISCUSSION

Routes of Application

HBOT is a full body experience that consists of patients entering a pressurized chamber that provides 100% oxygen at a pressure greater than sea level.[5] Typically administered at 2 – 2.5 atmospheric absolutes (ATA) for periods between 60 and 120 minutes once or twice daily.[5,10] A typical HBOT course might involve 15 to 30 sessions.[5] A more localized application of HBOT is available via topical oxygen therapy (TOT) devices, which consists of a cylindrical therapeutic chamber allowing for direct application of a 100% oxygen environment to the affected limb with the DFU.[11] However, TOT's smaller device size and localized application limit the ability to achieve high ATA ranges when compared to the full-body chambers of HBOT. [11]

Similar to TOT, ozone therapy administration for DFUs is localized to the affected limb or wound site, providing up to 5% ozone and 95% oxygen environment. Ozone therapy consists of a chemical called olefin, which is treated with gaseous ozone to form an ozonide delivered at atmospheric pressure into a limb bag, which has a flexible silicone cuff that helps seal the bag to the affected limb.[1,7] Wounds are thoroughly debrided before the foot or leg is placed inside the limb bag. A medical ozone generator connected to the limb bag aerosolizes the ozone solution, which is then circulated inside the bag, typically at an ozone dose of 70 µg/dL for 10 – 30 minute sessions over a 30-day period with a total of 10 sessions.[6,12]

Mechanism for wound healing

Impaired microcirculation in DFUs creates a hypoxic environment leading to decreased granulation tissue growth and diminished fibroblast production of collagen. HBOT's pressurized oxygen environment provides therapeutic effects by increasing the partial pressure of oxygen in arterial blood, stimulating angiogenesis, and improving tissue oxygen perfusion.[11] The revascularization effects in HBOT and TOT accelerate wound epithelialization by promoting granulation tissue growth and collagen production.[13] Unlike TOT, HBOT has added systemic effects by increasing insulin sensitivity in patients with diabetes mellitus and providing an additional physiological benefit by reducing blood glucose and HBA1C levels.[14]

During ozone therapy, the ozone molecule disassociates, resulting in an oxidizing effect on the DFU,

destroying proteins in bacterial cell membranes and leading to bacterial cell apoptosis.[14] Also, the ozone upregulates growth factors and activates the antioxidant system while preserving B-cell function, reducing hyperglycemia, edema, and inflammation of the affected peri-wound area.[3,6] Because ozone therapy consists of a 95% oxygen environment, it provides some therapeutic effects similar to HBOT by stimulating angiogenesis and accelerating wound epithelialization.[6,14]

Treatment outcomes

Wound healing outcomes for both treatments were accessed in various trials based on the outcome measures of wound size reduction, decreasing wound healing times, and reduced major amputation risk.

When HBOT was added as an adjunctive therapy to standard wound care, Ma et al. found that patients treated with HBOT had a statistically significant ($p<0.05$) decrease in mean ulcer area compared to the control group wound size reduction.[15] Santema et al. conducted a year-long multicenter, randomized, parallel-group superiority trial studying the reduction of healing time and concluded no statistically significant decrease in wound healing time with HBOT. However, long-term benefits in the HBOT treatment group were found, such as significantly fewer amputations performed proximal to the metatarsophalangeal joint and higher amputation-free survival in the HBOT group.[16]

In comparison, ozone therapy's antimicrobial effects lead to a statistically significant reduction in bacterial colonies after treatment.[18] However, Kabir et al. found no significant difference in DFU size and wound healing with ozone therapy.[18] In a blinded randomized clinical trial, Izadi et al. concluded that the average length of healing time with ozone therapy is significantly lower than the control group wound healing time.[19] Similar to HBOT's decreased risk of major amputation outcomes, combining ozone therapy with standard wound care treatment showed a significantly lower amputation rate in a systemic review by Wen et al., looking at treatment outcomes from 4 randomized clinical trials.[1]

Cost

HBOT and ozone therapy out-of-pocket costs vary by state and by individual patient healthcare coverage. The severity of the DFU, on Wagner's scale, can impact the number of sessions required for complete wound healing, further impacting the overall treatment cost.[5,6] While there were no statistically significant findings for cost-effectiveness for both treatments compared to standard care, a few studies noted an improved quality-adjusted life year (QALY) for patients with complete DFU healing due to the significant major and minor amputations averted when compared to standard care.[1,18] However, the difficulty in committing to weekly sessions for many patients due to socioeconomic factors contribute to a lack of compliance and completion of treatment course for both adjuvant therapies. [15, 18]

Adverse effects and Safety

Many HBOT studies have reported adverse effects in patients, such as barotrauma of the ear leading to ear pain, tinnitus, headache, and claustrophobia.[13] Khan et al. reported patients suffering from visual disturbances after HBOT, typically presenting as a reduction in visual acuity in 50% of patients receiving a 30-course treatment.[20]

Ozone therapy is regulated adjuvant therapy in several countries outside the U.S., but it is considered an unregulated therapy by the U.S. Food and Drug Administration (FDA). The FDA issued a warning against using ozone therapy for specific, adjunctive, or preventive therapy in 2019 due to the potential for ozone toxicity.[8] Lower concentrations of ozone used in clinical trials have minimal reported adverse effects, but concentrations greater than the efficacious dose can lead to ozone toxicity.[6,8] Exposure of a patient's mouth, nose, or eyes to ozone can result in temporary symptoms of coughing, nausea, vomiting, and headache.[8] Occasionally, patients experiencing ozone toxicity can present with temporary flu-like symptoms, known as the Herxheimer reaction.[8]

In both treatment modalities, TOT and the ozone limb bag, which deliver localized therapeutics, had lower systemic adverse effects by concentrating the treatment directly on the affected limb.[6,21]

CONCLUSION

Non-invasive adjuvant therapies such as HBOT and ozone therapy have great potential for enhancing wound healing in chronic nonhealing DFUs. Both treatment modalities promote wound healing by providing an oxygen-rich environment for the wounds.[11] The increased atmospheric pressure in HBOT promotes wound healing by stimulating angiogenesis and increasing oxygen perfusion to tissues. Ozone therapy provided the added benefit of having a bactericidal effect on DFUs by reducing bacterial colonies.[16]

A limitation of this review is the lower number of studies on ozone therapy compared to HBOT. A general literature search on HBOT and ozone therapy indicated a similar trend, revealing few papers published on ozone therapy. This trend can be explained by the fact that ozone therapy is not FDA regulated. Therefore the published clinical trials are from studies conducted outside

the United States. There is a strong case for conducting randomized trials to better define the extent of the benefits of the administration of both HBOT and ozone therapy in the specific treatment outcomes that are more impactful on the quality of life of a diabetic patient, such as lowering amputation risk, reducing wound size, and decreasing healing time. One of the more significant hurdles contributing to the evaluation of the efficacy of adjuvant therapies such as HBOT and ozone therapies is patient compliance with repeated sessions. With more studies and increased patient compliance, there will be a greater opportunity to access the benefits and safety of both therapies for clinical decision-making.

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National Foot & Ankle Review

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Hyperbaric Oxygen Therapy versus Topical Oxygen Therapy For Wound Healing: A Literature Review

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ABSTRACT

Oxygen is a necessary molecule for wound healing and is often the limiting factor in why chronic wounds may not heal. As chronic wounds commonly halt during the inflammatory phase of healing, it is important to optimize wound care therapy to help ensure optimal wound healing and to ultimately amputation. We conducted an updated literature review from 2016-2022 to highlight advances in hyperbaric oxygen therapy and local topical oxygen therapy for the treatment of chronic non-healing wounds. Hyperbaric oxygen therapy improves ulceration healing both in size and time when compared to standard treatment alone, and it reduces the necessity for amputation. Topical oxygen therapy traditionally costs less than hyperbaric oxygen therapy, is easier to administer in a variety of wound types and does not put patients at risk of systemic oxygen toxicity. Topical therapy does not, however, achieve pressures as high as hyperbaric chambers and current literature is more limited. Overall, more high-level evidence-based studies are required to support hyperbaric oxygen therapy and topical oxygen therapy as efficacious medical practices in chronic wound care.

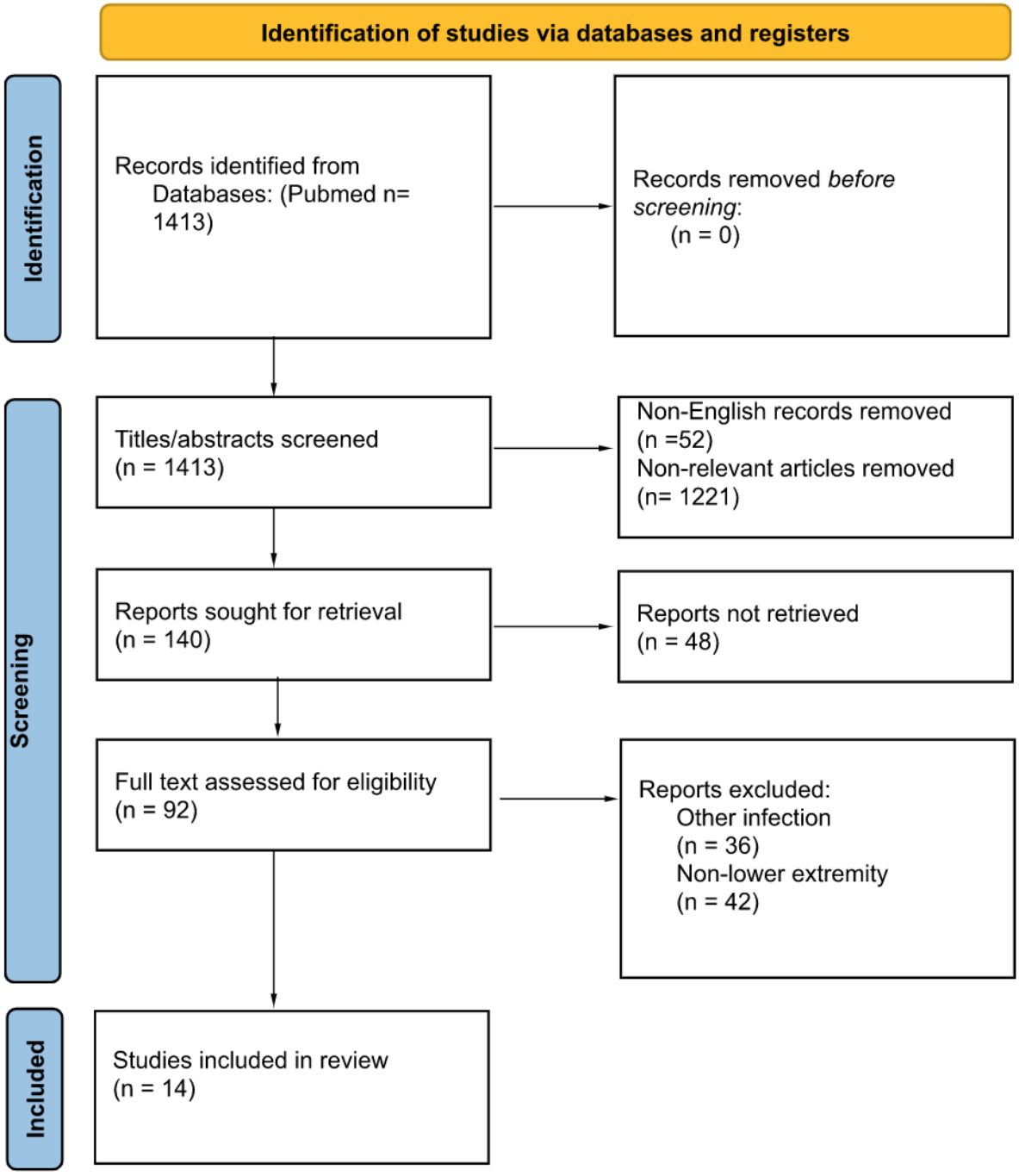
INTRODUCTION

Wound healing undergoes three chronological stages: inflammation (days 1-4), proliferation (days 4-21), and remodeling (days 21-2 years). When diabetic foot infections halt in the inflammation phase, it is important to use a variety of treatments to push healing into the proliferation phase. Diabetic foot infection often starts as a neuropathic ulceration. A standard treatment for diabetic foot ulcers is debridement of the wound base and edges. Newer research suggests using adjunctive therapies with debridement will optimize healing.[1] Current studies show that there is a direct correlation between hypoxia and delayed wound healing. In low-oxygen environments, bacteria can thrive and the neutrophils, fibroblasts and macrophages that carry out wound repair are unable to migrate and release cytokines that are essential to repair.[2] It is important to assess whether oxygen therapy can be used as an adjunct with debridement to decrease infection potential, increase healing and prevent limb amputation. Currently, it has been suggested that the partial pressure of oxygen that is optimal for wound healing should be between 50 and 100 mmHg.[2]Studies have shown chronic wounds to only have 10 to 30 mmHg of oxygen, as such the use of oxygen therapy should, in theory, stimulate wound healing.[2]

Currently two methods of oxygen therapy are used in wound care: hyperbaric oxygen therapy (HBOT) and topical oxygen therapy (TOT). HBOT stimulates healing through cell proliferation, antibacterial properties, and enhances angiogenesis which has reduced amputation rates.[2] Additionally, HBOT carries little to no negative side effects; the most common risk associated with HBOT being ear discomfort, which is easily remedied by equalization of middle ear pressure. Although there is a small risk of oxygen poisoning, this risk is greatly reduced when HBOT is used on small wound areas.[3] Topical oxygen therapy concentrates atmospheric oxygen and administers it through a fine tubing or through a lower extremity disposable chamber that encompasses the wound.[4] TOT is more advantageous than HBOT in that it is more cost-effective, easier to use both at the hospital and at home, and does not carry the risk of systemic oxygen toxicity.[4] Conversely, TOT does not achieve the efficacious pressures of HBOT and as such is often not covered by insurance carriers.[4]

METHODS

Table 1: PRISMA flow chart



Studies with reported use of hyperbaric oxygen therapy and/or topical oxygen therapy in lower extremity ulcers were searched in PubMed. Keywords of "hyperbaric oxygen therapy," "topical oxygen therapy," "diabetic foot ulcers," and "lower extremity" were used in the database search. Studies that were not done on humans, were not published in English, or were not in the lower extremity were excluded. Studies outside of the 2016-2022 range were excluded to maintain up-to-date review criteria.

RESULTS

Hyperbaric Oxygen

In hyperbaric oxygen therapy, the patient enters a chamber with 100% oxygen and the atmospheric pressure is gradually increased.[3] Patients receive varying lengths of treatments throughout the week based on their response to treatment. Treatment often takes months to achieve hyperbaric-induced neovascularization and wound healing. The use of hyperbaric

chambers has been used for decades to improve the healing of diabetic foot ulcers that have stopped responding to conventional therapies.[4] This has contributed to its increasing popularity as an adjunctive therapy in chronic diabetic wounds to reduce the risk of amputation.[4] In one study, HBOT was found to reduce the risk of amputation by 50%. [4]

The high pressure of the chamber, with 100% oxygen administration creates an optimal healing environment for an infected ulceration. HBOT enhances plasma antioxidant properties, which favors healing.[5] Moreover, oxygen promotes angiogenesis and vascular tone regulation which are important in reducing inflammation and suppressing anaerobic bacterial growth.[1] Irawan et al. found that HBOT reduces serum creatinine and HbA1c which increases wound healing and improves immune function.[6] Additionally, a 22.4% average drop in blood glucose has also been noted after 20 sessions of HBOT.[1] The literature shows that Wagner grade and degree of infection are integral predictors of amputation.[7] Chen et al. concluded that patients with a grade 3 Wagner ulceration had a 30% decrease in amputations, while patients with a grade 4 Wagner ulcer had a 52% decreased rate.

HBOT carries little risk of adverse reaction. A common complication is middle ear barotrauma, although this is easily prevented by educating patients on pressure equalization techniques.[4] The most serious risk associated with HBOT is fire, however, the National Fire Protection Association publishes standards for fire safety in clinics and hospitals using HBOT.[4] In rare cases, hypoglycemia was seen in some patients with diabetes mellitus receiving treatment. There have been references to oxygen toxicity seizures with HBOT, but these isolated cases only occurred in patients who did not exercise intermittent air breathing periods during each treatment.[2] There also exists specific training for the administration of HBOT to deliver HBOT effectively and safely. The largest drawback of HBOT in the realm of diabetic foot ulceration (DFU) is that it is only efficacious in chronic Wagner DFUs of 3 of greater. The financial cost of HBOT and time it takes patients to travel to an HBOT are also a concern.[8] Additionally, internal problems with referral pathways, lack of progression of care and poor follow-up with hyperbaric oxygen therapy all pose as drawbacks that need to be addressed.[8]

Topical Oxygen Therapy

Topical oxygen therapy (TOT) is an emerging therapy for treating non-healing wounds. The underlying concept includes the use of an oxygen generator to concentrate atmospheric oxygen and thin tubing with pads covered with conventional wound dressings or a small removable chamber that envelops the lower extremity. Topical application of oxygen allows oxygen to penetrate up to 700 mm into the skin surface.[9] A growing number of companies are developing devices that use this concept, one such device is the Natrox™ device. Tang et al. conducted a longitudinal, single-arm open prospective study looking at non-healing neuropathic ulcers over a 3-month period and found wound closure of at least 75% in 14 of the 20 patients they enrolled.[10] Another randomized double-blinded control trial was done using the TransCu O2® device and found a significantly higher proportion of patients healed versus those receiving standard of care only (46% vs 22%, P=.02). In addition to a greater number of patients healing, the rate at which they healed was significantly faster than those that healed with just standard of care therapy.[11] Furthermore, Thanigaimani et al. conducted a systematic review of six randomized control trials and found that topical oxygen therapy significantly increased the likelihood of ulcer healing compared to controls (risk ratio [RR] 1.94; 95% CI 1.19, 3.17; I2 = 57%; NNT = 5.33.).[12] This same group compared the topical oxygen therapy device TransCu O2® with wound vac therapy, SNAP Vac therapy, Dermagraft and Apligraf for wound closure. They found that the topical oxygen therapy device had a wound closure of 46% versus conventional therapies: 43% in Vac therapy, 30% in Dermagraft, and 50% in Apligraf. TOT was found to have no significant difference in the reduction of wound size, reduction in wound inflammation, and healing time or amputation rate between simple conventional moist wound dressings. However, the combination of TOT and conventional moist wound dressings had a significant reduction in all these categories.[13] This is further evidence that TOT is appropriate as adjunctive therapy with conventional standard of care.

Topical oxygen therapy provides advantages over HBOT including portability, the capacity for home therapy, integration of compression and moisture, and fewer contraindications than HBOT.[12] As the oxygen is delivered directly to the wound bed, systemic oxygen toxicity is not an issue with this therapy. No studies thus far have reported any adverse events directly due to the TOT devices Continuous diffusion of oxygen devices provides oxygen 24 hours a day, while other devices deliver it for many hours each day. More so, patient activity is not limited with TOT use. These advantages increase patient compliance and allow for more patient accessibility. Patients will need to be able to ambulate to their HBOT appointments, which is not required with TOT. This advantage can also help with keeping patients offloaded, if necessary.TOT is still in early development and further studies are needed to

support its use. Although the risks of TOT are few, there are disadvantages. The main drawback is that TOT cannot achieve high oxygen pressure, which may reduce healing rates. Even though the overall cost of topical oxygen therapy is less, these devices are often not covered by insurance.[4] This may be changing in the future as some TOT devices are reimbursed by the Veterans Affairs and other federal agencies such as the Department of Defense, Bureau of Indian Affairs, and Bureau of Prisons. The New York State Medicaid also provides reimbursement.[14] Further research and clinical applications are still needed to support TOT as an effective therapy.

DISCUSSION

Table 2: Advantages and disadvantages of both oxygen therapies: Topical Oxygen Therapy (TOT) and Hyperbaric Oxygen Therapy (HBOT)

	Advantages	**Disadvantages**
TOT	● Portable ● Compression and moisture to the wound ● Less contraindications ● Direct oxygen administration to the wound bed ● Easily accessible ● Patients can remain active ● Cheaper than HBO	● Low evidence currently exists on efficacy ● Not typically covered by insurance
HBO	● High pressure of oxygen delivered ● Little risk of adverse reactions ● Reduces serum creatinine levels ● Reduces HbA1c levels ● Decreased amputation risk in ulcers of Wagner grade 3+ ● Insurance coverage attainable	● Less accessible ● Patients must be sedentary during administration ● Expensive ● Low rates of follow up ● Systematic issues in chain of care and follow up

CONCLUSION

The literature confirms that HBOT and TOT work well as adjunctive therapies in wound healing. HBOT is well studied with proven efficacy in healing chronic Wagner Grade 3+ ulcerations, but has disadvantages that include a greater number of contraindications, higher cost, and patient compliance issues. Topical oxygen therapy is an emerging technology with fewer levels of proven efficacy , but it is easier to use with all wound types in combination with conventional wound therapy. Both oxygen therapies require further study with high evidence level and patient enrollment to conclude their efficacy on low-grade chronic wounds. A future study that includes a randomized trial with hyperbaric oxygen and topical oxygen arms would better provide evidence for a direct comparison of results between the two therapies.

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National Foot & Ankle Review

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A Literature Review: The Efficacy of Candida Albicans Immunotherapy in the Treatment of Verruca Plantaris

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ABSTRACT

Verruca plantaris, or plantar warts, are caused by the human papillomavirus (HPV); they first appear as a small, round area of rough or thickened skin on the plantar foot. Plantar warts often present as painless lesions but can become painful and cause discomfort. There are many methods for treating plantar warts, including laser therapy, chemical therapy, cryotherapy; and immunotherapy which uses a patient's own immune system to eradicate HPV infection. This review focuses on immunotherapy using *Candida albicans* antigen injection. Available literature suggests *Candida* intralesional immunotherapy is a safe and cost-effective treatment with greater efficacy than other methods, such as laser therapy and cryotherapy.

INTRODUCTION

Verruca plantaris and human papillomavirus

Verruca plantaris, or plantar warts, are caused by the human papilloma virus (HPV) which are benign proliferations of skin of the plantar foot. More than 100 types of HPV have been identified.[1] Plantar warts are a minor malady, but when left untreated, they can reach an average size of 0.5 cm or larger, which may curtail the activities of the person affected, owing to the pain caused by pressure on the warts.[2] HPV is usually found in a hot and humid environment and is spread by direct contact.[3] Pre-existing microtrauma of the epidermal barrier of the plantar foot allows the HPV to enter, where the virus actively divides in the basal epithelium until moving into the incubation period, usually lasting 1-20 months.[4] Statistically, verrucae plantaris is most likely to develop in the two to 12-year-old age group and is estimated to infect seven to 10% of the US population.[1,5]

The first sign of verruca plantaris is the formation of a small, semi-translucent macule, 1 to 2 mm in diameter without the appearance of inflammation. The macule tends to increase in size slowly until the diameter reaches a size of approximately 0.5 cm.[1] The incubation period of HPV also varies and is difficult to specify, as a number of factors affect its duration with varying routes of inoculation. Current literature suggests that typical incubation periods may vary from a few weeks to several years.[3] Most people are asymptomatic carriers of HPV, with plantar warts exhibiting an annual incidence of 14%. However, only 2% of the general population seek medical care for verrucae annually.[4] In populations that are vulnerable to verruca plantaris, such as immunocompromised individuals, the reasons for care-seeking include pain, embarrassment, and even cancers. [6]

There are many methods to treat verruca plantaris, including laser therapy, chemical therapy, and cryotherapy. The various treatment options currently available for verruca plantaris vary in effectiveness.[7] Immunotherapy using *Candida albicans* via injection is another treatment option. This method uses a patient's own immune system to eradicate HPV infection, with minimal adverse effects. However, the efficacy of *Candida* antigen therapy has not been well established. The goal of this paper is to review the available literature on *C. albicans* antigen therapy and compare treatment modalities for verruca plantaris.

Candida Immunotherapy

Candida albicans immunotherapy, a cost-effective and minimally invasive treatment for verruca plantaris, was first described in 2001.[5] *Candida* antigen therapy has been explored as an effective treatment with 2-5 injections to achieve complete clearance; the antigen injected is a dimorphic fungus that is present as a normal component of the human flora, and usually poses no threat to immunocompetent humans.[5,7] Although, *C. albicans* can be harmful if an individual is immunocompromised or if the normal body flora is disrupted.[5]

Candida antigen injection for wart treatment is thought to work by inducing a systemic T-cell mediated response; Th1 cells are activated, which causes a surge of cytokines including Interleukin-2 and interferon-gamma.[7] Cytotoxic and natural killer cells are produced as a result of the abundant cytokines and

eradicate the HPV infection, while ridding the overabundance of *C. albicans* in the body.[1,8]

The methodology of c*andida* injections for plantar warts has been described by several authors, although there are some variations. Using an insulin syringe, the largest wart or first known lesion is intradermally injected with 0.1-0.3 mL of a 1:1000 solution of *Candida* skin antigen.[5-9] Two studies described using an equal proportion mixture of candida skin antigen and 2% lidocaine for injection.[10,11] Patients return for injection therapy at 2-4 week intervals for a maximum of 3-5 treatment sessions, and studies have shown patients tolerate them well with minimal adverse effects.[5-12] The most common side effects experienced by patients include: pain at the site of injection, local erythema and mild flu-like symptoms.[5-12]

METHODS

Two online databases, PubMed and Google Scholar, were searched for relevant publications. Search terms included "verruca plantaris," "*Candida albicans* immunotherapy," "plantar wart," and "*Candida* antigen therapy." Inclusion criteria were applied and yielded articles published between 2008 to 2017. Articles that were heavily focused on unconventional techniques in the treatment of verruca plantaris were excluded.

DISCUSSION

Candida Immunotherapy Outcomes

Patients who undergo *Candida* immunotherapy for verruca plantaris have better outcomes when some form of tissue-destructive therapy was tried previously. In a retrospective medical record review published in 2015, Vlahovic et al. reported on the immunotherapeutic effect of intralesional *Candida albicans* injection for verruca plantaris.[5] This study included 80 patients who were treated for pedal verrucae between 2004 and 2007 with *C. albicans* injection; each individual was assessed for objective clinical findings, diagnosis and treatment.[5] Appropriate patient information such as sex, age, location of verruca, previous treatments, number and amount of *Candida* injected, and time to clearance and failure were recorded.[5] One injection of 0.1-0.3 mL of *C. albicans* skin antigen was intradermally injected into the first known lesion on the plantar foot at 1-month intervals; follow-up with patients was continued until all clearance criteria were met.[5] This study found an average of 4.68 treatments were required; 65% of patients responded with full clearance of plantar verrucae, while 35% had treatment failure.[5] Additionally, patients that received a tissue-destructive treatment before *C. albicans* injection were 2.769 times more likely to clear warts than those who had not (p-values <0.05).[5] Moreover, women were 4.308 times more likely to achieve clearance than men when a *C. albicans* injection was followed by a tissue destructive modality (p-values <0.05).[5] These findings suggest treating verruca plantaris with *Candida* immunotherapy after a previous tissue destructive treatment improves overall clearance rates.

In 2015, Garza et al. retrospectively reviewed records of children with recalcitrant and multiple warts who received intralesional injection of *Candida* antigen to determine the efficacy of this treatment.[13] From 2008 to 2013, 220 children treated with *Candida* antigen therapy for warts were reviewed; pertinent information including sex, age, location of lesions, number of lesions, and previous treatments were recorded.[13] Children were treated with *Candida* antigen only when they had greater than three warts or mosaic warts, and when previous treatments, such as keratolytics or cryotherapy, had failed.[13] One injection of 0.2 mL of *Candida* antigen was given in the largest wart or first known lesion at 3-week intervals.[13] This review found 156 patients (70.9%) had complete clearance of warts, 37 (16.8%) had partial clearance and 27 (12.2%) had failure.[13] Of the 156 patients who achieved complete resolution, the average number of treatments required was 2.7 and most of the warts that completely resolved were on the feet and hands.[13] Roughly two-thirds of the patients reviewed had plantar warts, of which 78% of them achieved complete clearance, which was the highest clearance rate achieved compared to other sites on the body.[13] Furthermore, 38 out of 47 patients that had distant warts not injected with *Candida* antigen achieved either complete or partial clearance.[13] Most patients experienced no side effects with the injection; 21 patients experienced bulla, edema, desquamation, febrile reactions, or pain.[13] This study further demonstrates the efficacy of *Candida* antigen therapy, especially after prior tissue-destructive therapy (cryotherapy or keratolytics) has failed.

Candida albicans versus other therapeutic agents

Besides immunotherapy other treatment modalities are available, including: topical salicylic acid, cryotherapy, intralesional injection of purified protein derivative, vitamin D3, and novel therapeutic use of MMR vaccines.

Liquid nitrogen cryotherapy freezes the plantar wart and the surrounding tissue. By rapidly cooling the cells, this agent disrupts cell membranes and alters their permeability. The subsequent thawing process induces cell death by causing an influx of water into cells. Khozeimeh et al. observed the effects of cryotherapy using liquid nitrogen and compared that with *C. albicans* injection.[12] At the end of the treatment course, patients had better responses to intralesional injection compared to cryotherapy (76.6% complete remission with *C. albicans* injection, 56.7% with

cryotherapy)[12]. The correlation between gender and therapeutic response was not available for both groups.

Wart treatment using purified protein derivative (PPD) injection has a mechanism similar to that of *C. albicans* injection. The PPD injection eradicates HPV using cell-mediated immunity to control wart growth via the production of Th1 cytokines. Nofal et al. compared the efficacy of *C. albicans* injection to PPD derivative. In this study, both the *C. albicans* and PPD injection therapy groups had greater efficacy than the control.[8] However, *C. albicans* had a statistically significant 82.5% complete wart clearance rate while PPD derivative injection had a 55.6% clearance rate. In addition, the recurrence rate after complete clearance was 2.3% for *C. albicans* injection, and 7% for the PPD group.[8,14]

The exact mechanism of action of vitamin D3 on a plantar wart remains uncertain, but several hypotheses propose that it involves immunoregulatory activities in cellular proliferation and differentiation.[11] By binding to vitamin D receptors that are located on various cells including melanocytes, keratinocytes, fibroblasts, and immune cells, vitamin D3 induces the expression of antimicrobial peptides.[15] A recent study by Abdlaal et al. examined efficacy distinctions between *C. albicans* and vitamin D3 injections. The team found no significant differences between the two groups. Both groups had complete clearance, and recurrence in treated patients was not significantly different.

The use of the MMR vaccine as treatment for plantar warts was investigated by Rageh et al. where the vaccine's efficacy was compared to that of *Candida albicans* antigen immunotherapy. Rageh et al. hypothesized that the use of MMR vaccine activates the immune system to recognize the injected viral antigens, stimulating the production of T cells in a delayed hypersensitivity reaction while working against the human papillomavirus (HPV), inducing its clearance. When compared to the intralesional injection of *C. albicans* antigens, the efficacy of the MMR vaccine is significantly lower (26.7% complete cure versus 80% complete cure in *C. albicans* immunotherapy); it also required more injections to reach complete clearance in this study group.[16]

Table 1. Summaries of Articles Reviewed in Literature

Author	Study Purpose	Participants	Findings
Vlahovic et al. (2015)	Retrospective medical review estimating the clearance rate and efficacy of *Candida* immunotherapy.	80 participants who were all injected with *C. albicans* antigen only.	Patients that received a previous tissue-destructive therapy before injection were 2.769 times more likely to clear verruca than those who had not ($p<0.05$, significant). 65% treatment success.
Khurshid et al. (2009)	Quasi-experimental study that compared the efficacy of *Candida* antigen injection versus saline injection.	60 participants (divided randomly into two groups). Group A = intralesional injection of *C. albicans* antigen with two percent lignocaine. Group B = intralesional injection of saline.	Group A had 67% effectiveness (greater than 60% resolution of warts). Group B had 20% effectiveness.
Alikhan et al. (2015)	Two-year retrospective chart review evaluating efficacy of *Candida* antigen injection for the treatment of verruca vulgaris.	100 participants needed greater than one candida antigen treatment to be included.	80% of participants had >50% response to healing. An average of 4.8 *Candida* antigen injections were received.
Nofal et al. (2021)	Compare the efficacy of immunotherapy with *Candida albicans* injection versus immunotherapy with purified protein	120 participants (divided randomly into three groups). Group A = intralesional injection of *C. albicans* antigen. Group B = intralesional injection of purified	A statistically significant difference was found between the studied groups in favor of *C. albicans* antigen.

	derivative.	protein derivative Group C = normal saline).	
Khozeimeh et al. (2017)	Compare the efficacy of liquid nitrogen cryotherapy versus immunotherapy with *Candida albicans* antigen.	60 participants (divided randomly into two groups. Group A = intralesional injection of *C. albicans* antigen. Group B = liquid nitrogen cryotherapy).	Intralesional injection of *C. albicans* antigen showed to offer a quicker result, fewer sessions, and capable of treating distant plantar warts.
Abdlaal et al. (2021)	Compare the efficacy of intralesional injection using vitamin D3 versus *Candida albicans* antigen for treating plantar warts.	40 participants (divided into two groups. Group A = intralesional injection of vitamin D3. Group B = intralesional injection of *C. albicans* antigen).	No significant difference is found between the two groups due to the limited participants.
Rageh et al. (2021)	Compare the efficacy of intralesional injection using *Candida albicans* antigen versus measles, mumps, rubella (MMR) vaccine for plantar warts.	60 participants (divided randomly into two groups. Group A = intralesional injection of *C. albicans* antigen. Group B = intralesional MMR vaccine).	Both are well tolerated, low cost and minimal downtime. However, *Candida albicans* antigen injection group resulted in a significantly higher cure rate than the MMR vaccine injection in the treatment of plantar warts.

CONCLUSION

Verrucae plantaris can be difficult to treat. This review's findings suggest that the use of *Candida albicans* antigen is an effective treatment for recalcitrant warts with minimal side effects. These side effects are most often limited to pain at the site of injection, local erythema, and brief mild flu like symptoms. However, *C. albicans* therapy is most effective only after another destructive treatment has failed. It should also be noted that this therapy usually takes multiple *Candida* injections at 2-4 week intervals to be effective. The contraindications include patients who have a diminished immune response, hypersensitivity or immunosuppressive disease. Further research needs to be conducted specifically on its use in the treatment of verruca plantaris with a focus on finding how long other treatments must be attempted before considering *Candida* injection, and the number of injections needed to eradicate HPV.

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National Foot & Ankle Review

Samuel Merritt University
College of Podiatric Medicine

Literature Review: Comparison of Bracing vs. Taping on Their Prophylactic Effects on Ankle Sprains

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ABSTRACT

The most common ankle sprain seen by physicians are lateral ankle sprains, which stem from injuries to the lateral collateral ligaments: anterior talofibular, calcaneofibular, and posterior talofibular. Studies have shown that both taping and bracing provide similar ankle instability prophylaxis; this review compares other parameters including: cost, accessibility, patient's confidence level with their ankle instability, and biomechanical effects. Pubmed was used as the primary database to identify literature, written within the past 10 years, about the prophylactic effects of taping and bracing for an ankle sprain. The literature shows that while both taping and bracing provide equal support for similar injuries, bracing is a more cost-effective solution being that it was reusable, whereas typically taping required reapplication several times weekly. While more research needs to be done to fully understand the psychological effects of taping and bracing, taping provided a higher sense of confidence and reassurance to athletes who were recovering from injury[6]. Biomechanically, both taping and bracing are similar in that support decreases with long periods of exercise. This review compares the differences and similarities between taping and bracing.

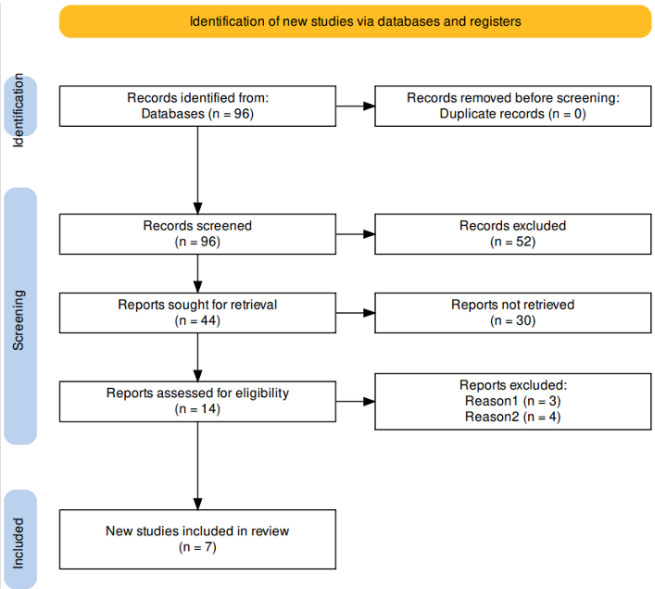
INTRODUCTION

Ankle sprains, especially inversion ankle sprains, are common, representing 25% of all musculoskeletal injuries.[1] The anterior talofibular ligament (ATFL) is the most commonly injured ankle ligament, and its rupture leads to more tension on the remaining ligaments and increases the internal rotation force on the foot.[1,2] If not treated properly, an ankle sprain can progress to chronic ankle instability. In fact, 30% of inversion ankle sprains become unstable.[3] However, there are preventive measures that can be taken to decrease the chances of chronic ankle instability.

Taping and bracing restrict range of motion (ROM) and increase proprioception to the injured ankle.[1] Although taping and bracing both help reduce ankle sprain risk, they have distinct advantages and disadvantages, as seen in literature comparing the two methods. Taping improves ankle stability by limiting the extremes of ankle ROM and improving musculoskeletal reflex contraction time, while braces can be rigid or semi-rigid allowing for a customizable level of support. Even though, there have been comparative literature between the two methods of ankle support, most of it only compares one aspect of taping and bracing. This comparative review will look at a more diverse range of the two methods such as the cost, confidence level of patients with chronic instability, and the biomechanical effects of ankle taping verse bracing. The expanded outlook in this comparative review will allow for a more inclusive analysis between ankle taping and bracing.

METHODS

Relevant publications from January 2010 to October 2022 were accessed through the online database, PubMed. Keywords searched are the following, "Ankle Taping," "Ankle Bracing," and "Ankle Instability." Inclusion criteria required that the journal articles



Reason 1: wrong treatment type
Reason 2: no comparison between taping vs bracing

be specific for primarily treating ankle instability with taping or bracing. Articles that did not highlight the efficacy of taping versus bracing for ankle instability were excluded. Two articles included a cost analysis. Two more studies included an analysis of the psychological effects of ankle racing versus taping. In total, seven articles were found to be relevant for this review, and all included a biomechanical analysis of taping versus bracing.

DISCUSSION

Costs

In a cost benefit analysis, Olmsted et al. assigned monetary values to the benefits of ankle taping and bracing. The authors determined the lowest cost as well as the effectiveness of each outcome.[2] The authors also assume the effects of taping and bracing were equal between intramural basketball and competitive soccer players.[2] Comparing the benefits of taping and bracing, the authors found that both taping and bracing appear to be beneficial in athletes with a history of ankle sprain. The cost of a single roll of tape was $1.37. It was assumed that it would take one roll of tape to cover one athlete's ankle, and that the athlete would be taped about 78 times within a 13-week season.[2] The cost of the brace was $35.00, and it was assumed that one brace would be used per ankle per season. Olmsted et al. found that ankle taping is about 3.05 times more expensive than bracing over the course of one season.[2] Zwiers et al. also supported this finding and concluded that bracing is more cost effective, as well as a better use of time.[4] The studies in tandem lead to the idea of ankle bracing being a better method of support for the ankle from a financial standpoint.

Perception of Stability

A less common approach to understanding why taping and bracing are frequently used treatments for ankle instability involves analyzing their psychological effects on patients. Geary et al. used a 4-point Likert scale to mark the level of stability athletes perceived during a balance test.[5] The test resulted in a significant difference between barefoot and taped conditions. The significance highlights an increased sense of confidence, stability and reassurance reported by athletes taping their ankles while performing a dynamic activity; athletes are more confident and have less anxiety that they will be injured while participating in their sport.[5] While there are positive aspects to this confidence, a paper by Simon and Donahue emphasizes that clinicians should be more cognizant of this perceived stability before using the taping and bracing methods on their patients or athletes as taping and bracing may create a false sense of security.[6] This notion may lead the athlete to take greater risks and therefore may increase their chance of injury or reinjury.

Biomechanical Effects

Ankle taping and bracing help prevent ankle sprains because they restrict ROM and they enhance proprioception. A current concepts paper by Zwiers et al. analyzes the biomechanical effects of taping and bracing on ankle sprains.[4] Taping creates more restriction of dorsiflexion at the ankle joint than bracing. In contrast, semi-rigid braces restrict eversion and inversion movement more. The total ROM restriction with taping is only 50%, and both bracing and taping lose their mechanical effects with prolonged exercise.[4] However, taping may allow enough time for the peroneal muscles to fire and slow down inversion and decrease the chance of an ankle sprain.[7] Semi-rigid bracing on the other hand has positive reinforcement on postural stability, maintaining balance during activities; taping did not improve postural stability.[4] A stable ankle joint can be created with either taping or bracing, as they both provide positive restriction to the joint; but they both have the same weakness in that their effectiveness decreases as exercise duration increases.

CONCLUSION

Taping and bracing are both mainstay methods of support for ankle injuries. While both are beneficial, it can be difficult to determine which is best for a given athlete. Our first conclusion is that bracing provides the same degree of ankle support, but at a lower cost than tape. Therefore, bracing may be the more cost-efficient method of support for an ankle injury. Biomechanically, taping inhibits more ankle dorsiflexion than bracing while semi-rigid braces restrict more eversion and inversion movements. However, even though both provide protection for the ankle, neither can withstand long periods of exercise. Finally, looking at the psychological effect of taping, evidence shows that there is an increased sense of reassurance and self-confidence in an athlete or patient who receives taping. Few studies have examined the psychology impact of bracing, so that is a need for additional investigation. Taping and bracing ankle sprains both have shown positive impact towards treating ankle sprains. However, more research needs to be done in understanding the stability both treatment methods provide to an ankle sprain.

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National Foot & Ankle Review

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Postmenopausal Ankle Joint Fracture: A Literature Review

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ABSTRACT

This review focuses on postmenopausal ankle fracture, where obesity, increased body mass index, smoking, diabetic neuropathy, and the use of hormone-replacement therapy may increase the risk of ankle fracture in postmenopausal women.

An understanding of postmenopausal impact on ankle joint fracture may improve treatment and compliance.

INTRODUCTION

Fractures of the ankle joint are common injuries that account for up to 10.2% of all osseous injury.[1] The literature shows that ankle fracture incidence follows a bimodal distribution with increased incidence in younger men and older women.[2,3] The mean age of women with an ankle fracture are about 49 years, whereas males peak at age 19. This trend may be explained by postmenopausal hormonal and metabolic changes.

Postmenopausal women are defined as those that reach the chronological landmark in their lives when menstrual periods stop permanently. Reaching this milestone varies but often begins between the ages of 45 and 55. During this time, new health issues appear such as hormonal fluctuation, estrogen deficiency, bone loss, and reduced metabolic rate.[4] Having certain underlying medical conditions such as obesity or diabetic neuropathy may increase the risk of ankle fracture. Hormone replacement therapy, on the other hand, may be protective. Another possible, somewhat controversial contribution to postmenopausal ankle joint fracture is osteoporosis, although osteoporosis is less common at the ankle joint.[5] This review investigates the role of osteoporosis in postmenopausal ankle fracture.

METHOD

A literature review was conducted using one database, PubMed. The key search terms included: ankle joint fracture and postmenopausal women. The inclusion criteria consisted of select studies that must include postmenopausal women as participants but not necessarily have ankle joint fractures. Sample size was not an exclusion criterion due to the limited availability of literature in this focused subject area. After the identification and screening processes, nine studies met the eligibility criteria and were selected to be included in this paper (Figure 1). The included studies were published between 2001 and 2022 (Table 1).

Figure 1. PRISMA Flow Diagram of Study Selection Process

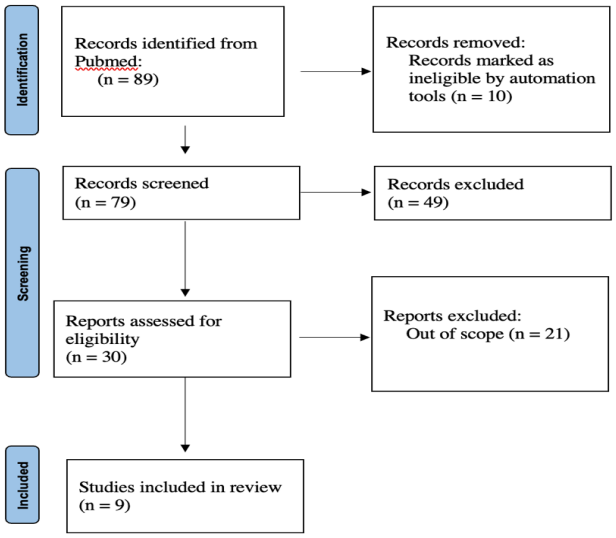

Table 1. Summaries of Articles Reviewed in Literature

Study	Participants	Conclusions
Armstrong et al. (2012)	1, 155, 304 postmenopausal women	Increasing adiposity is associated with an increased risk of ankle fracture. Physical activity has little association with ankle or wrist fracture.

Comptom et al. (2011)	60, 393 postmenopausal women	Obesity is associated with increased risk of ankle and upper leg fractures in postmenopausal women.
Charles et al. (2022)	3, 560 postmenopausal women	Obese or overweight leads to a greater risk of ankle fractures.
Need et al. (2002)	405 postmenopausal women	In postmenopausal women, smoking is associated with a reduction in calcium absorption which can lead to accelerate bone loss and are more prone to fractures.
Greeenfield DM. and Eastell R. (2001)	103 postmenopausal women with ankle fractures	In postmenopausal women, ankle fracture is not a typical osteoporotic fracture. Additionally, higher weight and body mass index are found to be associated with the increased risk of ankle injury.
Ho et al. (2006)	18 postmenopausal women with ankle fractures	Postmenopausal ankle fractures are not associated with osteoporosis. Diabetic neuropathy may be a risk factor for the injury.
Crandall et al. (2021)	47, 458 postmenopausal women with ankle fractures	Higher risk of subsequent fracture after initial fracture is more pronounced in all age groups, even the younger postmenopausal women from the age of 50 to 59. Additionally, the subsequent lower leg/ankle fracture seems to be more pronounced, compared to the other sites in the body.
Stein et al. (2011)	17 postmenopausal women with ankle fractures	Postmenopausal women with ankle fractures have lower bone mineral density, disrupted trabecular microarchitecture and decreased stiffness compared to postmenopausal women without ankle fractures.
Banks et al. (2004)	138, 737 postmenopausal women	Hormone therapy provides substantial protection against fractures, especially for the wrists, arms, and ankles. However, the protective effect of hormone therapy on fractures wears off after the halt in usage.

DISCUSSION

Anatomy

The ankle joint is also known as talocrural joint. This joint is formed by the articulation between the talus and the tibia medially and the talus and fibula laterally. The ankle joint is classified functionally as a diarthrosis and structurally as a synovial ginglymus (hinge) joint. The ankle joint displays triplanar motion but primarily functions in the sagittal plane with dorsiflexion and plantarflexion.

The ankle joint is stabilized by several ligaments that are divided into two groups: lateral collateral ligaments and medial collateral ligaments, also known as the deltoid ligament. The lateral collateral ligaments consist of the anterior talofibular ligament, calcaneofibular ligament, and posterior talofibular ligament. These are the ligaments most often sprained or injured, especially the weaker anterior talofibular ligament. The medial collateral ligaments include the anterior talotibial ligament, tibionavicular ligament, calcaneotibial ligament, and superficial and deep part of the posterior talotibial ligament. These ligaments are thick and strong, they reinforce the ankle joint medially and they are rarely injured.

Mechanism of Injury

An ankle fracture typically results from a low-energy injury rather than high-impact trauma. The common mechanism of ankle injury in postmenopausal women is a fall from a standing height, which often occurs during daily activities such as, exercising, jogging, walking down the stairs, or getting out of a vehicle.[6]

Ankle fractures can be classified based on the anatomical location of the fracture, which is described as either isolated medial malleolar fracture (involving solely the tibia), isolated lateral malleolar fracture (involving solely the fibula), bimalleolar fracture (involving both the medial malleolus of the tibia and lateral malleolus of the fibula) and trimalleolar fracture (involving both the medial and posterior malleoli of the tibia and lateral malleolus of the fibula).[7] Another common classification system is Danis-Weber, which bases the classification on the location of the lateral

malleolar fracture in relation to the distal tibiofibular syndesmosis. A type A fracture is below the syndesmosis, type B is at the level of the syndesmosis, and type C is when the fracture is above the syndesmosis.[7] The Lauge-Hansen classification, one of the most common ankle fracture classification systems, classifies ankle fractures by the mechanism of injury using two-word descriptors. The first word describes the position of the injured foot at the time of injury (i.e: supination or pronation) while the second word describes the motion that caused the fracture pattern (i.e., adduction, abduction, or external rotation). With this classification, four groups with at least 13 different fracture patterns have been described (table 2).[7,8]

Most ankle fractures in postmenopausal women are from low-energy impact, thus open fractures are rarely reported with ankle injuries. A study by Court-Brown et al. reported that 70% or approximately two thirds of all ankle fractures were isolated malleolar fractures, most often isolated lateral malleolar fractures.[9]

Table 2. Lauge-Hansen Classification

Supination-Adduction	Stage 1	Transverse fracture of the fibula below the ankle joint
	Stage 2	Vertical or oblique fracture of the medial malleolus
Supination-External Rotation	Stage 1	Anterior inferior tibiofibular ligament is disrupted or avulsed
	Stage 2	Oblique or spiral fracture of the fibula at the ankle joint
	Stage 3	Posterior inferior tibiofibular ligament is disrupted or avulsed
	Stage 4	Deltoid ligaments are disrupted or transverse fracture of the medial malleolus
Pronation-Abduction	Stage 1	Deltoid ligaments are disrupted or transverse fracture of the medial malleolus
	Stage 2	Anterior or posterior inferior tibiofibular ligament is disrupted
	Stage 3	Oblique fracture of the fibula at the level of ankle joint
Pronation-External Rotation	Stage 1	Deltoid ligaments are disrupted or transverse fracture of the medial malleolus
	Stage 2	Anterior inferior tibiofibular ligament is disrupted with extension into interosseous ligament
	Stage 3	Oblique or spiral fracture of the fibula above the ankle joint
	Stage 4	Posterior malleolus fracture or posterior inferior tibiofibular ligament is disrupted

Contributing Factors of Ankle Joint Fracture in Postmenopausal Women

There is an association between ankle fracture risk in postmenopausal women and obesity. In the study conducted by Compston et al. in 2011, the risk of ankle fracture increased by 60% in postmenopausal women with obesity compared to those without obesity.[10] Contrary to the popular belief that obesity is a protective factor against ankle fracture due to the additional soft tissue padding around the osseous joint, obesity is rather a risk factor.

Body mass index (BMI) quantifies obesity. Women who have BMI higher than 25 are significantly more prone to experience ankle fractures than those with normal BMI, as suggested in the study by Charles et al.[11] Present and previous studies also reaffirm that the risk of ankle fractures are significantly reduced in the lowest quartile of the weight gain parameter, showing that obese women fall more often.[6,10] With falling being the most common mechanism of injury in ankle fracture in postmenopausal women, it is possible that increasing weight predisposes them to have unsteady gait and diminishes the performance of gross motor coordination.

Other predisposing factors for ankle fracture emphasized in many studies include prior history of ankle fracture, smoking, and diabetic neuropathy. Women, who sustained a previous injury, had reduced bone mineral density and bone tensile strength, and are more prone to experience a future fracture. This trend, noted by Stein et al., seems to be even stronger in the early postmenopausal group, between ages 50-59.[12,13]

Several mechanisms explain the effect of smoking on ankle fracture risk. Smoking, which has a dose-dependent effect, prevents bone healing.[14] Need et al. suggest that postmenopausal smokers have poor calcium absorption from suppression of the parathyroid hormone-calcitriol axis, which may accelerate bone

loss and contribute to the lifetime risk of fracture.[15] Additionally, the production of carbon monoxide and nicotine from smoking can negatively influence night vision and cognitive performance, thus advancing the risk further.[14] Diabetic neuropathy and loss of proprioception in the feet may also contribute to falls in this population.[16]

Osteoporosis may or may not contribute to ankle fractures. A study by Greenfield and Eastell,[17] which focused on the risk factors for ankle fracture in postmenopausal women, decreased bone mineral density was not noted in the ankle fracture cohort. This finding was strengthened by Hasselman et al.[18] who suggested that ankle fracture is not related to osteoporosis and is not affected by bone mineral density. Stein et al.[12] countered this view, believing postmenopausal women with ankle fractures had lower volumetric bone mineral density with disrupted trabecular microarchitecture and had reduced stiffness compared to women in the control group without fracture.

The use of prescribed hormone-replacement therapy (HRT) has also been discussed in the literature as a protective factor against ankle fracture. HRT reduces the risk of having an ankle fracture in both perimenopausal and postmenopausal women by preserving bone density and metabolism. This protection rapidly wears off after the termination of usage, and such effect does not depend on the duration of HRT.[14,19]

Treatment of Ankle Fractures in Postmenopausal Women

In treating ankle fractures in postmenopausal women, both conservative therapy and surgical procedure are considered. The treatment plan is dependent on the severity, displacement of the fracture, the involvement of the surrounding soft tissue, and the condition of the patient.

Non-surgical therapy is often the initial choice for patients with or without severe illnesses who have high surgical risk or have underlying diseases such as circulatory disorders of the legs and any other medical conditions that are contraindicated to surgery or have limitations on non-weightbearing during the recovery period. In cases of mild non-displaced ankle fracture, plaster casting often is the treatment of choice that generally requires four weeks of non-weight bearing in a cast, followed by two weeks of ambulating in a walking cast. Subsequent early weight bearing improves outcomes in older patients and is encouraged. In addition to the removable braces or plaster castings, a combination of rest, ice, compression, and elevation, which is known as the RICE therapy, is recommended to treat and allow time for the injured bones to heal which takes four to eight weeks.

A novel pharmacological approach uses raloxifene, a selective estrogen receptor modulator that functions as a mimic of estrogen in bone tissues. Randomized, placebo-controlled studies have shown that raloxifene is effective in increasing postmenopausal bone mineral density and significantly reduces the incidence of ankle fracture with a 60 or 120 mg/day dosage.[20] Surgical intervention, with the goal of ankle joint functional restoration, is preserved for instances when either failure of conservative therapy is inevitable, or the fractures are inherently too unstable or displaced. The risks of surgical treatment such as compromised soft tissues, hardware failure, nonunion, or delayed union potential are weighed prior to the procedure. Surgical treatment using open reduction and internal fixation (ORIF) is most common. ORIF is the treatment of choice for patients with bimalleolar or trimalleolar ankle fractures. Trimalleolar fracture requires ORIF augmented by postoperative casting for an additional 4-6 weeks. In postmenopausal women, because of the reduced mechanical strength of bone, implants that help to minimize the stress shielding of bone are preferred for internal fixation such as screws, tension band wires, and intramedullary pins.[21] The use of tibiotalocalcaneal (TCC) nailing is also recommended in complicated patients who are older with comorbidities such as diabetes mellitus or peripheral vascular disease as TCC is minimally invasive and allows for early weight-bearing postoperatively.[3]

CONCLUSION

Ankle fracture is a public health issue in postmenopausal women. Limited evidence is available to assess ankle fracture in the postmenopausal population. Studies have shown that the most common cause of ankle injury is low-energy trauma, such as falls from a standing height. Obesity, smoking, underlying diabetic neuropathy, and history of previous fracture are all considered as the predisposing factors that increase the risk of postmenopausal ankle fracture. Hormone replacement therapy is a protective factor against ankle fracture. This literature review also emphasizes that osteoporosis is not associated with postmenopausal ankle fracture.

Treatment for ankle fractures includes both operative and non-operative options. In non-displaced and stable fractures, immobilization with casting is ideal. RICE therapy is also recommended to expedite the healing and to relieve pain. Literature selection process is an area of improvement in the methodology of this paper. In this review, PubMed was the only source for collecting literature, however, other databases may have additional papers on this topic. Future research should include clinical trials that specifically target the postmenopausal subpopulation.

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National Foot & Ankle Review

TEMPLE UNIVERSITY
School of Podiatric Medicine

How Well Do You Know Your Shoes? A Cross Sectional Analysis of Temple University School of Podiatric Medicine Students on Their Level of Confidence with Recommending Different Footwear

Sharon Dei-Tumi, M.P.H., B.S., Jennifer Vazquez, M.S., B.S., Julius A. Hatcher IV, M.S., B.S., Miranda Royds B.S.

ABSTRACT

Podiatrists are uniquely positioned to help patients with their shoe selection. As such, knowledge of shoes should ideally be emphasized during the four-year podiatric medical school education. To the best of our knowledge, no research has reported on the level of confidence podiatric medical students have in making recommendations for comfortable footwear. The first goal of this study was to capture and report this perception among podiatry students at Temple University School of Podiatric Medicine (TUSPM). The second goal was to assess which type of shoes most students are asked to recommend and which resources they rely on in making their recommendations. A 15-question online survey was developed with questions that assessed different variables, including respondents' ability to differentiate between a motion-control and stability-control running shoe and the level of confidence in recommending shoes in general versus sport-specific shoes. Respondents were also encouraged to suggest ways to help improve their knowledge gap. Data were obtained from 66 respondents across all four classes (2023-2026) at TUSPM. The results of the study suggest that most podiatry students at TUSPM find it challenging to recommend appropriate footwear. Additionally, most students do not feel adequately prepared on the subject matter based on formal classes at TUSPM. Thus, formal knowledge of footwear should be incorporated into podiatric medical education.

INTRODUCTION

Shoes are more than a fashion statement. In the best possible way, they serve as a means of foot support. With the right shoes, one can stand for long hours, run for miles, or strut into an interview confidently and without discomfort. Similarly, with the wrong shoes, one can be assured of troubles, including foot pain and more permanent foot problems, including hallux valgus, neuromas, digital contractures, and possibly ulcerations.[1,2]

In many ways, podiatrists are uniquely positioned to help patients make optimal footwear selection decisions. This vantage point, however, is only practical if the podiatrist is adequately equipped with the knowledge to do so. Formal education in podiatry is gained primarily during a four-year medical school program, with surgical competencies improved upon during residency. As such, most formal knowledge of footwear is expected to be obtained during podiatric medical school. Historically, podiatry students are often asked for footwear recommendations during their clinical rotations as third and fourth-year students or in a more casual setting by family and friends. This study will help determine the current level of knowledge that students have, allowing them to answer these questions.

To the best of our knowledge, research has not been conducted on the level of confidence podiatric medical students have in making recommendations for comfortable footwear. Therefore, the aim of our research is two-fold. First, we hope to capture and report this perception among podiatry students at Temple University School of Podiatric Medicine (TUSPM). Second, we aim to assess which type of shoes generate the most recommendation requests and which resources students use to make their recommendations.

For our first goal, we hypothesize that although some students may have a high level of confidence in making a footwear recommendation, this subset will be a minority. Students reporting a high level of confidence would likely be third- or fourth-year students, whereas first- and second-year students are expected to report a lesser level of confidence. For our second aim, we hypothesize that running shoes will generate the most requests for recommendation, with respondents indicating that they rely on Google or personal experience for making those recommendations.

METHODS

A 15-question online survey was developed by a third-year podiatry student in consultation with two faculty members. These faculty included one Doctor of Physical Therapy and Doctor of Podiatric Medicine. The survey was estimated to be completed in less than 10 minutes and was emailed to the first, second, third, and fourth year TUSPM students. Survey responses were collected anonymously using Microsoft Forms. Subsequent reminders to complete the survey were made via word of mouth or social media platforms, specifically Facebook and GroupMe. Questions included categorical multiple-choice, a 5-point Likert scale for rating, and free-response item formats. Survey responses were analyzed with Microsoft Excel. No question included in the survey was compulsory.

The first set of questions (questions 1 – 6) focused on the respondent's expected graduation year (e.g., class of 2024); how often they are asked to recommend comfortable shoes in general and sports-specific shoes; as well as their level of confidence in making these recommendations. Respondents were also asked about which specific category of sports shoes they were asked about the most – with this question; they could choose between a list of specific sports shoes in addition to "other." A follow-up question encouraged respondents who chose "other" to list the shoe type excluded from the options.

The next set of questions (questions 7 - 14) asked about resources students rely on to make recommendations for running shoes and shoes in general and specific knowledge of different shoe brands. Again, students who selected "other" were allowed to indicate which resources they rely on. To exclude personal bias while assessing students' level of confidence on shoe details, two objective questions were included in this section, one on how to measure the metatarsal heads for a shoe fitting and the other inquiring about the ability to differentiate between a motion-control and a stability control running shoe.

Finally, students were asked to make suggestions on what they think can help them feel more comfortable with their recommendations.

DATA

Of the 297 students contacted via email, 66 (22%) responded to the survey. Each participant finished the survey in its entirety. Data were collected from respondents in all four classes: 11 (16.67%) from the class of 2023, 20 (30.30%) from the class of 2024, 20 (30.30%) from the class of 2025, and 15 (22.72%) students from the class of 2026.

RESULTS

When asked how often others inquired them to recommend good/comfortable shoes in general as well as sports-specific shoes, respondents were able to choose from a 5-point Likert scale where 5 was equivalent to always, and 1 was equivalent to never. A majority, 37.88%, of respondents indicated that they are "often" asked to recommend good/comfortable shoes in general. In comparison, 28.79% indicated they are "sometimes" asked to recommend good/comfortable sports-specific shoes. Table 1 displays these details by respondents' year group or class. Table 2 represents details on respondents' level of confidence in making recommendations for shoes in general as well as specific shoes. We found that 36.36% of respondents felt "sometimes" confident when recommending shoes in general, while 28.79% felt "rarely" confident when making recommendations for sports-specific shoes.

Table 1: Respondents by year of graduation (N = 66

Anticipated Year of Graduation	N (%)
Class of 2023	11 (16.67%)
Class of 2024	20 (30.30%)
Class of 2025	20 (30.30%)
Class of 2026	15 (22.73%)

Table 2: Frequency of inquiries about **shoes in general** vs. **sports-specific shoes** (N= 66)

	Class of 2023	Class of 2024	Class of 2025	Class of 2026	
shoes in general					**n (%)**
1 = Never	0	0	0	1	1 (1.51%)
2 = Rarely	0	5	2	4	11 (16.67%)
3 = Sometimes	3	7	7	3	20 (30.30%)
4 = Often	7	5	7	6	25 (37.88%)
5 = Always	1	3	4	1	9 (13.64%)
sports specific shoes					
1 = Never	0	4	2	3	9 (13.64%)
2 = Rarely	4	6	4	4	18 (27.27%)
3 = Sometimes	2	5	7	5	19 (28.79%)
4 = Often	5	5	4	2	16 (24.24%)
5 = Always	0	0	3	1	4 (6.06%)

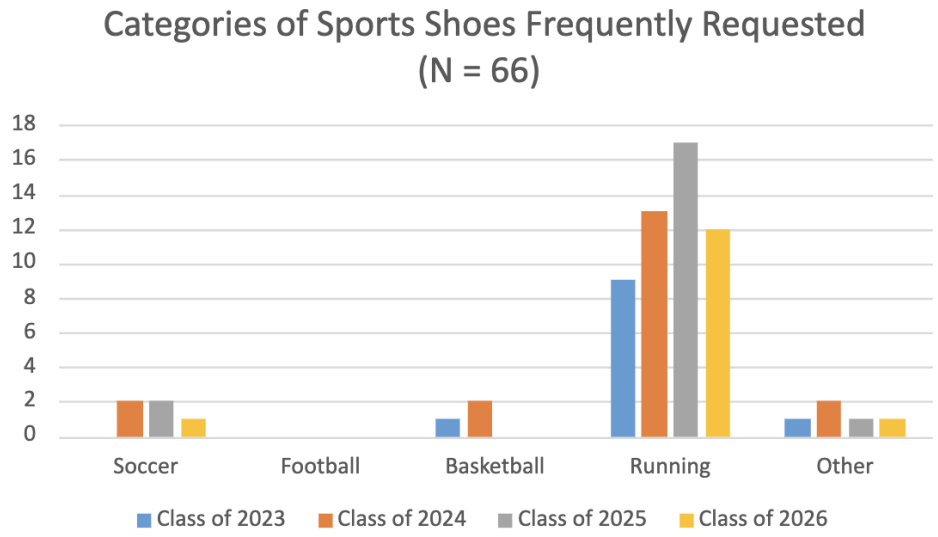
Running shoes

Graph 1 illustrates that 51 of 66 respondents (78.8%) indicated that they are asked about recommendations for comfortable running shoes compared to soccer, basketball, dress, etc. While 50% of this subset indicated that they know the key components of a running shoe, 70% admitted that they cannot differentiate between a motion control and a stability control running shoe (Graph 2). The majority of the respondents (29.4%) indicated that they were "sometimes" confident in their recommendations (Table 3). Additionally, over 60% attributed their confidence to prior knowledge of running shoes from working at a podiatrist's office or a shoe store (Graph 3 & 4; Image 1). Incidentally, formal sources of education, including the Sports Medicine Class and Sports Medicine Club, were the lowest ranked resource for making recommendations on running shoes (5.33% each). When asked about specific running shoes in the free-response section, the most listed shoes were Hoka, Asics, Brooks, and New Balance (Image 1).

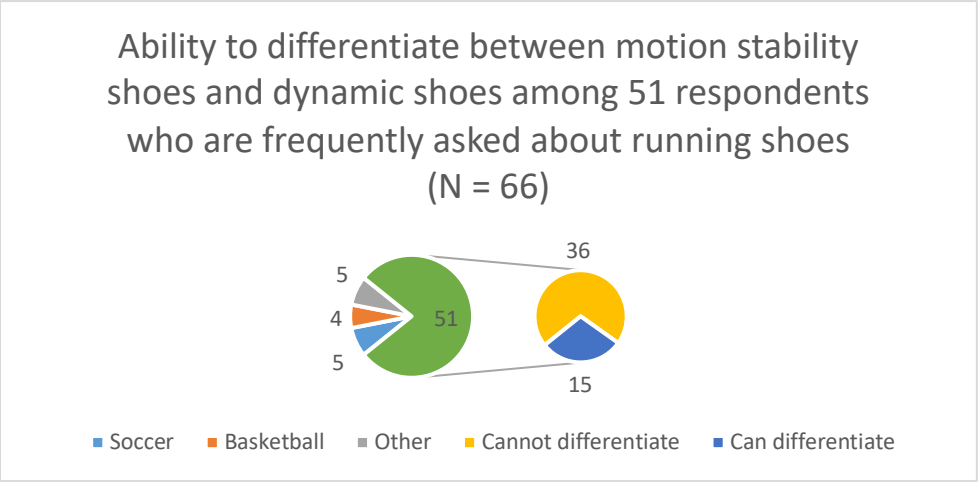
Table 3: Level of confidence in making recommendations for **shoes in general** vs. **sports specific shoes** (N= 66)

	Class of 2023	**Class of 2024**	**Class of 2025**	**Class of 2026**	
shoes in general					**n (%)**
1 = Never	0	0	1	1	2 (3.03%)
2 = Rarely	1	7	4	1	13 (19.70%)
3 = Sometimes	2	9	9	4	**24 (36.36%)**
4 = Often	6	4	4	6	20 (30.30%)
5 = Always	2	0	2	3	7 (10.61%)
sports specific shoes					
1 = Never	1	4	2	2	9 (13.64%)
2 = Rarely	0	6	8	5	**19 (28.79%)**
3 = Sometimes	4	6	4	4	18 (27.27%)
4 = Often	5	4	5	1	15 (22.73%)
5 = Always	1	0	1	3	5 (7.57%)

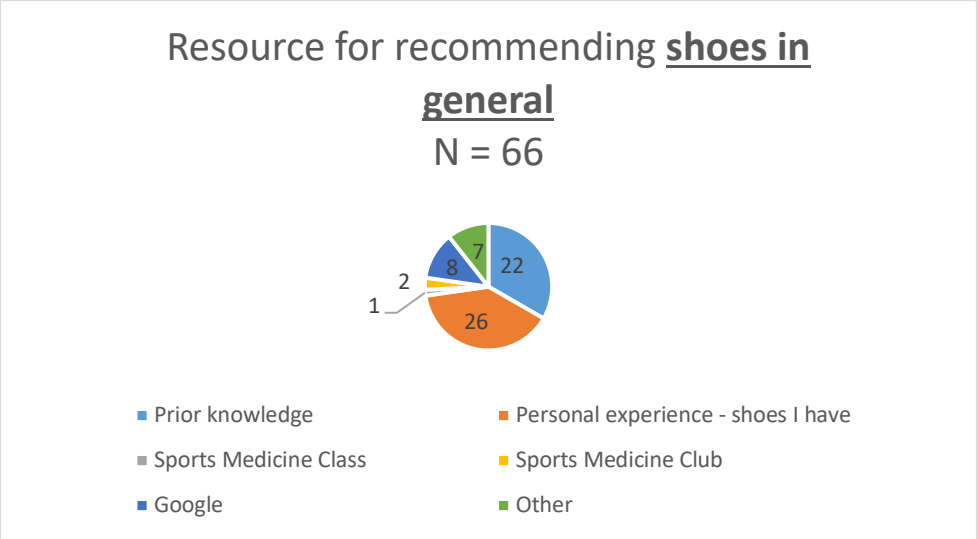
Graph 1: Category of Sports Shoes Requested



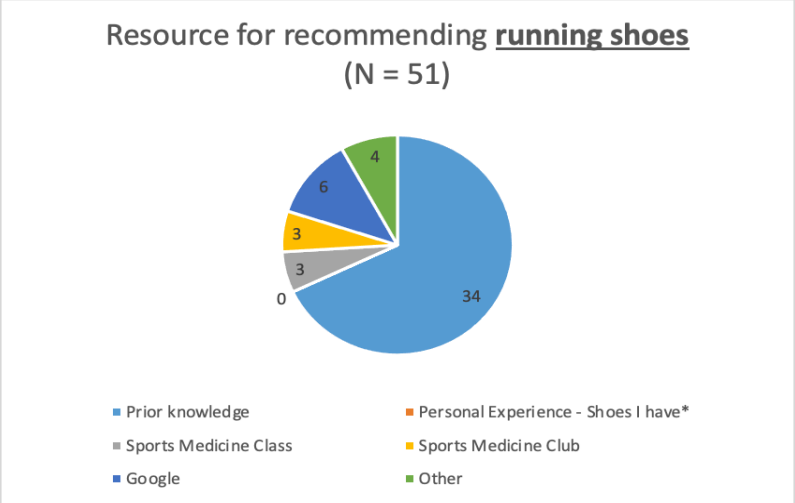
Graph 2:



Graph 3:



Graph 4:



**Although "Personal Experience" was an option, no respondents in the running shoes subcategory selected it.*

Recommendations

All survey respondents were asked to suggest, in one sentence, what they think can help them feel more confident in their recommendations. Again, 49 of the survey respondents (74.24%) answered this question. Responses ranged from suggesting shoe-specific lectures for different foot types and pathologies to requesting sample shoes to try on. The general themes of the recommendations are captured as a word cloud in Image 4.

DISCUSSION

Shoes have a significant role in our lives and in the health of our feet. This significance has been underscored by the plethora of publications on shoes and their effect on different groups, including, but not limited to, people with diabetes mellitus, the elderly, children, and women who are pregnant. Podiatrists are in a unique position to help guide patients in the selection of shoes. However, there is no "one size fits all" approach, and substantial education is required to ensure that podiatrists are equipped to make effective shoe recommendations. Current courses in sports medicine, orthopedics, biomechanics should incorporate additional footwear content.

Surveying TUSPM students about their confidence level in making recommendations for shoes yielded unique and novel findings. While the majority, 37.88%, of respondents indicated that they are "often" asked to recommend good/comfortable shoes, 36.36% admitted that they are "sometimes" confident in their recommendations. Similarly, while 28.79% indicated that they "sometimes" asked about recommending good/comfortable sports-specific shoes, the same proportion of students was "rarely" confident about their recommendations. Of the students who indicated high levels of confidence, they attributed this to their prior knowledge from working with a podiatrist or shoe store before matriculating at TUSPM. While consistent with our first hypothesis, these results suggest that students do not feel adequately prepared on the subject matter based on formal classes at TUSPM. Our findings were also consistent with our second hypothesis, with survey respondents (78.8%) selecting "running shoes" as the most frequently, requested sport-specific footwear recommendation, Again, the majority relied primarily on prior knowledge (66.7%), followed by Google web search (11.7%). Based on the findings of this study, we can infer that students frequently find themselves in a position where they are unequipped to provide accurate footwear information. Thus, additional footwear content should be added to the current podiatric medical curricula.

Limitations and directions for further research

Although the survey results provide valuable information about the perception of TUSPM students' confidence level in recommending footwear limitations must be acknowledged. The primary limitation of this survey is a non-respondent bias. This can be attributed to inadequate response time leading to a low response rate. Due to unforeseen circumstances, the survey was not emailed until September 2nd, with responses due on September 6th. This allowed participants five days to complete the survey. During this timeframe, first, second and third-year students were preparing for exams, while most of the fourth-year students were away on clerkships. Arguably, a non-respondent bias may be inherently present in our results; however, the non-response rate is a poor predictor.[3]

The present study provides, to our knowledge, the first overview of the confidence level of podiatric medical students at TUSPM in making recommendations about shoes. In future research, we hope to extend this project to all podiatric medical schools. Our goal is to capture, if present, the knowledge gap across both podiatric medical schools and years of podiatric medical school experience. Other quantitative measures such as gender identification, prior experience before matriculation into medical school, and objective measures for footwear will be included to identify any biases present.

APPENDIX

How well do you know your shoe survey questions:

1. What year are you?
   Options: Class of 2023/2024/2025/2026
2. How confident are you in making recommendations for shoes in general (i.e., dress shoes, tennis shoes, running shoes)?
   Likert Scale: 1 = never 2= Rarely 3= Sometimes 4= Often 5 = Always
3. In your experience, which category of sports do most of the request you receive fall into?
   Options: Soccer, football, basketball, running, other
4. How confident are you making recommendations for sports specific shoes (i.e. for running shoes)? (Likert scale)
5. What do you rely on to make recommendations for shoes in general? (Likert scale)
6. How confident are you making recommendations for sports specific shoes (i.e. for running shoes)? (Likert scale)

Shoes in general

7. What do you rely on to make recommendations for shoes in general?
   Options: Personal experience – shoes I have used; prior knowledge of shoe types; sports medicine class; sports medicine club; google; other
8. Which of the following can be used to measure the fleshy part of the foot just proximal to the toes (metatarsal heads)?

Running Shoes

9. Do you have any specific knowledge about any running shoe brands?
10. Can you differentiate between a motion-control and stability control running shoe?
11. Do you know the key components of a running shoe?
12. What do you rely on to make recommendations for running shoes?
13. In one sentence, what do you think can help you feel more confident about your recommendations?

Graph 5:

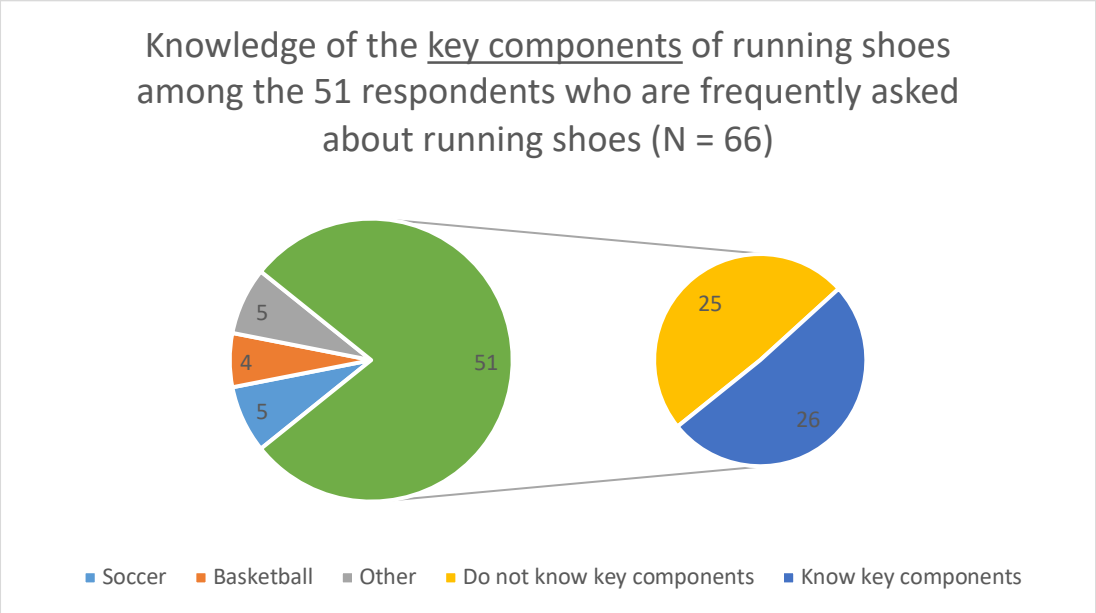


Image 1: Specific knowledge about any running shoe brands (N = 34)

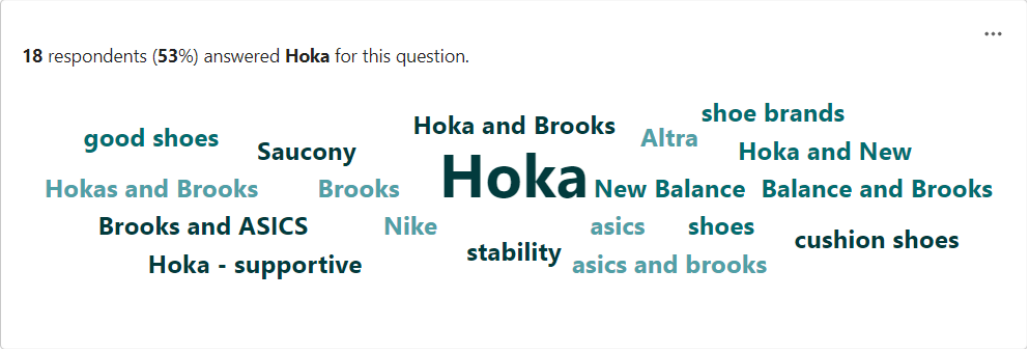


Image 2: "Other" sources for making recommendations on **shoes in general** (N = 14)

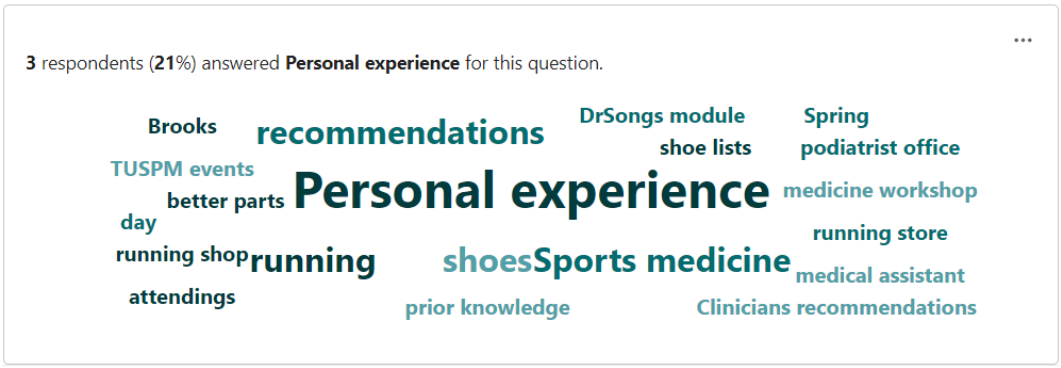
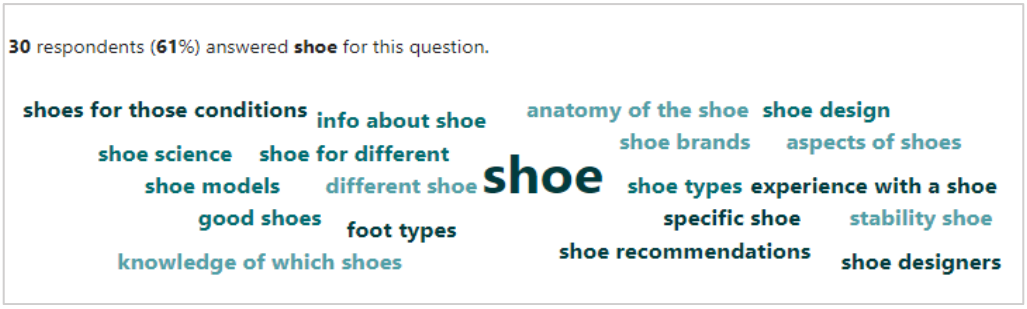


Image 3: "Other" sources for making recommendations for running shoes (N = 7)

Image 4: Recommendations to improve your knowledge on shoes



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National Foot & Ankle Review

Samuel Merritt University
College of Podiatric Medicine

A Literature Review: Calcaneal Lengthening for Pes Planovalgus Foot Deformity in Children with Cerebral Palsy

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ABSTRACT

Children with cerebral palsy (CP) are at a higher risk of developing pes planovalgus (PPV). PPV is a foot deformity with depression of the medial longitudinal arch and valgus rotation of the heel. CP is a heterogeneous group of conditions involving permanent motor dysfunction affecting muscle tone, posture, and movement. Children with CP have a high incidence of developing call uses , recurrent ulceration and many have pain while weight-bearing. This paper reviews the current literature related to the Calcaneal Lengthening Osteotomy (CLO), also known as the Evans procedure. A preliminary search was performed on PUBMED, Ebsco and Google scholar using the keywords: "cerebral palsy," "pes planovalgus," "calcaneocuboid lengthening," and "evans procedure" to identify articles published between 2000 and 2022. The outcomes, complications, and limitations of nine studies demonstrate that CLO is the preferred treatment for children with PPV and CP. CLO corrects the deformity without sacrificing calcaneocuboid joint motion. Complications that were reported include: subluxation, recurrence, and postoperative pain. Long-term outcomes include reduced pain increased range of motion, better gait, and better radiographic.

INTRODUCTION

Pes planus is a term used to refer to collapse of the medial longitudinal arch of the foot. Loss of the medial longitudinal arch causes the medial aspect of the foot to drop upon weight-bearing. When the calcaneus is in valgus orientation, the heel is directed outward and is lateral relative to the ankle. This position of the foot is referred to as pes planovalgus. Pes planovalgus is characterized by plantarflexion of the talus, external rotation of the calcaneus, with medial deviation of the talar head and subtalar joint eversion.[1-3]

Pes planovalgus is a common foot deformity in children with cerebral palsy.[10] It can cause both anatomic and structural changes in the foot and should be corrected according to its severity as measured by imaging and gait analysis. The pedobarographic measurement, which is part of gait analysis, measures the severity of pes planovalgus by recording pressure on the plantar aspect of the foot. Mild cases of pes planovalgus can be treated with orthotics, but more severe cases may require surgical treatment, including subtalar joint arthrodesis or a calcaneal lengthening osteotomy or both.

Calcaneal lengthening osteotomy is a common surgical treatment for pes planovalgus. The procedure restores foot alignment and preserves joint motion.

METHODS

The purpose of this literature review is to highlight the efficacy of the c alcaneal lengthening o steotomy in the treatment of pes planovalgus in children with cerebral palsy. Research publications from 2000 to 2022 were accessed through three online databases, PubMed, EBSCO, and Google Scholar. The key terms included in the search were: pes planovalgus, children, cerebral palsy, Evans procedure, lateral lengthening, calcaneal lengthening, and calcaneocuboid joint motion which yielded 18 results. To be included in the review, the journal articles had to be specific to treating pes planovalgus with a lateral lengthening osteotomy. Articles that did not highlight this procedure or did not mention cerebral palsy in children were excluded. Additionally, articles highlighting complications and limitations to the lengthening osteotomy were included in this literature review to assess all components. As a result, a total of 18 articles were identified , eight were excluded and 10 were included in this literature review.

SURGICAL TECHNIQUE

The surgical procedure chosen in every article found in this literature review was the Evans procedure, with or without adjunctive intervention. Surgical adjuncts differed within the articles, such that some authors considered a tendo- Achilles lengthening, tibialis anterior transposition, peroneus brevis tendon lengthening or extensor digitorum longus lengthening. To begin, a lateral incision is placed over the peroneal tendons, taking care to protect the sural nerve. The peroneal tendons are then retracted, exposing the calcaneus. Once the calcaneus is visible, an oblique osteotomy is made anterior to the peroneal tubercle, between the anterior and middle facets of the calcaneus. In addition, a Z-lengthening of the peroneus brevis tendon is performed and the aponeurosis of the abductor digiti minimi is released.[1] One or two Kirschner wires are inserted distally through the cuboid, across the center of the calcaneocuboid joint and stopping before the osteotomy to transfix the joint.

A laminar spreader is used to open the osteotomy, enabling the size of the trapezoid-shaped graft to be determined. The choice of grafting material and fixation differed in all studies, as can be seen in **Table 1**.

In Aboelenein AM et al., a tendo-Achilles lengthening procedure was performed. In three of their 22 subjects a medial cuneiform osteotomy with medial soft tissue procedure was performed, helping to correct forefoot supination.[1] In Ettl V. et al. , a tendo-Achilles lengthening or a gastrocnemius recession was performed for an isolated contracture, a transposition of the tibialis anterior tendon under the navicular was performed for a depressed arch, and peroneus longus and brevis lengthening was performed for tight peroneal tendons.[2] In Zeifang, F. et al., only soft-tissue procedures were necessary after the bony procedures.[3] In total, eight feet underwent boney procedures, five feet underwent shortening of the navicular or cuneiform bones, and six feet underwent medial talocalcaneonavicular capsular reefing. In Luo CA et al., all patients had to undergo tendo-Achilles lengthening or gastrocnemius release with a few other feet undergoing additional procedures of flexor hallux longus lengthening and extensor digitorum longus lengthening.[4] In Sung KH et al., all peroneus brevis tendons were lengthened, but the peroneus longus tendon was left intact. In addition, procedures in this study only had tendo-Achilles lengthening or Strayer procedure for patients with ankle equinus. [5]

RESULTS

Ettl et al. conducted a level of evidence IV, retrospective case series evaluating the outcome of calcaneal lengthening in children with cerebral palsy with emphasis on the child's ambulatory status.[2] Nineteen children (28 feet) of which 14 were ambulatory (19 feet) and five non-ambulatory (nine feet) were followed in the years between 1995 and 2004. The clinical outcome in this study was classified by Mosca's criteria.[2] An acceptable and satisfactory outcome was considered when: 1) prominence of the talar head was removed, 2) there was no recurrence of ulceration, 3) the hindfoot valgus was corrected, 4) creation of a longitudinal arch, 5) no pain or callus under the talar head, 6) patient was able to tolerate a brace or shoe and 7) two-thirds of the radiographic parameters were in the normal range.[2] Of the 28 feet studied, 75% had a satisfactory outcome per Mosca's criteria. In addition, the American Osteopathic Foot and Ankle Society ankle-hindfoot score (AOFAS) ranged from 28 to 100 with a mean of 68.5. Furthermore, the AOFAS in ambulatory children had a mean of 76.8 and in non-ambulatory children the mean score was 51. Similar to other studies, weight-bearing radiographs were taken pre and post-operatively to assess the following angles: calcaneal pitch angle, lateral talo-horizontal angle, and lateral talo-first metatarsal angle. Upon evaluation, all angles improved in both ambulatory and non-ambulatory patients (**Table 2**).

Yoo et al. conducted a relatively large study with 56 children (92 feet).[6] The authors studied the results of calcaneal lengthening in ambulatory children with planovalgus foot deformity and history of cerebral palsy. In this study, there were 69 cases (75%) with a satisfactory clinical outcome. In addition, post-operatively there were improvements in the children's gait parameters, including power generation, ankle motion in the sagittal plane, and foot progression angle.[6] Although there were differences in the pre and post radiographic measurements, it was discovered that if children presented with both a preoperative talocalcaneal angle greater than 25 degrees and a calcaneal pitch on WB lateral radiographs less than five degrees, the deformity was too severe and there was a greater risk of a poor outcome (**Table 2**).

Zeifang et al. conducted a prospective study of 46 severe and symptomatic flexible flatfeet in 32 children with cerebral palsy.[3] This study investigated the clinical and radiologic outcome of calcaneal lengthening in severe pediatric

flexible flatfoot deformities that were spastic in origin. The clinical outcome was evaluated by a modified protocol proposed by Phillips which included four parameters: correction in stands, need for orthosis because of foot deformity, pain or pressure ulceration and gait function. These four parameters were used to classify a foot as excellent, good (slight hindfoot valgus), fair (slight hindfoot valgus with slight forefoot abduction), or poor (overcorrection or relapse with the need of an ankle foot orthosis). Among the 46 feet, 11 feet were excellent, 19 were good, nine were fair and seven were poor. As a result, patients who had the Evans procedure achieved a 65% (30/46 feet) good or excellent clinical outcome. Radiographic measurements were documented before and after the procedure and included: calcaneal pitch angle, talo-metatarsal angle, talocalcaneal angle, and the Moreau-Costa-Bertani angle. Upon evaluation, all radiographic parameters improved when compared to pre-operative measurements (**table 2**). CLO was found to be an effective procedure to correct this deformity in the short and mid-term; however, additional soft tissue procedures were necessary in very severe spastic deformities. For instance, it was frequently necessary to lenghten the peroneus brevis tendon and the triceps surae muscle after the CLO surgery.

Andreacchio et al. analyzed 15 children (23 feet) whom were ambulatory with a history of spastic cerebral palsy and flexible planovalgus deformities. Similar to the Zeigang et al. study, children in this study exhausted conservative treatment and continued to have painful instability while walking, making the children candidates for a lateral column lengthening procedure. Two options were pursued: lateral lengthening through the calcaneocuboid joint or lateral lengthening through the calcaneus. Post-surgery patients had two years of follow-up and were evaluated based on clinical and radiographhic outcomes. The authors classified the patient's clinical outcome as good, fair or poor. Twelve feet (75%) of the 11 children who underwent the lateral lengthening procedure through the calcaneus had a good clinical outcome, four feet (25%) had a poor outcome. 71 percent of the children who had a calcaneocuboid joint lengthening had a good outcome, 29% a fair outcome and none had a poor outcome . Regardless of the chosen procedure, there were 17 feet (74%) with good results, two (9%) with fair results, and four (17%) with poor results. Radiographic evaluation results are listed in **Table 2**. According to the authors, poor outcomes were a result of the deformity recurrence.[1]

Sung et al. conducted a retrospective study to evaluate the amount of correction that can be achieved after calcaneal lengthening in children with cerebral palsy and a planovalgus foot deformity.[5] A total of 75 patients with CP were enrolled in this study and follow up was roughly one year. Although the authors commented on the importance of clinical outcomes, they prioritized radiographic evaluation in their study . Preoperatively and postoperatively the following radiographic angles were measured: AP talo-first metatarsal angle, calcaneal pitch angle, lateral talocalcaneal angle, lateral talo-first metatarsal angle, naviculocuboid overlap, relative calcaneal length, and calcaneocuboid subluxation. After calcaneal lengthening, the mean difference between the preoperative and postoperative radiographic measurements were evaluated: 19.9 degrees in AP talo-first metatarsal angle, 9.1 degrees in the lateral talocalcaneal angle, 18.5 degrees in the lateral talo-first metatarsal angle, and 31.2 degrees in the naviculocuboid overlap. The authors concluded that patients with a greater than 23 degrees AP talar-first metatarsal angle, 35 degrees lateral talo-first metatarsal angle and 72% navicular cuboid overlap should be considered for this procedure as it may lead to insufficient correction with calcaneal lengthening alone.

Table 1. Summary of grafts used per study.

Article	Graft	Fixation
Aboelenein AM et al.[1]	Bi-cortical iliac crest bone	K-Wire
Ettl V. et al.[2]	Bi-cortical bone graft taken from the iliac crest or ipsilateral fibula	K-Wire

Luo CA et al.[4]	Wedge of a tricortical iliac crest autograft	nnulated screw and K-wire
Sung KH et al.[5]	Commercially available human iliac crest allograft bone wedge	No stabilization

Table 2. Summary of the radiographic measurements after calcaneal lengthening in children with cerebral palsy.

Author	n	Radiographic Angle	Pre-Op (°)	Post-Op (°)	P-value
Andreacchio et al.[1]	5 (23 feet)	AP Talonavicular coverage	13 +/- 19	0 +/- 8	Not reported
		L. TC	19 +/- 8	26 +/-7	
		Lateral talo-1st metatarsal	0 +/- 7	3 +/- 6	
Ettl et al.[2]	9 (28 feet)	CP (ambulatory)	14.4 +/- 7.7	18.4 +/- 9.4	<0.05
		Talo-horizontal (ambulatory)	27.4 +/ 8.5	24.0 +/- 8.5	<0.05
Sung et al.[5]	75	CP	2.9 +/- 8.8	7.3 +/- 8.1	<0.001
		L. TC	47.0 +/- 9.5	37.9 +/- 9.2	<0.001
		Lateral talo - 1st metatarsal	30.2 +/- 15.6	11.6 +/- 13.1	<0.001
Yoo et al.[6]	56	CP	4.1 +/- 5.1	11.6 +/- 6.1	0.00047
		L.TC	37.6 +/- 7.0	28.1 +/- 5.2	0.00021
		Lateral talo - 1st metatarsal	24.9 +/- 9.2	4.8 +/- 7.7	0.00043
Zeifang et al.[3]	2 (46 feet)	CP	3.26 +/- 9.87	13.89 +/- 7.76	<0.0001
		L. TC	42.63 +/- 6.31	36.17 +/- 6.79	<0.0001
		Lateral talo - 1st metatarsal	32.9 +/- 13.9	18.0 +/- 12.5	<0.0001

Radiographic measurements in degrees with mean and standard deviation per study.
Abbreviations: n = number of patients, CP = Calcaneal Pitch, L. TC = Lateral Talocalcaneal

Table 3. Independent predictors and predicted probability for under correction.

Number of Predictors	Corrected Group, No. (n=17)	Undercorrected Group, No. (n=13)	Predicted Probability of Undercorrection, %
0	9	0	0
1	8	8	50
2	0	5	100

Abbreviations: n = number of patients

DISCUSSION

Martinkevich et al. conducted a prospective study on ten pediatric patients to evaluate calcaneocuboid joint (CCJ) motion and calcaneal lengthening osteotomy (CLO) stability one year after CLO was performed for pes planovalgus.[9] The study used radio stereometric analysis (RSA) with and without weight-bearing during a one-legged stance to measure the translation and rotation of the CCJ, which is used to evaluate CCJ motion and CLO stability. The conventional weight-bearing lateral x -ray of the CCJ was not used to measure the displacement of the CCJ because the measurement is taken from a two-dimensional x-ray (which does not take into consideration variations of the CCJ in indviduals). Hence, RSA was used to evaluate the CCJ motion and CLO stability for each patient. One year after the CLO, the osteotomy was assumed to be stable, and RSA data for CLO stability was provided to confirm these assumptions. Because the steotomy is stable, the CCJ motion recorded will determine if there were changes in CCJ motion before and after CLO was performed. The results were obtained from 10 pediatric patients, three males and seven females, all of whom had a CLO performed for symptomatic flexible pes planovalgus. The data obtained were as follows: the CCJ exhibited a mean 1.04 mm joint distraction/widening, 2.27 mm cuboid dorsal translation, 1.94 mm cuboid medial translation, and 7.43 degrees adduction.[9] The data, when compared to those obtained from an adult during weight-bearing with normal foot posture and asymptomatic for foot problems, was very similar.

In a retrospective study by Kadhim et al., ambulatory pediatric patients with cerebral palsy who underwent subtalar fusion and calcaneal lengthening received long-term follow-up.[10] The study was limited to children who had at least a six year postoperative follow-up that included radiographic measurements and gait analysis. Among the pool of 248 patients, only 24 patients met the study's criteria. Within these 24 patients, 43 feet were included, and 15 feet underwent calcaneal lengthening. Results of the study indicate that calcaneal lengthening is an effective form of treatment in ambulatory children with cerebral palsy with pes planovalgus.

Kruger et al. took another approach in observing the outcome of CLO, as this study included patients who were transitioning into adulthood and work life.[8] This was the first study to report the long-term outcome in adult patients with CP who were treated with CLO in childhood. The follow-up for these patients included radiographic measurements which were within normal range. In this study, only 13 patients were evaluated, limiting the study's power.

Although several studies have demonstrated support for calcaneal lengthening for pes planovalgus in children with cerebral palsy, controversy remains in under-correction and long-term outcomes. Luo CA et al. analyzed the risk of calcaneal lengthening in children with cerebral palsy. Preoperative angles were obtained. Angles determined to be independent predictors for under correction were the following: an AP talonavicular coverage (AP-TN) of over 24 degrees and a calcaneal pitch angle less than -5 degrees. The AP-TN angle correlates with any valgus or varus deformities of the calcaneus. A pes planus foot type is correlated with a lower calcaneal pitch and a pes cavus foot type is correlated with a higher calcaneal pitch. From **Table 3**, if these two predictors are present, then the probability of under-correction during surgery is 100%. If only one predictor is present, then undercorrection would be 50%.

Kruger, K M., et al. Identified the long-term outcome of CLO patients. Many had muscle contracture with weakness and gait changes. Patients developed a combination of hindfoot plantarflexion with forefoot dorsiflexion, indicative of a midfoot break. Patients had decreased range of motion in the sagittal plane with no degenerative joint disease, further indicating internal forces are not a contributing factor in long-term outcome.

CONCLUSION

In conclusion, CLO or CLO with an adjunctive procedure improved foot deformity and function. In adulthood, for example, patients are capable of loading the foot with a normal posture and without pain during the stance phase of gait. However, progression of CP leads to increased muscle contracture and spasticity.

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National Foot & Ankle Review

Posterior Tibial Tendon Transfers in Treating Foot Drop Patients: A Systematic Review

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ABSTRACT

Foot drop is a disorder characterized by the partial or total loss of dorsiflexion and eversion at the talocrural joint. Common etiologies are injury to the common peroneal nerve, sciatic nerve injuries, leprosy, Charcot-Marie-Tooth disease, and cerebral palsy. The most common etiology is injury to the common peroneal nerve (CPN). During gait, foot drop is characterized by the inability to lift the forefoot upon initiation of the cycle, causing the forefoot to strike the ground prior to the heel. This type of gait is known as steppage gait, which can be debilitating as it disrupts patients' ability to perform daily activities. Conservative treatment, such as the use of ankle foot orthoses (AFOs), is typically the first-line treatment. However, if conservative treatment fails, the next appropriate option is surgical intervention, which includes tendon transfers to correct the deformity. Of the tendon transfer procedures, the posterior tibial tendon transfer is most frequently used to treat drop foot deformity. Data from 157 patients and 161 feet were used to assess the effectiveness and patient satisfaction after undergoing posterior tibial tendon transfers as a treatment for foot drop secondary to common peroneal nerve injury. Post-operative Stanmore, AOFAS, or patient satisfaction grading assessments were then completed. Of the patients assessed using the Stanmore grading system, 92 patients recorded good or excellent results, 22 patients recorded moderate results, and 9 patients recorded poor results. This article analyzes the effectiveness of posterior tibial tendon transfers in patients with foot drop secondary to peroneal nerve trauma or injury.

INTRODUCTION

The peroneal nerve is the most frequently affected peripheral nerve of the lower extremity that causes foot drop. [1] Injury to the nerve is varied in etiology and may include trauma, infection, congenital, or iatrogenic. Injury to the nerve results in loss of dorsiflexion, ankle eversion, and toe extension. [2] Injury is also characterized by an equinovarus deformity at the ankle and hindfoot. [3]

During the heel strike phase of the normal gait cycle, the ankle remains in either a slight extension or a neutral position. During the swing phase, an active extension of the toes and ankle is required to clear the ground. [2] However, with foot drop, the patient slaps the foot on the ground and drags it along the ground during the swing phase of gait. As a result, the patient has to flex the hip more than normal to lift the entire foot off the ground, which is known as a high steppage gait. [2]

Conservative treatment for drop foot includes the use of Ankle Foot Orthosis (AFO). The use of AFOs helps maintain the foot in a plantigrade position during the loading response phase of gait and prevents foot dropping during the swing phase. [3] However, this treatment is not well tolerated, especially in the active young adult population. [1] The AFO can be uncomfortable and not visually appealing in the shoes because of its bulkiness. In addition, the increase in material between the foot and the ground may affect balance. [4] The brace may also lead to ulceration with footwear due to the increase in pressure points around the foot and ankle.

Various surgical techniques have been described in the literature to address a drop foot, but the gold standard is considered to be dynamic tendon transposition of the tibialis posterior tendon. [1] Codivilla in 1899 and Putti in 1914 are credited for first describing the transfer of the posterior tibial tendon to the dorsum of the foot to restore appropriate dorsiflexion in the foot. [1] This transfer allows almost normal functional gait and prevents the possible equinovarus deformity caused by the tibialis posterior tendon. [2] Possible questions such as the best route of transfer, the type of insertion, the place of insertion, best the candidate for transfer, and the tension of the transferred tendon are essential and are still being investigated. [5]

Many techniques have been discussed and implemented for tibialis posterior tendon transfer. Putti, in 1914 transferred the tendon anteriorly through the interosseous membrane to the dorsum of the foot. In 1954, Watkins et al. reported 'good' or 'excellent' results in 24 out of 25 patients using this technique. [1] Many modifications have been discussed since then in the literature, including the Bridle procedure, which was first prescribed by Daniel Riordan in 1973. [3] This procedure was designed to address under or over-correction of coronal plane position where the attachment of the tibialis posterior tendon was either placed too far lateral or too far medial. [1] The Ober procedure was described in 1933, whereby the muscle belly lies in contact with the tibia. [6] Other modifications include different attachment sites of the tendon in the foot. One attachment may be a tendon-to-bone fixation, by which the tibialis posterior tendon is looping around the second metatarsal (modified Ober procedure), and another is tendon-to-tendon fixation, where the attachment site is the tibialis anterior tendon. [2]

The focus of this systematic review is to use the reported outcomes of each chosen retrospective or case study to evaluate the effectiveness of posterior tibial tendon transfer in patients with drop foot secondary to peroneal nerve injury.

METHODS

Search Strategy and Criteria

This comprehensive systematic literature study was conducted according to PRISMA guidelines. The search term "Tibialis Posterior Tendon Transfer for Foot Drop" was used to seek out relevant articles. The electronic databases used to find relevant articles to the aforementioned search term were PubMed and Google Scholar. All studies published up until September 2022, at which point this study was conducted, were evaluated and screened for inclusion. In addition, all references cited in identified reviews were manually searched for potentially relevant information on the topic of this article.

Inclusion and Exclusion Criteria

The literature was screened for subjects that underwent some form of tibialis posterior tendon transfer for the treatment of foot drop; with or without additional procedures and disregarding age, sex, ethnicity, etc. All studies were included, disregarding the year of publication as well.

Identified studies were included if they met all of the following inclusion criteria: (1) articles written in English or translated to English; (2) articles with full-access to readers via electronic databases PubMed and Google Scholar; (3) acquired etiology of CPN injury leading to foot drop; (4) retrospective case studies, case studies, and retrospective case series; (5) follow-up time of at least 6 months; (6) clinical scores are taken using approved clinical methods.

Case reports, cadaver studies, publications including subjects with congenital or infectious disease etiology of CPN injury leading to foot drop, or publications failing to mention etiology of CPN injury leading to foot drop were excluded from this systematic review

Assessment of Study Quality

The assessment of the quality of included studies was done by all participants of the study as a whole and then later screened for a second time by two authors— sophomore and junior podiatric medical students using the same consensus rule. The purpose of the second screening was to ensure that all articles definitively met the inclusion and exclusion criteria outlined above.

Data Collection and Abstraction

All abstracts identified from PubMed and Google Scholar literature searches were manually screened against the outlined inclusion and exclusion criteria. During the second screening process, for each publication, two authors— sophomore and junior podiatric medical students— assessed the included literature based on the following criteria: study design, follow-up, and population. Any disagreements on the inclusion of publication were discussed between all authors of literature to reach a consensus. After the abstracts were reviewed and screened for inclusion, the authors assessed the remaining included publications' full-text articles.

For all remaining eligible studies, the following characteristics were extracted: author(s), publication year, study type, time to follow-up assessment, number of subjects, number of feet, number of male subjects, number of female subjects, and age range of subjects in each publication. Said data was extracted from article texts and any tables or figures reported in article texts.

RESULTS

A total of 99 potential articles were collected from online databases. After the addition of inclusion and exclusion criteria, 10 articles were found to be relevant for the purpose of this review. Of those articles, one article was a case study, and the remaining nine articles were retrospective studies. The publication dates of the articles ranged from 2001-2021. It should be noted that each patient included in this review experienced trauma or injury to the peroneal nerve or fibular portion of the sciatic nerve. Central neurological causes of foot drop were not considered.

Methods Flow Chart

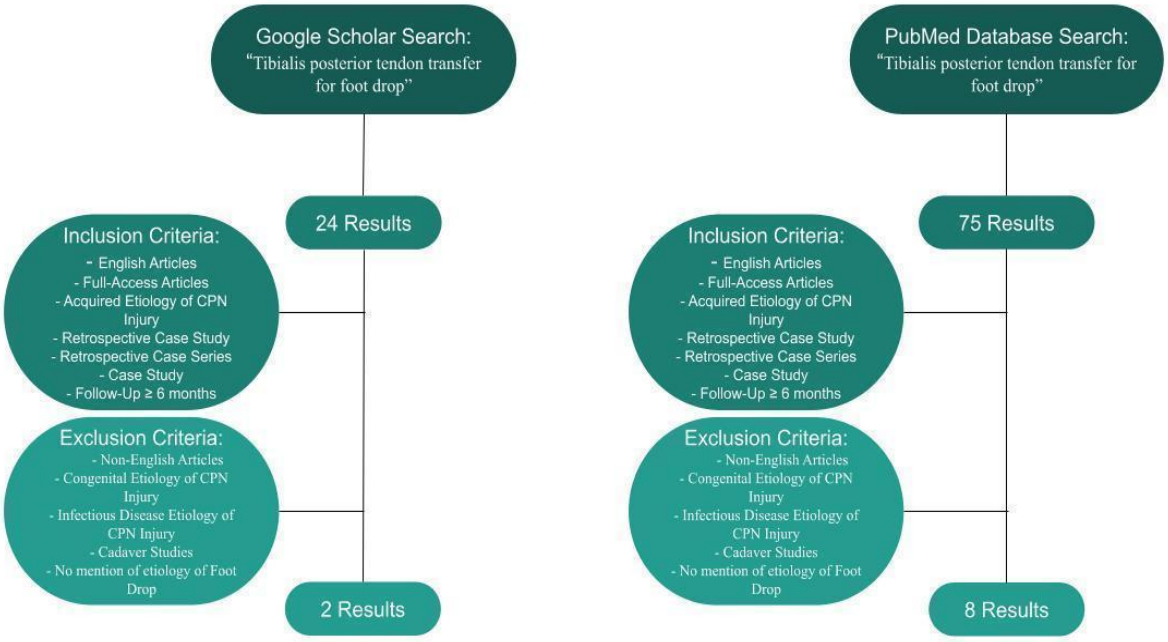

Table 1: Studies included in this Review

Study Number	Authors	Publication Year	Study Type	Time of Follow-up Assessment
1	Muhammad Imran Khan et al.	2021	Retrospective Study	6 months (mean 34.3 months)
2	Adolfo Vigasio et al.	2008	Retrospective Study	24 months (mean 65 months)
3	Yeap et al.	2001	Retrospective Study	6 months (mean 64.6 months)
4	Yeap and Birch et al.	2001	Retrospective Study	24 months (mean 90.4 months)
5	Cho et al.	2017	Retrospective Study	12 months (mean 65.6 months)
6	Kilic et al.	2008	Retrospective Study	Not specified (mean 25.3 months)
7	Niranj	2020	Case Study	6 months
8	Yeganeh et al.	2013	Retrospective Study	6 months
9	Johnson et al.	2015	Retrospective Study	12 months (mean 22.8 months)
10	Flynn et al.	2014	Retrospective Case Series	44.4 months (mean 61 months)

Table 2: Cohort Characteristics

Study Number	Number of Patients	Number of Feet	Male	Female	Age Range
1	32	32	28	4	28-34 yr
2	16	16	10	6	11-44 yr
3	18	18	9	9	12-73 yr
4	12	12	7	5	12-56 yr
5	17	17	10	7	18-59 yr
6	13	15	7	6	10-46 yr
7	1	1	1	0	24 yr
8	14	15	9	6	10-55 yr
9	19	19	14	4	23-57 yr
10	15	16	9	6	17-72 yr

Table 3: Procedure Scoring Criteria *In Study 8, one patient did not complete the follow-up questionnaire.

Study Number	Scoring Criteria	Patient Scoring Results	Post-operative AFO Usage
1	Excellent, Good, Moderate, Poor Active Dorsiflexion Assessment	7, 14, 9, 2	2
2	Stanmore Grading System	8, 5, 2, 1	2
3	Stanmore Grading System	4, 7, 2, 5	13 once weekly, 1 twice weekly, 0 constantly
4	Patient Satisfaction: Excellent, Good, Moderate, Poor	6, 4, 2, 0	1 constantly, 1 intermittently
5	AOFAS, FAOS, FAAM	N/A	1 (occupationally)
6	Stanmore Grading System	7, 3, 3, 2	1
7	Physician Assessed	N/A	0
8	Stanmore Grading System	10, 4, 0, 0*	0
9	Stanmore, Statistical Analysis	12, 7, 9, 0	2 (for athletic purposes)
10	AOFAS	N/A	0

Patient Characteristics

A total of 157 patients and 161 feet met the criteria for this review. Of those, 104 patients were men, and 53 patients were women. The total age range of patients was 10-73 years old. From the included cohorts, there were a total of 157 patients, and 161 posterior tibial tendon transfers were performed as several patients had operations on both feet.

Scoring Criteria

Five of the studies used the Stanmore assessment questionnaire. The Stanmore questionnaire assesses

pain, need for orthoses, ability to wear normal shoes, ability to complete daily function, degree of active dorsiflexion (measuring both muscle strength and degrees), and foot posture. Each of these criteria is graded. The total possible score adds to 100. Excellent or Very Good scores achieve 100-85 points, Good scores achieve 84-70 points, Fair or Moderate scores achieve 69-55 points, and Poor scores achieve <55 points. Study one used their own scoring criteria where they measured the success of the posterior tibial tendon transfer procedure on the patient's ability to actively dorsiflex at the ankle. Excellent scores achieved >15 degrees active dorsiflexion, Good scores achieved 5-15 degrees active dorsiflexion, Moderate scores achieved no active dorsiflexion and no foot drop, and Poor scores presented with plantarflexion. Study four measured their outcomes based on patient satisfaction. Study seven measured their success based on active dorsiflexion and physician satisfaction. Studies five and ten measured their success using an array of different criteria such as the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot scores, Foot and Ankle Outcome Score (FAOS), Foot and Ankle Ability Measure (FAAM) scores, Hindfoot Scale and Short Form (SF)-36 forms and objective clinical and radiographic measurements.

Of the 123 patients whose follow-up progress was graded using the Stanmore criteria or similar satisfaction criteria, 92 (74.8%) patients recorded excellent or good results. 22, (17.8%) of patients recorded moderate results, and 9 (7.4%) of patients achieved poor results. The patients in study 5 were scored according to the AOFAS, FAOS, and FAAM; the results discussed below favored posterior tibial tendon transfer as a viable method to restore function in foot drop patients. According to the cohort in study 10, all patients verbally communicated they were satisfied with the procedure and would undergo a posterior tibial tendon transfer again. Postoperatively, 15 patients required the use of an AFO intermittently during the course of a week, one patient required the use of an AFO occupationally, two patients required the use of an AFO for athletic purposes, and six patients required the use of an AFO consistently to perform daily functions.

DISCUSSION

This systematic review analyzed various articles that focused on the transfer of the posterior tibial tendon in patients diagnosed with drop foot secondary to peroneal nerve injury or trauma. This review was conducted to analyze the efficaciousness of the tendon transfers using the reported outcome measures of each article. Stevoska et al. [7] has conducted a similar review and analysis on the topic, citing another article by Wagenaar et al. [7] that performed a similar discussion on the topic at hand.

Alternative Procedure Effectivity Grading Criteria

Tibialis posterior tendon transfer is the gold standard in treating foot drop secondary to peroneal nerve injury. Multiple attachment sites have been suggested based on the etiology and the desired correction. [2] The route through which the tendon is passed to the dorsum of the foot is also dependent on the etiology, skill of the surgeon, and the severity of the drop foot. Two commonly used attachment sites are to the 2nd metatarsal bone and to the tibialis anterior tendon. [2] Khan et al. initially looked at whether one of those attachment sites is superior to the other. In the 6th post-operative month, both groups had similar results, with 80% of the patients having good to excellent dorsiflexion. However, at the 34th post-operative month, significant differences were observed between the groups, indicating that long-term differences are likely to be observed when using these two specific attachment sites. [2] The group with a tendon-to-tendon fixation showed deterioration of function, and only a minority of patients reported excellent results. Instead, 40% had moderate results. The authors addressed the shortcomings of the interosseous route by lengthening the tibialis posterior tendon before fixating it to the 2nd metatarsal. This allows the tendon to have enough length to maintain its strength, restore adequate dorsiflexion and prevent an equinovarus deformity that could potentially result from an unopposed pull of a short tibialis posterior tendon. [2] This lengthening of the tibialis posterior tendon was hypothesized to lead to slippage or rupture due to the thinning of the tendon. Still, such complications were not observed in the study. Although tendon-to-bone fixation is surgically demanding in dissection and insertion [2], this article highlighted that the interosseous route with a 2nd metatarsal insertion led to better outcomes when restoring function and providing patients with normal gait without a need for ankle foot orthoses. Limitations included sample size.

Yeap et al. used patient satisfaction, which correlated with the muscle power and degree of active dorsiflexion, to determine the success of their surgery. The authors found that the best results were achieved in the younger population, specifically in males under 30 years of age. [8] This demographic showed excellent results and was able to achieve active dorsiflexion beyond neutral. [8] Although the ankle range of motion upon dorsiflexion increased significantly postoperatively, the torque generated by the affected limb was only around 30% of the torque generated by the unaffected limb. [8] The authors could not comment on whether stretching the tendon or attaching the tendon

distally to the cuneiform resulted in function deterioration, except that some patients reported weaker dorsiflexion following pregnancy and recent falls. The authors did not comment on some patients having multiple procedures to reach adequate results. In this study, the interosseous route was preferred over the subcutaneous route even though it was more surgically challenging because it is more direct, produces less pronation, and achieves more dorsiflexion. [8] They admitted that despite all procedures having undergone the interosseous route, patients had different tendon attachment sites depending on the case's severity. This made it difficult to interpret the results and compare the groups. This also means they can no longer isolate the success of the tendon transfer to the initial procedure. The authors overall recommend tibialis posterior tendon transfer as it potentially improves the function of 80% of patients, especially males under 30 [8], but were not able to provide insight on whether a distal or a proximal tendon attachment would be beneficial for the patients.

Cho et al. found that the long-term function of patients following tibialis posterior tendon transfer was satisfactory. The most important factor to highlight was that daily activities and gait functionality improved at the 3 year follow up and thereafter. [9] The authors also restored a considerable ankle range of motion, but the dorsiflexion strength was only about 33% of the unaffected limb, which is in line with what Yeap et al. found. [8,9] Although some patients were able to achieve a more significant power output, they were considered above the overall average. The authors found no evidence of progression to flat feet, whether radiographically or clinically definitive, in this retrospective study. The authors were unable to determine which tendon transfer method was the best for the patients. Still, they highlighted that the most important prerequisite for post operative success is to be careful with patient selection, being thorough in preoperative examination, and only offer surgical intervention to patients who will clinically benefit from the tendon transfer. [9] The article highlighted the importance of passing the tibialis posterior tendon under the extensor retinaculum in case a subcutaneous route is chosen for the surgery. It also highlighted the importance of appropriate rehabilitation at week six post-operative to work on mobilization and range of motion. [9] The study mentioned that there is an iatrogenic collapse of the medial longitudinal arch that has been described as a potential adverse effect of the tendon transfer. This is limited to a few case reports [9] of which, according to the authors, surgical intervention should have never been offered in the first place as these cases were unlikely to be successful long term. The authors claimed that sacrificing the tibialis posterior tendon would not lead to any medial arch vulnerability and the stated that an acquired flat foot deformity as a result of the tibialis posterior tendon transfer is debatable in the literature. [5] In this study, they did not find any long-term arch issues. The authors recommended further long-term studies to assess whether sacrificing the tibialis posterior tendon would directly lead to an acquired flat foot. The authors also highlighted that although adequate peak torque and range of motion will be restored towards dorsiflexion, active plantarflexion at push-off was significantly reduced as the tibialis posterior tendon could no longer contribute to plantarflexion. [9] Limitations for this retrospective study included that the corresponding physicians did preoperative muscle strength and assessments, and therefore the authors were not able to determine the accuracy of these measurements. This study also did not include any gait analysis and dynamic electromyography postoperatively or during the rehabilitation period. The authors did not comment on why they chose to pass the tendon from under the extensor retinaculum as it might lead to impingement. It may be because of cosmetic reasons or to avoid adhesions, but these are our speculations, as no comments were made in the discussion.

Abdelaziz et al. Looked at common peroneal nerve injury patients who haven't had any intervention for over a year. They were careful in their population selection to not include any patients with an equinus that needed a tendo-chilles lengthening. They also made sure that all the patients selected had supple ankle joints to guarantee the best outcome and isolate potential failures to be only due to failure of the tibialis posterior tendon transfer and not due to other etiologies at play. They highlighted the importance of stretching exercises for the Achilles tendon for patients who could not dorsiflex their ankles past neutral. This was crucial because delaying the time of the tibialis posterior tendon transfer leads to the shortening of the Achilles tendon due to the unopposed pull and the weakness of the opposing anterior crurals; therefore, preoperative stretching of the Achilles tendon is very important for the success of the tendon transfer. [10] The authors highlighted the importance of the degree of tension in the tibialis posterior tendon after it is tied down because tibialis posterior has an excursion of only 2 cm when compared to opposing muscles like tibialis anterior and extensor hallucis longus, which have excursions between 3-5 cm. [10] If the tibialis posterior is to be sutured to one of those tendons in a tendon-to-tendon fashion, the degree of tension will need to be adjusted accordingly as the passive arc of movement will always be less on the operated side than the unaffected side. [10] The authors preferred the interosseous route over the subcutaneous route mainly for cosmetic reasons and to avoid adhesions that are likely to result. They highlighted that the interosseous route is more surgically challenging but provides better results,

including less pronation and greater dorsiflexion. They chose to stay superficial to the extensor retinaculum to have a longer moment arm and to avoid impingement. They also chose a tendon-to-tendon fixation as inserting the tendon to bone required a tendon graft which was not available to them. All the patients reported excellent results and were satisfied with the tendon transfer. The results were in line with the existing literature. [8,9,10]

The Bridle procedure combines a tri-tendinous anastomosis to restore active dorsiflexion of the ankle, [3] Flynn et al. highlighted one of the modifications to the original Bridle that they used was to include a subtalar arthroereisis in their patients, which did cause some mild pain at the sinus tarsi. Still, the patients were able to maintain a plantigrade foot.[3]The idea behind the implant was to prevent an acquired flat foot deformity from forming long-term, despite sacrificing the tibialis posterior tendon. This was done to guarantee no long-term pronation problems. The authors highlighted that three of their patients complained of a lack of hallux extension, which was also mentioned by previous literature and is an important side effect of the bridle procedure. [3] The authors admitted that their patients had no midfoot motion during heel rise and did not develop a flat foot postoperatively. However, the authors did not show any radiographic or clinical evidence of an acquired flat foot in the patients who did not receive the subtalar implant. The study did show that the patients who received the implant did not go on to develop a flat foot. This raises the question whether the arthroereisis was a necessary modification or whether it was not needed. The authors highlighted the limitations being the low number of patients, particularly with long term follow up. The authors admitted that only three patients continued to follow up long term, and those three patients did not receive the implant, so the authors were not able to determine the significance of the implant. The authors complained of loss to follow up, with only eight patients in total returning out of 15. Nonetheless, the authors were pleased with the outcome of both groups and recommended the Bridle procedure with or without the arthroereisis for the treatment of foot drop. [3]

In the case study conducted by Niranj at the Madurai medical college, they reported on a 24 year old male patient that had an injury to the sciatic nerve 1.5 years preceding the study. [11] After conservative management, the common peroneal nerve showed no signs of recovery and they performed a modified Obers'procedure out of phase tibialis posterior tendon transfer. [11] The PT tendon was detached from its insertion at the navicular and rerouted subperiosteally through anteromedial aspect of the tibia and then split into two slips via a separate incision. [11] The two tendon slips were inserted to EHL and EDL tendons using the Pulvertaft's technique. [11] The patient was immobilized post operatively using a below knee cast for three weeks, maintaining a mildly dorsiflexed position of the foot. [11] The patient then underwent physiotherapy to regain mobility and strengthen the new antagonistic action of the tibialis posterior muscle. [11] At the end of six months, there was good functional outcome according to the physician assessors, and the patient had up to 10 degrees of active dorsiflexion and sufficient muscle power that could withstand moderate resistance. [11] The authors found that this out of phase transfer possessed excellent functional results, despite the ideal type of transfer being an in-phase transfer. [11] Additionally, they concluded that the tendon anastomosis following the surgery required less postoperative care in comparison to tendon-to-bone anastomosis. [11] The limitations of this study revolved around the lack of information about how functionality was scored. This study was physician assessed, but failed to highlight the criteria used to make the conclusion that the patient had excellent results following the procedure.

Stanmore Score Outcome Measures

The Stanmore assessment questionnaire, otherwise known as the Stanmore Score, is focused on the goals of the posterior tibial tendon transfer. [7] This assessment system offers an objective evaluation of posterior tibial tendon transfer, and it facilitates comparison of diverse modifications to operative technique. [6] It is commonly used to assess the functional outcome of patients undergoing tendon transfer following peroneal nerve injury and was used in five of the 10 articles (50%) included in this review.

A common theme in articles assessing posterior tibial tendon transfer is the difficulty in objectively comparing outcome measurements. Yeap proposed a new system for assessing posterior tibial tendon transfer for treatment of drop foot resulting from nerve palsy. [6] Yeap highlights the deficit in previous evaluation methods in this article to provide clear definitions of the methodology used to analyze posterior tibial tendon transfer outcomes. [6] The authors proposed a scoring system consisting of seven sections: pain, orthosis necessity, ability to wear normal shoes, level of activity, ankle dorsiflexion muscle power, degrees of active dorsiflexion, and foot posture. [6] Yeap defines the maximum total score as 100, with different classifications assigned to ranges of scores. [6] Excellent results were defined as scores between 85 and 100, good results between 70 and 84, fair between 55 and 69, and poor as scores lesser than 55. [6]

The retrospective study initially included 25 patients, of which only 18 were considered in the final representation due to refusal of participation, death,

and loss of follow up. [6] The age of the patients spanned from 12 years old to 25 years old, the gender of patients was not specified in article. [6] The cohort characteristics exhibit limitations in the study population that could impact result interpretation. The cohort represents an incomplete population of patients who have undergone treatment, which could lead to a biased sample population due to lacking patient results. Yeap discloses that one patient who refused to participate potentially had a poor outcome, citing that the patient's mother was dissatisfied with the results. [6] This highlights the potential bias that could occur from the excluded patients from the original population. Additionally, the wide range in age between patients could affect the ability to objectively compare components of the proposed scoring system, such as level of activity and ankle dorsiflexion muscle power. Yeap had accounted for the potential discrepancy in level of activity and assessed functional outcome by observing the ability of the patient to conduct activities of daily living as well as recreational activities. [6] The possibility of the older cohort population having other conditions impacting activity levels was considered. The author decided that only functional limitation secondary to foot drop was considered in this study. [6] However, the author did not disclose how functional limitation secondary to foot drop was determined and did not disclose potential health conditions. The addition of this information would offer a more transparent and accurate interpretation of results on behalf of the reader.

The Stanmore system showed 22% of the cohort had excellent results, 38.8% had good results, 11.1% had fair results, and 27.7% had poor results. [6] An average score of 67.2% was calculated, correlating to overall fair results of the tendon transfer. [6] In contrast, patient ratings showed 38.8% excellent results, 27.7% good results, 16.6% fair results, and 16.6% poor results. [6] The article discusses the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale, aimed at assessing surgical outcomes for painful foot and ankle pathologies. In agreement with the author, this outcome measure does not adequately evaluate tendon transfer of the tibialis posterior because the aim of posterior tibial tendon transfer is functional control of the deformity and not pain control. [6] This outcome measure is cited in other systematic reviews [7], when it may not be the most appropriate measurement to assess efficacy of a tendon transfer procedure. Similarly, the author brings attention to the contrast in outcome scores when assessed via an objective scale like Stanmore versus a more subjective scale such as a patient rating. Conflicting results of both outcome measurements, coupled with the inadequacy of the AOFAS Ankle-Hindfoot scale, agree with the author's rationale behind a new proposed scaling system.

Yeap states that the suggested scaling system would offer a better objective evaluation that may be better tailored to assessing tibialis posterior tendon transfer outcomes. [6] The system can be assessed and recorded both preoperatively and postoperatively, providing a baseline reading to compare to the final patient outcomes. This could potentially increase accuracy in evaluating surgical outcomes. Yeap states that although the patient is the final assessor in the outcome, the evaluation of procedure outcome based solely on patient assessment could pose inaccurate and unreliable results. [6] Patient satisfaction is easily biased as a result of different expectations and varying degrees of pain unique to each individual. An objective analysis would be beneficial to accuracy and theoretically decrease subjective bias. The author specifies that this system would be specific for posterior tibial tendon transfer surgical results, [6] facilitating accurate comparison of patient outcomes without the limitation of factoring in differing operative techniques. To aid in the comparison of different surgical modifications to the procedure, an additional objective measurement, such as the Stanmore scale, could be used. [6]

From the introduction of posterior tibial tendon transfer in 1933 by Ober, [12] there have been several developments in surgical techniques, procedures, and fixation techniques. Commonly, the tibialis posterior tendon is transferred to the dorsum of the foot, anchored to cuneiforms or metatarsals, to compensate for the forfeiture of the tibialis anterior muscle. [12] Yeganeh conducted a case study to find an alternative fixation point on the dorsal surface of the foot to prevent adverse effects of skin problems and ulceration caused by knop along the plantar anchorage site of tendon transfer. [12] The author recruited patients with post-traumatic common peroneal nerve palsy from 2009 until 2012, explaining the benefits of the original tendon transfer compared to the proposed benefits of transferring the tendon to the dorsal aspect of the foot. [8] The cohort included nine men and six women, ranging in age from 20 to 55 years old. [12] The procedure with an alternative dorsal anchorage site was conducted on 15 patients, dependent on patient preference and inclusion criteria of the study. The cohort presented with non-improving peroneal nerve palsy after 18 months despite nerve repair or releasing procedures, confirmed by electromyography and nerve conduction velocity tests. [12] The cohort had follow up evaluations at the two month, three month, and six month range. [12] One could argue that more than the maximum follow up time of six months is needed to adequately assess surgical results, a longer follow up period could add more insight into the long term effects of the procedure. Some limitations included a lack of control group, as well as a small case population, and retrospective nature of the study. [12] Another

limitation was the failure of a patient to complete the therapy, reducing the already small cohort population. [12] All of these limitations were determined using the Stanmore scoring system. Despite the limitations, the study yielded adequate results of the tendon transfer with Yeganeh's new proposed fixation method.

In Johnson's retrospective study, the aim was to analyze clinical outcomes and objective functional measurements expected in patients that have undergone the Bridle procedure for drop foot management secondary to traumatic peroneal nerve injury. [1] The study included 19 patients who suffered traumatic peroneal nerve injury from 2005 to 2010, having undergone the Bridle tibialis posterior tendon modification procedure by one of two surgeons. [1] The author disclosed that some patients within the cohort had previously undergone other procedures, such as peroneal nerve neurolysis, nerve repair, or grafting. [1] This disclosure prevented assumption bias of the reader to erroneously think that the subjects had only undergone the Bridle operation. Additionally, the author stated the etiology of the peroneal nerve injury within the cohort, preventing the assumption that all etiology was the same within the study population. The study also included an initial period of conservative nonoperative treatment, showing that these patients had no improvement prior to surgery and highlighting the effectiveness of the Bridle procedure on functional outcome. There was a descriptive analysis of cohort based on chart review and history intake, providing a well-rounded foundation of each patient's condition and presentation. A control group was formed of 10 participants without foot and ankle injury; they were matched to the study participants by age, weight, gender, and height. [1] The availability of a control group in this retrospective study adds to the viability of result interpretation and functional outcome measurements. Matching the control group to the study population also provides a personalized comparison while minimizing variables that may potentially affect accurate evaluation between cohorts. Johnson described the operative procedure in detail, allowing the reader to factor in all aspects of surgical technique and fixation methodology when evaluating the study results. Functional outcomes were assessed subjectively via a patient questionnaire, which included activity levels, VAS scale measurements, and AFO use. [1] It was also assessed objectively via the AOFAS Hindfoot Ankle scale, Stanmore scale, ankle range of motion, Star excursion balance, radiographic alignment, and muscular strength of ankle dorsiflexion and plantar flexors. [1] The objective measurements were standardized, and a detailed statistical analysis was conducted, allowing for comparison of sex, race, and similarity of involved sides. [1] Due to assumptions needed for this statistical analysis, the author evaluated multiple joints' range of motion as well as ankle dorsiflexor strength and transverse plane alignment to counteract the limitations set by this method of analysis. [1] The author also disclosed the exact statistical tests used to assess multiple outcome measurements, providing the reader with detailed methodology and emphasizing the accuracy of their results.

The author described the original Bridle procedure article written by McCall in 1991 and compared their results to the results yielded in Johnson's retrospective study. Additionally, there was mention of the Modified Bridle procedure study by Rodriguez. The aforementioned studies rarely discussed the clinical outcome and objective measures and contained few details of operative technique. [1] In contrast, Johnson discussed all of the previously mentioned factors and highlighted the importance of including them in the study. This case-controlled retrospective study yielded high satisfaction rates with good or excellent self reported outcomes, as well as a 100% success in the cessation of AFO use for daily activities. [1] Johnson's outcomes are in agreement with the notion that the Bridle procedure is an appropriate and effective treatment option in traumatic peroneal injury induced dropfoot. Although the Foot and Ankle Assessment Measurement (FAAM) scores were lower in the Bridle population versus the control group, there was still improvement seen in daily activity ability and sports activity. [1] This result was compared to a similar study by Rodriguez in which better results were noted concerning range of motion. Despite the better results, Johnson states that Rodriguez's results were not measured using validated outcome measures, objective assessments, or a control group comparison. [1] Similarly, Johnson provides comparison to other studies assessing operative techniques of posterior tibial tendon transfer and provides evidence as to why the results may differ from those seen in his study.

The limitations of this study included its retrospective nature, a lack of preoperative data in some of the cohort population, and a decreased sample size from the original 30 patients due to inclusion criteria. [1] The study group also possessed a heterogeneous nature of injury, included various sites and mechanisms of injury, and a wide age range. [1] However, the potential limitations of the study that additional evaluations or alternative assessments could counteract were proactively addressed by Johnson et al. and seemingly caused no harmful effects to result interpretation or accuracy in functional outcome measurement. The remaining limitations, such as heterogeneous nature of injury and those regarding cohort characteristics, are seemingly on par with other studies focused on posterior tibialis tendon transfer assessment. Despite all limitations, a well-rounded evaluation of surgical

outcome of the Bridle procedure was achieved, with standardized results and strongly backed by evidence obtained by objective measurements and statistical analysis.

In Viggasio's retrospective study, they reviewed 16 patients who underwent a posterior tibialis tendon transfer via the interosseous membrane transfer to the tibialis anterior tendon and rerouted through new insertion onto the third cuneiform and flexor digitorum longus tendon. [13] The homogenous cohort of patients operated on from 2008-2015 were evaluated at minimum follow up of 24 months (range 24-114 months). [13] Ten patients were male and six patients were female, the mean age of the cohort was 25.8 years, and eight patients had previously undergone microsurgery for common peroneal nerve repair with unsuccessful results. [13] The authors included information regarding the evaluation of the patients' following microsurgery and how they determined if their surgery was unsuccessful, they waited a mean of 18-24 months from time of referral until they were considered for tendon transfer. [13] The authors also provided an in-depth analysis of patient cohort characteristics, such as etiologies of their nerve injuries and the level at which the nerve was injured, adding to the reliability of the study. [13] They used EMG and nerve conduction velocity testing to assess muscle function during pre-operative clinical evaluation. [13] Their results showed that in all cases, transosseous rerouting of the anterior tibial tendon provided enough tendon length that allowed tendon to tendon suturing, proximal to the extensor retinaculum. [13] They concluded that the new origin of the tibialis anterior tendon at the third cuneiform was the optimal traction line to yield maximum degrees of dorsiflexion with minimal imbalance during pronatory and supinatory movements of the foot-ankle complex. [13] Thirteen patients were able to surpass zero degrees of active dorsiflexion and possessed balanced foot posture and a muscle power grade of five. [13] Eight patients (50%) possessed muscle grades of four or more, fourteen patients (87.5%) showed no toe drop and eleven of those fourteen patients (69%) were able to actively dorsiflex their toes. [13] At follow up evaluation, fourteen patients (87.5%) discontinued their AFO use for ambulation, none of the patients disclosed pain to the dorsum of the foot nor the midfoot during gait while ambulating with shoes. [13] They provided detailed descriptions of individual patient outcomes such as slight flat foot, digit hyperextension, and treatment failure due to tendon adhesions. [13] The one case of failure was deemed to have been a consequence of an incorrect indication for tendon transfer due to the crush nature of the patient's injury and subsequent skin necrosis from the injury. [13] The study also concluded that the patient's postural balance showed improvement due to the reduction of compensation in bipodal stance, as well as an improvement in gait progression. [13] According to the results of the Stanmore scoring system, eight patients (50%) yielded excellent results, five (31.2%) yielded good results, two (12.5%) had fair results, and one (6.2%) had poor results. [13] The average Stanmore score was 77.8, reflecting good results of the study as a whole. [13] Patient rating scores echoed those of the Stanmore citing that nine (56.2%) patients had excellent scores, four had good results (25%), fair in one (6.2%), and poor in two (12.5%). [13] The study possessed the characteristics of a well-researched and unbiased study, it proves to be a great resource in considering tendon transfers for correction of dropfoot. The inclusion of important details such as mechanism of injury, detailed patient outcomes, biomechanical and functional outcomes using a standardized scoring system make this study stand out among the rest.

CONCLUSION

The results of this analysis aligned with the selected studies. Posterior tibial tendon transfer procedures provide a benefit that outweighs that of conservative treatment for patients experiencing long term foot drop secondary to peroneal nerve trauma or injury. Possible limitations to this study include failure of patients to follow-up, potential population bias, small sample size, and different postoperative scoring criteria. Should a similar analysis be conducted, it would be beneficial to have cases using the same scoring criteria or review both retrospective and prospective studies to compare results. The results of this study are also limited by the exclusion of non-English literature, case reports, and cadaver studies which further decreased the available data for analysis.

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The Reverse Home Run Screw, A Novel Plate Design for the Lapidus: A Literature Review

Tushar Singh, B.S., Emily Zink, B.S.

ABSTRACT

The first tarsometatarsal joint (TMTJ) arthrodesis (Lapidus) is a procedure that has changed substantially since its original development and has become a mainstay for hallux valgus correction. The evolution has primarily come via the institution of newer constructs and procedure methods, which have reduced operative difficulty and created greater rigidity across the joint space for adequate arthrodesis.

In this review, the two authors performed a PubMed database search regarding historical fixation for the first TMTJ fusion. The goal was to determine if the proposed construct which addresses fixation on the tension side of the TMTJ had been described for the Lapidus in previous literature. The results demonstrated various designs incorporating screws and plates in various combinations but did not have the below proposed configuration of screw and lag plate.

The new plate design posited by this review is a dorsomedial locking plate design with an interfragmentary screw directed from dorsal medial cuneiform to plantar first metatarsal. The addition of this screw would allow for compression across the plantar tension side of the joint space and compress along the axis of force applied to the joint through gait.

INTRODUCTION

The procedure originally described by Albrecht in 1911 was popularized by Lapidus decades later and fixated using chromic catgut. [1, 2] Since, more rigid constructs have been developed and described in the literature with a litany of devices introduced. Researchers have demonstrated unique fixation methods within the newer plates, including dorsal, medial, or dorsomedial plate fixation approaches. [3] The common theme across a majority of these plate designs is the maintenance of the traditional home run screw which compresses the joint from dorsal distal to plantar proximal, opposite the direction of the forces encountered during ambulation.

Historically, barebones designs with minimal fixation involve the use of the "home run screw" directed from dorsal first metatarsal to the plantar medial cuneiform. Building on the simplistic home run screw, screw-only designs add a crossing screw directed from the dorsal medial cuneiform to the plantar first metatarsal with additional intermetatarsal or intercuneiform screws (**Figure 1**) for added sagittal plane stability. [5] Since the advent of locking plates, several companies have developed their plates for the Lapidus, some with integrated interfragmentary screw or staple holes for compression. Tension side fixation has been a topic of recent interest and seeks to ensure union via prevention of motion across the site that is most likely to open with normal activity.

The considerations for the simplification and evolution of the arthrodesis involve assessing the biomechanics of the first ray, which has a cantilever motion with tension side on the plantar aspect and compression side on the dorsal aspect of the first tarsometatarsal joint (TMTJ) during the stance phase of the gait cycle. [6] The points of comparison are concepts that are logically and sequentially related: comparisons between plate and screw fixation; comparisons between plates with integrated compression screw holes and those with plates separate from their interfragmentary screws; and the type and location of the fixation, whether plantar, dorsal, or medial.

METHODS

A systematic search was conducted via PubMed for research regarding techniques and considerations for Lapidus Fixation. Two co-authors independently performed searches with terms including "Lapidus, Lapidus fixation, tension side fixation, and first ray biomechanics". The inclusion criteria was that the literature had to be specific to the fixation methods of the first TMTJ. Articles without mention of specific

fixation techniques or involving adjunctive procedures were excluded. In addition, 19 studies, including literature reviews, randomized control trials, cadaveric studies, cohort studies, technique guides, and retrospective studies, were reviewed.

RESULTS

As previously mentioned, Lapidus popularized the TMTJ arthrodesis and had originally fixated with catgut. Bacardi et al. [7] took the principles from that original concept and applied rigid internal fixation to it utilizing 4.0 screws from the first metatarsal to the second metatarsal base along with an adjunct screw going from dorsal first metatarsal base to the plantar medial cuneiform which is now termed the "traditional home run screw" (**Figure 2**). As this construct evolved,

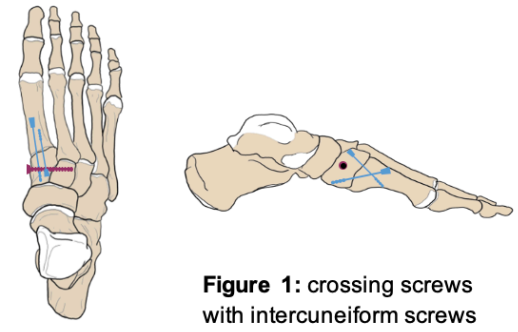

Figure 1: crossing screws with intercuneiform screws

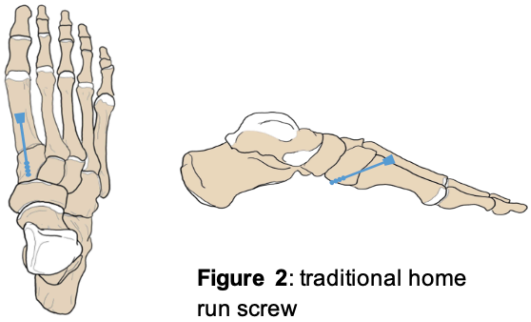

Figure 2: traditional home run screw

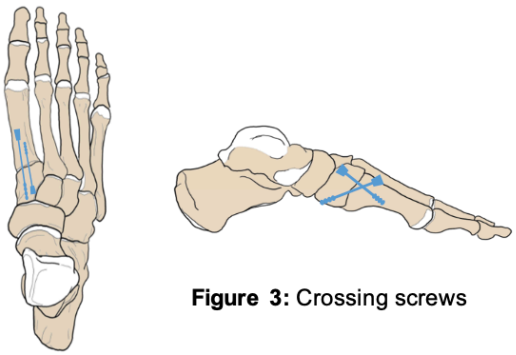

Figure 3: Crossing screws

Myerson [8] described a technique in which he performed a crossing screw from the base of the first metatarsal to the medial cuneiform and vice versa (**Figure 3**). With regards to the biomechanics of the first ray and the forces it faces, Christensen et al.[6] discuss the nature of the cantilever load application during midstance. The cantilever-oriented load is applied, and the metatarsal shaft is deferred to a dorsal position with plantar soft tissue structures acting as a tension band to hold the plantar aspect of the joint together. Thus the plantar side is referred to as the "tension" side in gait.

Locking plates have become a mainstay in the fixation of podiatric osseous procedures. They have often been cited as having improved strength vs. crossed screws in fixating the TMTJ arthrodesis site, while screws are the more economical option. To investigate the strength of the fixation constructs with specific regards to screws and locking plates, Klos et al. [9, 10] performed a cadaveric biomechanical study utilizing a crossed screw, a plate, and screw construct. The crossed screw construct used two 4-mm cannulated compression screws, with the first inserted in traditional home run fashion and the other inserted dorsal medial cuneiform to the plantar first metatarsal. The plate and screw arthrodesis used an X plate flush with the medial aspect of the TMTJ along with a compression screw directed in traditional home run fashion. The locking plate and screw construct showed lower gapping displacement than the crossed screw constructs. Additionally, the number of cycles to failure was significantly higher in the plate and screw than in the crossing screw ($p<0.05$) with the Kaplan Meier plot demonstrating lower cumulative survival probability. Another cadaveric investigation by Klos et al.[10] comparing dorsomedial plating (**Figure 4**) and plantar plating (**Figure 5**) constructs demonstrated improved performance in load to failure in the plantar plating group ($p<0.05$).

While a cadaveric study may be adequate for biomechanical analysis, it may not necessarily provide information regarding clinical outcomes. Saxena et al. [11] attempted to determine clinically significant differences in the crossing lag screw construct when compared with specifically a locking plate construct with a lag screw directed from distal plantar medial aspect of the first metatarsal to the proximal dorsolateral medial cuneiform (**Figure 6**). There were no significant differences between the intervention groups in the intermetatarsal angle (IMA) or American Orthopedic Foot and Ankle Society (AOFAS) scores. However, based on their previous literature, they discussed the benefits of the locking plate construct in that it was able to bear weight two weeks prior to crossing screw constructs with no significant differences in complication rate.

Anecdotally the author found that they had to perform fewer adjunctive Akin osteotomies when performing Lapidus with plantar lag screw fixation.

Both aforementioned studies demonstrate that locking plate and lag screw constructs are biomechanically and clinically sound approaches to performing a Lapidus. However, there are other factors that can alter the clinical outcome of the procedure. One of these considerations is the integration of a lag screw into the locking plate.

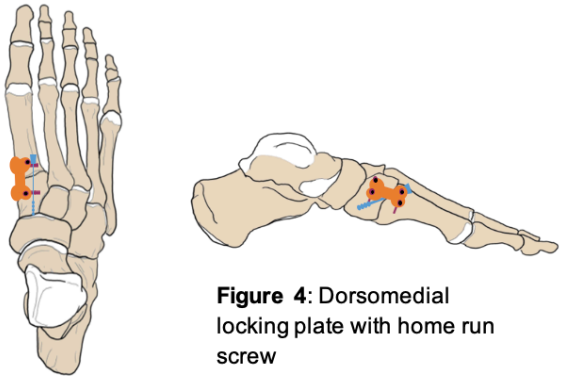

Figure 4: Dorsomedial locking plate with home run screw

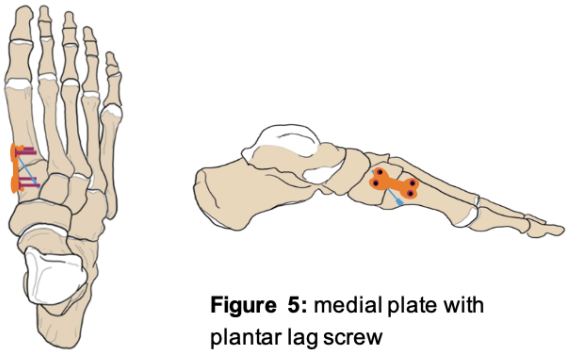

Figure 5: medial plate with plantar lag screw

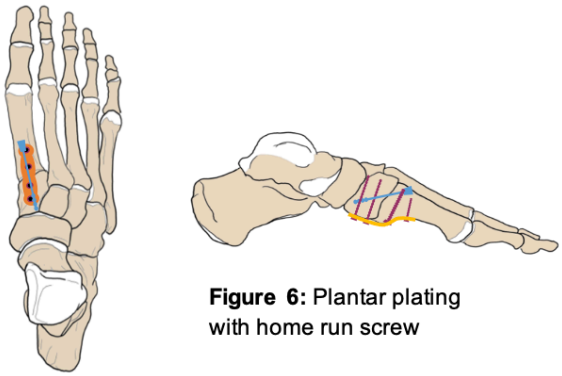

Figure 6: Plantar plating with home run screw

Barp et al.[12] utilized three fixation techniques: crossing solid core screws, a single interfragmentary screw with a simple T locking plate (**Figure 7**), and a locking plate with an integrated compression screw (**Figure 8**). The integrated compression screw construct allowed for 2 days earlier weightbearing at 27 days vs. 29 for the other groups. Additionally, odds of weightbearing within 30 days were 73% lower for the crossing screw and single plate with interfragmentary screw when compared to the integrated compression screw group. The nonunion rate was lowest in the integrated screw fixation group, but the difference was not statistically significant. Additionally, there was no statistically significant difference in the rate of hardware removal between the integrated screw and plate plus screw fixation groups. With all other factors remaining the same, the integrated plate had earlier weightbearing giving it a distinct advantage relative to the comparison groups.

More recently, clinicians have explored the possibility of tension side fixation and compared the constructs when fixation is placed variably along the joint surfaces. While in theory, plantar fixation would be an excellent approach, the presence of the peroneus longus and the tibialis anterior tendons limit plantar plate fixation's viability due to irritation and the amount of dissection required to access the fixation sites.[13] However, orthopedic developers and clinicians have successfully been able to conduct trials with tension side fixation for the Lapidus.

Dayton et al.[14] utilized direct dorsal-medial 90 degree locking plate constructs on TMT joint models in the control (**Figure 9**) vs. a standard dorsal plate with an angled medial plate extending from the medial proximal side contouring the bone plantarly as it extended to its distal attachment (**Figure 10**). Simulated joint loading was performed to mimic gait forces. Tension side fixation demonstrated a statistically significant greater load to failure and required nearly double the number of loads to fail compared to the biplanar construct oriented at 90 degrees.

While this construct does not incorporate a lag screw extending on the tension side, it contributes further data to earlier weightbearing for patients undergoing lapidus arthrodesis. Additionally, the study posits a means of fixation on the tension side of the joint via a dorsal approach.

Drummond et al.[15] investigated various biomechanical measures on 34 composite metatarsals stressed in cantilever fashion. The three groups were all initially fixated with a crossing screw construct with screws going dorsal first metatarsal to plantar medial cuneiform and dorsal medial cuneiform to plantar first metatarsal, each followed by either a dorsal locking plate (**Figure 11**), medial locking plate

(**Figure 12**), or plantar locking plates (**Figure 13**), all of which were identical locking plate systems. The dorsal plating system was not optimal in any of the measures. The plantar plating system recorded the highest stiffness, yield force, and failure strength, while medial demonstrated the highest failure displacement and yield displacement.

In their study, Cottom et al.[16] utilized a medially oriented locking plate with a lag screw driven from the proximal aspect of the base of the first metatarsal to the dorsal aspect of the medial cuneiform (**Figure 14**). Of the 88 patients, 2 had a nonunion at follow-up. The functional results show a 33.76 point improvement in the AOFAS scores on average. The researchers cited a congruency in the contact of bones during the loading cycle and the absence of plantar gapping as in traditional home run screw or generic non-tension side plated constructs. A criticism of this construct is the nature of the plantar screw fixation and its proximity to the medial and plantar attachments of the PL and TA muscle attachments.

To that point, Schilde et al.[13] conducted an anatomical study utilizing two plantar plating systems. It determined that PL and TA tendons may be considerably irritated during the plantar plating approach. Between the two plate constructs investigated, the study demonstrated that there was a potential irritation on the tendon site, with the first construct having peripheral contact in some way with the TA tendon in 42% of the cases and the second construct having contact with the TA tendon 8% of cases. Niehaus et al.[17] additionally found signs of tendinopathy on advanced imaging and moderately reduced inversion strength in 59% of patients undergoing Lapidus fixation with plantar plate application. The studies demonstrated that there is a potential for irritation or functional diminution that would lead to hardware removal procedures later on in the lifespan of the procedure should the surgeon elect to perform a plantar plating approach.

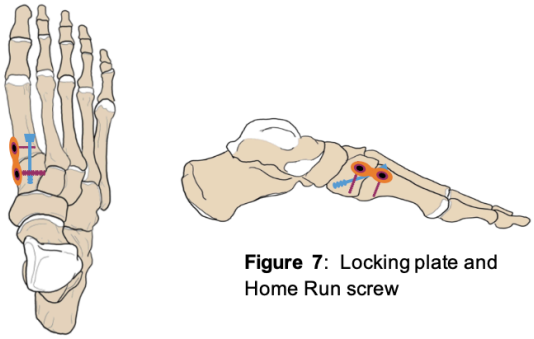

Figure 7: Locking plate and Home Run screw

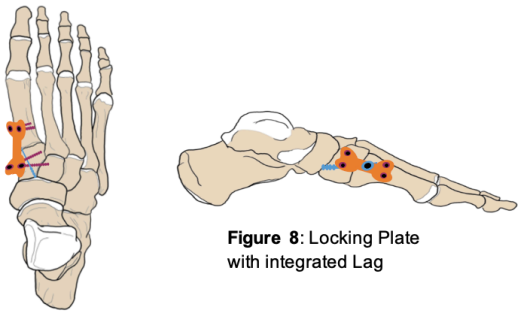

Figure 8: Locking Plate with integrated Lag

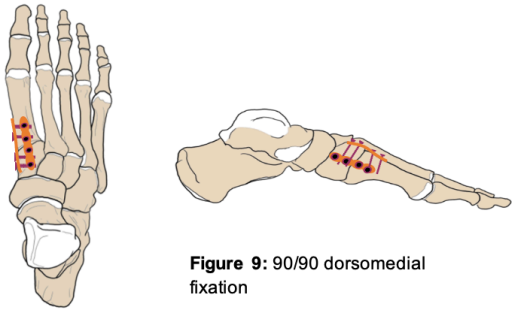

Figure 9: 90/90 dorsomedial fixation

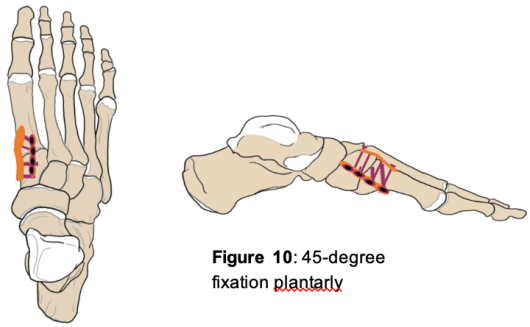

Figure 10: 45-degree fixation plantarly

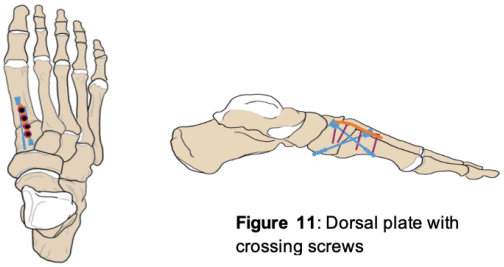

Figure 11: Dorsal plate with crossing screws

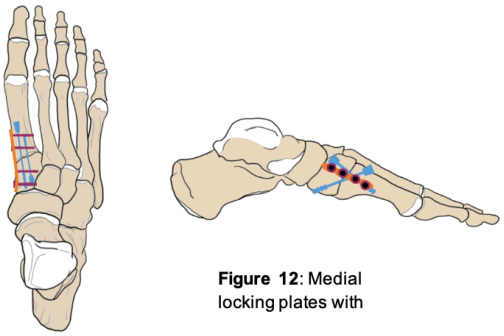

Figure 12: Medial locking plates with

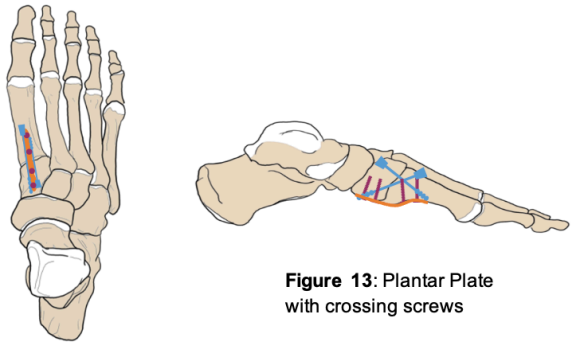

Figure 13: Plantar Plate with crossing screws

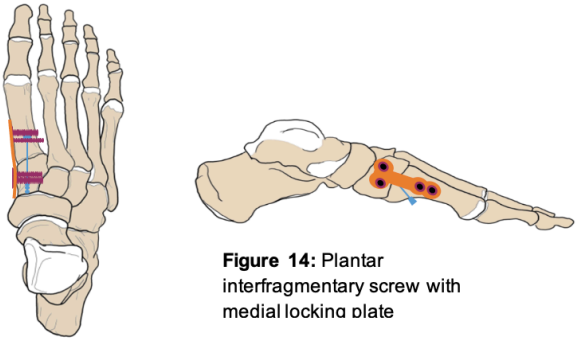

Figure 14: Plantar interfragmentary screw with medial locking plate

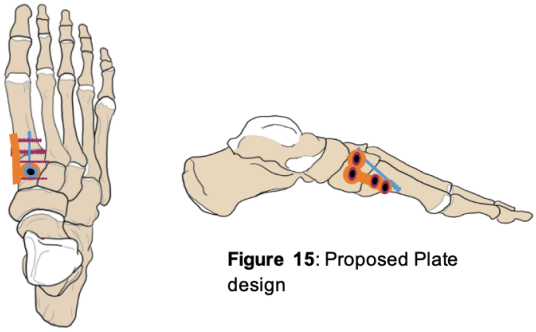

Figure 15: Proposed Plate design

CONCLUSION

The novel plate (**Figure 15**) has merits based on the prior literature. The proposed plate is a T shaped dorsomedial plate with dual locking screws in a linear fashion on the distal medial aspect of the TMTJ purchasing the medial first metatarsal base. The proximal end of the plate would involve a medial locking screw and a dorsal recession created within the surface of the medial cuneiform to allow for a Herbert style screw to be placed and generate compression dorsally from the plantar aspect of the metatarsal base to the medial cuneiform in line with the compressive forces applied during gait. The distal aspect of the screw would get minimal cortical purchase from the plantar aspect of the metatarsal, is sufficient to gain compression across the joint.

This construct would accomplish several goals of fixation, taking inspiration from the strengths of the constructs mentioned in this review while addressing the concerns mentioned with the various existing constructs. The excessive dissection involved in the plantar aspect associated with plantar plating is avoided with the insertion of the reverse home run screws along with potential osseous irritation from prominent hardware. The lack of penetration of the lag screw through the plantar metatarsal also keeps the soft tissue structures intact. The integration of a lag screw into the plate ensures that the patient would be able to bear weight on the surgical limb earlier than a non-integrated lag screw.

Due to the nature of this study serving as a primer to a new construct, it presents with various limitations. The previous biomechanical studies that have been included were conducted independently and did not provide a head-to-head comparison with similar equipment to allow for assessment of every construct described. The relative strengths of the constructs are assumed despite not having a valid comparison. Additionally, there is not a viable model of the suggested plate to undergo assessment for its strength and compression characteristics. The dissection and implantation assumptions are based on prior anecdotal evidence and cadaveric studies without having a tangible and practicable experience with the suggested construct.

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18. Images courtesy of Dr Roberto De Los Santos, https://prepodiatryclinic101.com/basic-anatomy-of-the-foot-and-ankle/

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SCHOOL OF PODIATRIC MEDICINE

Arthroscopic vs. Open STJ Arthrodesis

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ABSTRACT

Subtalar joint (STJ) arthrodesis is a treatment that is indicated for STJ arthritis, adult-acquired flatfoot deformity, calcaneonavicular coalition, neuromuscular diseases that affect the motion of the rearfoot, and idiopathic pain isolated to the STJ. There are two approaches to STJ arthrodesis: open and arthroscopic. The open procedure has been used successfully for decades; however, arthroscopic arthrodesis of the STJ novel and somewhat unproven. Few studies have compared the two approaches. This review compares open and arthroscopic STJ arthrodesis procedures. The primary outcomes analyzed were fusion rates, union time, and complication rates. The secondary outcomes analyzed were the length of hospital stay, pain score improvements, and functional outcomes. Using a rapid review approach, 10 studies were combined for a total of 515 cases. Union rates are found to be 90% and 97.2% for the open and arthroscopic procedures, respectively. Union time averaged 12.8 weeks for the open procedure approach and 10.4 weeks for the arthroscopic approach. At the same time, complication rates average at 35.12% and 14.4% for the open and arthroscopic procedures, respectively. In all primary outcomes, the arthroscopic procedure outperformed the standard open procedure. This comparative review concludes that arthroscopic STJ arthrodesis is a non-inferior alternative to open STJ arthrodesis and should be considered a viable surgical treatment for STJ pathologies.

INTRODUCTION

The subtalar joint consists of the articulation between the talus and the calcaneus; also known as the talocalcaneal joint, it consists of three facets: the anterior, middle, and posterior. The middle facet and the anterior facet are commonly a continuous structure, whereas the posterior facet is completely distinguished from the other two and possesses its own capsule.[1] Between the posterior and middle facets is the tarsal canal, which extends across the lateral aspect of the joint and widens into the sinus tarsi. The sinus tarsi and the tarsal canal house the artery of the sinus tarsi. This artery, branching from the perforating peroneal and anterior tibial arteries consistently anastomoses with the artery of the tarsal canal. Also found inside the sinus tarsi are three important ligamentous structures: the interosseous talocalcaneal ligament, the cervical ligament, and the inferior extensor retinaculum. Motion at the STJ is triplanar, with most motion occurring in the frontal plane as inversion/eversion.[1] The STJ has a range of motion between 44º and 53º, which allows for dynamic ambulation on uneven ground.[1-3]

Indications for fusion of the STJ include but are not limited to the following: painful arthritis of the STJ of various etiologies, planovalgus foot deformities, progressive adult-acquired flat foot, tarsal coalitions, intra-articular fractures, and neuromuscular diseases that affect the motion of the hindfoot.[2-6] Conservative treatment should be pursued prior to surgical intervention, especially in cases where arthrodesis is being considered. Authors Thorpe and Wukich recommend the upper limit of correcting hindfoot valgus with isolated STJ fusion alone at 15º or less.[7] They suggest that a valgus rearfoot exceeding 15º degrees with substantial arthritic changes to the talocalcaneal joint should be corrected with a triple arthrodesis (STJ, calcaneocuboid, and talonavicular fusions). Authors Buck et al., reported that when a fusion of the ankle and rearfoot is being conducted a proper alignment of 0º "neutral flexion", 0º-5º eversion, and 5º-10º of abduction is ideal for proper ambulation.[8]

Various complications can result from either successful or unsuccessful fusion of the STJ.[2-7] Fusion of the STJ necessarily places more strain on surrounding joints, and they should be assessed before committing to an isolated STJ fusion. Arthritic changes to the surrounding joints will likely progress following fusion. Under-correction of varus or valgus deformities can result in worse clinical outcomes than if a fusion was never attempted. Other complications include non-union and delayed union, infection, hematoma, pain from hardware, and sural neuropathy. In 2000, Easley et al. identified smoking, 2 mm of avascular bone at the fusion site, and prior failed fusion attempts to be the greatest risk factors for a non-union.[9] This study of 184 open STJ fusions is included in this comparative review and will be discussed in further detail later.

Isolated arthrodesis of the talocalcaneal joint was first introduced by Gallie in 1943.[2-8] In the years since,

the procedure has evolved. Green, in 1945, further popularized the concept by using a bone graft wedged into the sinus tarsi, effectively introducing the extra-articular STJ fusion. Most procedures at that time did not include the use of fixation and complications were common. Modern techniques, such as internal fixation, have greatly reduced non-unions and other complications.[2-7] Still, complications secondary to the extensive dissection of the talocalcaneal region encouraged author Parisien to describe arthroscopy of the STJ in a preliminary report published in 1986.[3] This ultimately led to the introduction of the arthroscopic subtalar joint arthrodesis in 1992 by Tasto.[3] 1996 saw a further adaptation of the procedure using the posterolateral and posteromedial portal approach for STJ arthrodesis or PASTA by van Dijk et al.[3] This procedure is seen as an advancement over the previous anterolateral and anteromedial portal approach by some authors.[2-8] In the decades after, the arthroscopic procedure has failed to be accepted as an alternative to the open procedure. Perhaps this is a result of the procedure's steep learning curve and its perceived lack of support in the literature.

METHODS

A rapid review strategy was conducted to identify studies that tracked the outcomes of open STJ arthrodesis and studies that tracked the outcomes of arthroscopic STJ arthrodesis. PubMed, Google Scholar and Barry University Library databases were searched. Keywords such as "STJ," "talocalcaneal," "arthrodesis," "Subtalar," "Arthroscopic," "open," and "fusion" were used to refine the search. Inclusion criteria were studies that tracked clinical and radiographic outcomes of isolated open and arthroscopic STJ arthrodesis. Studies were excluded if they were case studies, did not report union rates, or reported on procedures other than an isolated STJ arthrodesis. Four papers that were included reported on open procedures and nine reported on arthroscopic procedures. A total of 10 studies are included in this analysis, with 284 cases of open procedures and 231 arthroscopic procedures. All the papers were published between 1999 and 2021. See **Table 1** below for a complete representation of the articles used in the analysis.

DATA ANALYSIS

Data from identified studies included in this review were compiled into a Microsoft Excel® spreadsheet. Data collected included union rates, time to union, complication rates (not including non-unions), and days spent in the hospital. When available, reported values of functional scores, pain scores, and time to return-to-work were also tabulated. However, the sparse reporting of these parameters lead the author to exclude them from the analysis.

Data analysis consisted of the computation of the weighted means of the reported parameters. For example, the weighted mean fusion rate was calculated by multiplying the fusion rate of each study population with the number of intervention-specific cases in that study and dividing by the total number of intervention-specific cases in all of the studies combined, then summing that value for all of the utilized reports. The values of the mean rates of fusion, complication, time to fusion, and days in the hospital were tested for statistical difference between the open and arthroscopic procedure using the Student T-Test and with 95% confidence intervals. The null hypothesis is that there are no differences between the reported outcomes of open and arthroscopic STJ procedures. P-values of less than .05 lead to a rejection of the null hypothesis.

RESULTS

The weighted average of union rates for the open and arthroscopic groups was calculated to be 90.5% (95% CI: 82.4%-98.6%) and 97.2% (95% CI: 94.5%-99.9%), respectively. The weighted mean of the union rate for the arthroscopic group was greater than the open group, and the T-test results of .017 (less than p-value of 0.05) fail to support the null hypothesis. This indicates a statistical difference between the two values. In contradiction, the 95% confidence intervals for the two values overlap. We must conclude there is no consensus or satisfactory evidence of a statistically significant difference between the two values. Thus, arthroscopic STJ union rates are non-inferior to open STJ union rates. Similarly, time to union had a T-test value of .01, rejecting the null hypothesis, but also had mean values with overlapping 95% confidence intervals. These results and the other analyzed reported outcomes are included in **Table 2,** with **Table 3** showing the results of statistical analysis.

CONCLUSIONS

This report directly compares open and arthroscopic STJ fusions via an aggregate of data. The scope of comparison, including the results of 515 cases of STJ arthrodesis, is of a degree not currently found in the literature. Few studies exist that directly compare the two procedures. We have produced data that supports the hypothesis that arthroscopic STJ arthrodesis is a non-inferior procedure to its more traditional open alternative.

Though the confidence intervals of mean fusion rates overlap, the arthroscopic procedure had a greater average fusion rate by 7.2%. This, paired with the fact that Student's T-test indicates a statistical difference between the two values, suggests that with further investigation, arthroscopic outcomes may prove to be superior to their open counterpart in some ways.

Similarly, weeks until union have a weighted average difference of 2.3 weeks favoring the arthroscopic procedure and T-test values rejecting the null hypothesis but overlapping CI ranges. This also supports the conclusion of the non-inferiority of the arthroscopic procedure.

Arthroscopic fusion of the STJ is associated with minimal scaring and less compromise of neurovascular structures but may have limited efficacy in addressing more severe pathology, when being compared to the open approach. Prudent patient selection should play a role in deciding between the two approaches. The individual surgeon employing the arthroscopic technique might find benefit in utilizing it on patients with less severe deformities and pathology.

Future studies should focus on randomized controlled trials (RCTs) to directly compare the open to the arthroscopic STJ fusion approach.

Outcomes such as pain before and after should be tracked with the VAS pain score. Similarly, a standard AOFAS functional assessment score and the time in weeks to reach various stages of the post-op phase should be the primary outcomes being assessed by future studies.

More control of the participant populations should also be attempted in future research. Studies can focus on sub-populations, such as those with diabetes mellitus, those with high or low BMIs, or even age. If it can be determined that certain patients have better outcomes with either the open or arthroscopic procedure, then surgery can be catered to the person more than the pathology.

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Hammertoe Correction with K-wire or Implant Fixation: A Comparative Literature Review

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ABSTRACT

Hammertoes are common lesser-toe sagittal plane digital deformities often treated via arthrodesis or arthroplasty of the proximal interphalangeal joint (PIPJ). Axial K-wires are the current accepted gold standard for the internal fixation of hammertoes. However, due to reported rates of pin tract infection, malunion, and hardware migration or breakage, novel intramedullary (IM) implants have been developed as an alternative fixation modality. This literature review summarizes the current evidence comparing clinical and radiographic outcomes in patients that received PIPJ arthrodesis with either K-Wires or IM Implants. A literature search of PubMed and Embase was conducted by two independent authors yielding the incorporation of 14 peer-reviewed English language articles. Studies demonstrate promising results in patient satisfaction and union rates using IM devices compared to K-wires. The two internal fixation modalities had no advantages in parameters such as pain levels, foot-function index scores (FFI), or complication rates. As the clinical outcomes of IM implants were not shown to be superior to those of K-wires, the authors recommend internal fixation with axial K-wires as a cost-effective and reliable treatment option for PIPJ arthrodesis of hammertoe deformities.

INTRODUCTION

Lesser toe sagittal plane deformities are seen in approximately 33% of the US population.[1] These deformities include hammertoe, mallet toe, and claw toe which arise from a biomechanical imbalance between the long and short flexor and extensor tendons with an insufficiency of the soft tissue structures. Clinically, patients present with painful joints, calluses, ulcerations, and pain in footwear. Conservative treatment includes non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroid injection, taping, footwear modification, orthotic modification, padding, and offloading. If these modalities fail to improve symptoms, surgical treatment may be warranted. Multiple surgical interventions exist for the treatment of rigid sagittal plane lesser toe deformity. These include arthrodesis of the PIPJ, arthroplasty, and, rarely, amputation.

Multiple fixation techniques have been described for the internal fixation of PIPJ arthrodesis. Axial Kirschner-wire (K-wire) fixation is the current gold standard fixation modality due to its availability and affordability.[1] K-wire fixation adequately and reliably stabilizes the surgical site; however, studies have reported complications including hardware migration and breakage, pin tract infection, and deformity recurrence –believed to occur partly due to the inability of K-wire fixation to provide compressional or rotational stabilization. [1] To help reduce these complications, the use of fixation with novel intramedullary (IM) implants has been developed which may enhance clinical and radiographic outcomes in patients with PIPJ arthrodesis.[2] The high cost of these devices currently limits their widespread use. This literature review compares surgical outcomes in PIPJ arthrodesis with K-wire fixation versus IM implant fixation.

Surgical Techniques[3]

Rigid hammertoe repair by PIPJ arthrodesis via K-wire and IM implant fixations follow identical dissection patterns. Typically, a dorsal longitudinal incision is made over the PIPJ to the level of the EDL tendon, and the tendon is transversely cut. The joint capsule is excised followed by severance of the lateral and medial collateral ligaments. Releasing the collateral ligaments allows exposure of the proximal phalanx condyles, and the proximal phalanx head is transected at the diaphyseal-metaphyseal junction with usually either a sagittal saw or double-action bone cutter. A rongeur is then used to smooth prominent areas from the proximal phalanx stump. The middle phalanx base is then resected with a sagittal saw or double-action bone cutter.

For K-wire fixation, the pin is inserted at the PIPJ and is driven distally through the head of the distal phalanx. The K-wire is then driven retrograde toward the proximal phalanx while the toe is held in the appropriate alignment. The wire exiting the tip of the toe

is then bent and excess K-wire is cut with a pin cutter. The ends of the K-wires are protected with pin caps, and the surgical site is closed with 3-0 Nylon in an interrupted vertical mattress fashion.

For implant fixation without graft placement, a 2.0-mm drill is inserted centrally at the base of the middle phalanx and the head of the proximal phalanx. A broach enlarges the canals made from the drilling. The temperature-sensitive implant is removed from the refrigerator and inserted into the canals made within the intramedullary canals with the longer end placed into the proximal phalanx until the grasper contacts the bone. The distal portion is then manually fit into the middle phalanx. The middle phalanx is held abutting the proximal phalanx in place while the implant expands into position from the body heat. The implant's position is confirmed with fluoroscopy, and the surgical site is closed with 3-0 Nylon using an interrupted vertical mattress suture.

For implant fixation with graft, a diameter depth reamer is selected based on the phalanx size. It is then pushed up to the laser line meeting the resected surface while remaining within the IM canal with the reamer; this is done with both the distal stump of the proximal phalanx and the proximal stump of the middle phalanx. Using forceps, the allograft is inserted into the proximal phalanx. Gradual pressure is applied until the allograft clicks into a fully seated position. The implant is then manually placed into the middle phalanx, and pressure is applied until bony contact is achieved. The implant's placement is verified with fluoroscopy, and the surgical site is closed with 3-0 Nylon in an interrupted vertical mattress fashion.

METHODS

A systematic published literature review was completed through Embase and PubMed for research comparing rigid hammertoe repair by arthrodesis via K-wire versus IM implant. Two independent authors conducted the literature search that included the following search terms: hammertoe, hammer toe, PIPJ, pip joint, K-wire, Kirschner wire, Tenfuse, Smart Toe, Stayfuse, and Toegrip. Articles between 2010-2020 were selected. Randomized controlled trials (RCTs), critical literature reviews, systematic reviews, comparative studies, and case series were included in this literature review. The following parameters were extracted from the articles: sample size, sample population, study design, interventions, primary/secondary outcome measure(s), and results.

RESULTS

Strength of K-wire Fixation vs. Implant Fixation

A comparative biomechanical cadaveric study evaluated IM devices including the Smart Toe and X Fuse PIPJ arthrodesis implants against K-wire fixation.[4] After the removal of all soft tissues from the cadavers, the implants were installed. Six second toes were prepared with K-wire fixation, and the Smart Toe implants were installed into the contralateral counterparts. Six other 2nd toe PIPJs were fixed with K-wires while the contralateral 2nd digit PIPJs were prepared with the X fuse implant.

The toes were individually fixed with set screws to the loading jig. Each specimen's plantar aspect was oriented upward, and the loading pin was aligned 7.0 mm distal to the PIPJ. The toes then underwent cyclical loading with incrementally increasing degrees of force. Compressive forces of 2.0 N increasing increments for 10.0 cycles were exerted each cycle until failure of the specimen or if the limits of the jig were met. Failure was defined as 4.0 mm of net displacement relative to the initial reference displacement of 20 N load.

For the first half dozen specimens, the K-wire arthrodesis' average force of failure was significantly greater than that of the X fuse implant at 91.0 N versus 63.3 N, respectively ($p<0.05$). However, no significant difference was discovered for the initial stiffness. For the second six specimens, the K-wire also demonstrated a significant difference in the force of failure at 102.3 N when compared to that of the Smart Toe at 53.3 N.[4]

Patient Satisfaction

Obrador et al. retrospectively compared functional outcomes in 96 patients who had received PIPJ arthrodesis with either Smart Toe, TenFuse, or K-wire fixation.[5] Authors found higher rates of patient satisfaction in the IM implant cohort compared to K-wire fixation 1-year post-PIPJ arthrodesis. 3.7% of K-wire patients reported "satisfied" compared to 22.2% and 26.7% of Smart Toe and TenFuse patients, respectively. No significant difference in patient satisfaction was observed between the IM implant cohorts ($p<0.05$).[5] Richman et al. also found that a higher proportion of persons in the K-wire cohort reported being unsatisfied with their surgery compared to the CannuLink cohort (26/96 vs. 7/96, respectively).[6] Angirasa et al. evaluated patient satisfaction at seven days and six months post-PIPJ arthrodesis.[7] They found no statistically significant difference in patient satisfaction levels between patients with K-wire fixation vs. Smart Toe ($p<0.05$).[7]

Union Rate

The osseous union rate was evaluated using radiographs in all included studies to quantify fusion

mass consolidation. Jay et al. found that in 45 toes treated with K-wire, 7 developed union at six months compared to 38/47 toes treated with IM implant.[8] These differences were statistically significant ($p<0.05$). Obrador et al also found that K-wire fixation resulted in higher non-union rates compared to both Smart Toe and TenFuse implants.[5] They found that in 65 toes treated with K-wires, 23 developed non-union compared to 3/94 and 1/27 toes treated with Smart Toe and TenFuse, respectively.[5] Authors also reported significantly lower rates of pseudoarthrosis in the K-Wire cohort (26/65) compared to the Smart Toe cohort (50/94); however, significantly higher rates of pseudoarthrosis were seen in the K-wire cohort compared to TenFuse (16/27) ($p<0.05$).[5] No differences were observed between the two IM implant cohorts. Conversely, Scholl et al. found no significant difference in non-union rates between toes treated with Smart Toe implant vs. K-wires, with 68.9% of IM implants achieving osseous union vs. 82.1% of K-wires ($p<0.05$).[9]

Index Scores

Index scores to assess and compare post-surgical functional and clinical outcomes include the Visual Analog Scale (VAS), Foot Function Index (FFI), Bristol Foot Score (BFS), and Short Form 36 (SF-36). Jay et al. found significantly higher BFS scores in the IM implant cohort at one week post-operative but no significant difference thereafter at 3-week, 6-week, 3-month, and 6-month time points ($p<0.05$).[8] When assessing FFI, no significant differences between cohorts were noted at all time points. Similarly, Obrador et al. found no statistical differences in FFI and SF-36 scores between IM implants and K-wire fixation patients one year post-operative ($p<0.05$).[5] No statistical difference was observed between cohorts when assessing 1-year post-operative pain levels via VAS ($p<0.05$). Stratification of FFI scores by domain (pain, stiffness, difficulty, activity, and social) also displayed no statistical significance between groups in any category in both studies.

Complication Rates

Jay et al. defined "complications" as implant failure, delayed bone union, infection, wound dehiscence, recurrence, and persistent pain.[8] The authors reported no differences in rates of complications between both cohorts ($p<0.05$). Scholl et al. found no statistically significant differences in rates of revisional surgery and hardware fracture between Smart Toe and K-wire fixation ($p<0.05$).[9] Obrador et al. assessed rates of wound complications, deformity recurrence, and implant breakage between K-wire, Smart Toe, and TenFuse fixation. No significant difference between groups was assessed for wound complications and deformity recurrence; however, Smart Toe implants displayed significantly higher rates (10/94) of hardware breakage compared to K-wire (0/65) and TenFuse (0/27) cohorts.[5] Lastly, a comprehensive review of 15 articles undertaken by Hendrick et al., assessed complication rates between SmartToe, ToeGrip, and Percutaneous K-wire fixation. SmartToe implants displayed higher proportions of infection rates and hardware breakage and migration.[2]

Cost-Effective Analysis

A cost-effective analysis by Albright et al. averaged that the total cost of hammertoe treatment with K-wire fixation totaled $5,041 with an effectiveness of 0.82 QALY whereas IM implant fixation totaled $6,059 with an effectiveness of 0.83 QALY.[10] The incremental cost-effective ratio—the difference in cost between the two interventions divided by the difference in their effect—of implants measured $146,667. Authors concluded that the additional benefits of implants are considered worthwhile if the cost of the implant is less than USD$300; however, a report by Dr. Allen Jacobs DPM estimates that present-day implants cost upward of USD$500.[10]

DISCUSSION

Implant and K-wire strength have been evaluated biomechanically in cadaveric settings to demonstrate that K-wires are capable of withstanding greater forces than implants. Studies also show that the complications of K-wire fixation, such as, pin tract infection, migration, rotational instability, breakage, nonunion, or malunion remain minimal with a strict postoperative course and patient compliance.

K-wire fixation for hammertoes has been used since 1940 and continues to be commonplace as they are stable, easily placed and removed and they are effective at holding alignment. However, migration, rotational instability, breakage, and pin tract infection are risks with a 2.5% failure rate with 0.045-inch K-wires.[11] Another study found an 18% infection rate when K-wires were left implanted for six or more weeks.[11] K-wires are now commonly removed at three weeks.[3] Wire fracture is also a complication of K-wires; however, it is rarely symptomatic. The malleability of K-wires allows for post-operative correction, which can improve digital alignment.[3]

Patient satisfaction remains a criticism of K-wire fixation. This perhaps is from K-wires exposure during the three-week post-operative period.

In addition to patient satisfaction, nonunion and malunion is an area of concern. The lack of compression, as well as friction provided by a K-wire, contrasts with implants.[3] The ridges on the implants allow

for greater stability and maintenance of alignment; however, studies demonstrate no significant difference in rates of non-union between Smart Toe and K-wires. From the patient's perspective, it has been demonstrated that K-wires and implants show no significant difference in measures of foot pain, foot function, and impact of foot problems on quality of life. Patient satisfaction is comparable between cohorts after K-wire removal. Similarities in pain levels between cohorts could suggest that improved pain outcomes may be attributed to the forefoot deformity correction regardless of the fixation device used.

Limitations

Many of the studies encountered were literature or systematic reviews, or retrospective observational studies which limit the quality of evidence and may introduce potential biases. Similarly, one of the studies in favor of K-wire fixation used cadavers, which is limited in its ability to translate to living subjects.

CONCLUSION

K-wire fixation is a viable fixation option. Although it may not provide as much compression, rotational stability, or low likelihood of infection as implant fixation, it has unique benefits. IM implants do not present superiority in clinical parameters compared to K-wire fixation, despite higher rates of radiographic union. Like all hardware, implants sometimes need to be removed which can result in the need for digital arthrodesis. Additionally, these implants come with higher costs. However, implants allow a faster return to normal footwear. Overall, K-wires remain an optimal fixation device for hammertoe correction as they present a reliable and cost-effective fixation modality in the stabilization of PIPJ arthrodesis.

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National Foot & Ankle Review

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Surgical Management of Diabetic Ankle Fractures with a Focus on Syndesmotic Fixation: A Literature Review

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ABSTRACT

Diabetes mellitus creates a physiological environment with an increased susceptibility to skeletal fracture, as well as a heightened risk for perioperative and postoperative complications. This is well documented in the literature. A robust knowledge of the proper surgical management of ankle fractures, especially those with a syndesmotic component, is imperative to intraoperative success and mitigation of both short and long-term sequelae. Overwhelmingly, the literature is strongly in favor of the application of more hardware in the setting of diabetes mellitus due to impaired healing potential and weakened osseous integrity. Although studies provide guidelines for syndesmotic fixation, there is debate regarding fixation selection and guidelines for techniques regarding those selections. Studies available surrounding this topic do not illustrate a clear delineation between ankle fractures with a syndesmotic component in the setting of diabetes mellitus and principles regarding rigid versus dynamic fixation. Furthermore, they do not address the number, orientation or size of screws to be used in this situation. Diabetic ankle fractures present a unique challenge to the surgeon, warranting a thorough evaluation of fixation options to provide the patient the best chance of success in the setting of progressive neuropathic risk. The goal of this paper is to critically review and evaluate the current literature surrounding the surgical management of diabetic ankle fractures including syndesmotic fixation in the patient population that includes patients with diabetes who have sustained ankle fractures. Databases consulted include PubMed, Cochrane Library and Embase.

INTRODUCTION

In the United States, the prevalence of diagnosed and estimated undiagnosed diabetes mellitus accounts for 14.7% of the country's adult population.[1] As medicine has progressed, so has the improvement in medical management of the diabetic condition, as well as management of sequelae associated with microvascular complications of a hyperglycemic state. The prevalence of diabetes mellitus continues to trend upward, necessitating a constantly evolving understanding of the pathogenesis and management of related conditions.

The risk of perioperative complications in patients with diabetes mellitus is heightened for a variety of reasons, predisposing patients to risk of malunion, delayed union, nonunion, impaired wound healing, infection and progression to Charcot neuroarthropathy.[2] Charcot neuroarthropathy is a pathology seen in the foot and ankle commonly characterized by a destructive progression of bone and joint breakdown, secondary to neuropathy. There are two main hypotheses behind the etiology of Charcot; the neurotraumatic theory describes a repetitive microtrauma on a limb that is insensate, while the neurovascular theory describes a failure of the central sympathetic system resulting in hyperemia and elevated osteoclastic activity. Both hypotheses, through different mechanisms, agree that a neuropathic process causes the eventual weakening of foot architecture, predisposing the foot to demineralization, dislocation and distension. More recently, the hypothesis that Charcot neuroarthropathy is related to an excess of pro-inflammatory cytokines affecting bone integrity, also referred to as the neurological-bone-inflammatory hypothesis, has come into favor. A variety of literature illustrates that the incidence of diabetic ankle fractures continues to rise, noted to be over 160,000 patients between 1988 to 2000.[3] The presence of impaired immune function predisposes diabetic patients to a host of complications specifically related to bone and wound healing, as well as the surgical management of that event.[4]

MATERIALS AND METHODS

Literature review was conducted through PubMed, Cochrane Library and Embase databases. Key words including "diabetes, ankle fracture, neuropathy, Charcot, syndesmosis, ankle fracture fixation" were used to determine appropriate literature to be referenced. The inclusion criteria were studies that articulated treatment of diabetic ankle fractures with or without syndesmotic fixation, studies that examined the diabetes mellitus population, studies categorized as randomized control trials, systematic reviews, meta-analyses, case studies

and reports, as well as expert opinions. Exclusion criteria were studies that were published in a language other than English and studies that did not examine the diabetes mellitus population.

DISCUSSION

Etiology and Pathogenesis of Diabetic Ankle Fractures

Diabetes mellitus is commonly regarded as part of a larger metabolic syndrome, consisting of multiple metabolic conditions that result from a chronic hyperglycemic state. Glycosylation of the microvasculature classically manifests as retinopathy, neuropathy and nephropathy, depositing glucose in multiple tissue systems in an unregulated fashion across the body. The risk of diabetic-related neuropathy is a constant concern for managing ankle fractures. Statistics show that greater than half of all patients with diabetes mellitus over the age of 60 report some level of peripheral neuropathic symptoms.[4] In particular, loss of protective sensation often complicates healing following surgical fixation of ankle fractures, requiring an increase in intraoperative fixation, and lengthening the postoperative non-weightbearing period. The progression of an insensate diabetic patient to Charcot neuroarthropathy is an increasingly prevalent fear and warrants discretion at the hands of the surgeon when determining proper surgical fixation.[5] Bone healing is a realistic concern for the surgeon as peripheral neuropathy, duration of surgery and hemoglobin A1c levels of above 7% have been documented as significant contributors to post-operative complications such as malunion, delayed union and nonunion in diabetic foot and ankle surgery.[2]

Syndesmotic Components of Ankle Fractures

Syndesmotic injury that occurs in association with ankle trauma is typically accompanied by fracture. Syndesmotic disruption occurs in 10% of all documented ankle fractures and is involved in 20% of ankle fractures that necessitate internal fixation.[6] Classification of these ligamentous injuries is most typically categorized by either the Lauge-Hansen Ankle Fracture Classification or the Danis and Weber AO Classification. In terms of the Lauge-Hansen Classification, established from cadaveric specimen analysis, syndesmotic injury most often occurs during stage 2 of a pronation-abduction (PAB) or stage 2 of a pronation-external rotation (PER) ankle injury.[7] The Danis-Weber Arbeitsgemeinschaft für Osteosynthesefragen (AO) Classification is determined based on the fibular fracture level. A fracture located proximal to the syndesmosis, constituting a Danis-Weber C injury, directly involves syndesmotic ligamentous disruption; this is typically due to abduction and external rotation stress to the foot.[7]

It is important to determine which syndesmotic injuries require fixation in the setting of ankle fractures, especially when the patient has diabetes mellitus. Clinical examination following ankle fracture might not exhibit an accurate representation of syndesmotic injury due to pain and swelling following such an injury. Radiographs are a more standardized and objective way to determine syndesmotic integrity and the potential need for surgical fixation.[6] Classically, radiographs that show more than 1mm of syndesmotic widening indicate the need for syndesmotic repair.[6] Intraoperative testing yields beneficial clinical information regarding the presence or absence of syndesmotic disruption; however, these tests are typically unable to be performed in the clinical setting due to limitations of pain. Examinations such as the external-rotation stress test or hook test provide significant utility in this vein.[6] The external-rotation stress test, also known as the Kleiger Test, is performed in an outpatient setting with the patient's leg at the edge of an examination table while the examiner both stabilizes the distal leg and uses the other hand to apply an external rotational force on the foot. A positive test indicating concern for syndesmotic injury consists of pain at the distal interosseous membrane in the region of the syndesmosis. The modified hook test, first described by Frederic Cotton, performed intraoperatively to assess syndesmotic integrity after fixation of the fibula has been established.[8] Using a bone hook to distract the distal fibula manually, tibiofibular clear space is observed under fluoroscopy; a clear space greater than 5mm indicates an unstable syndesmosis that requires fixation.[8] Patients with diabetes mellitus and those who are obese have a higher likelihood of developing syndesmotic disruption in the setting of ankle fractures. This relationship warrants more attention to additional syndesmotic fixation to provide support to the fixation construct in patients that put more force through the ankle joint from weight, as well as those who have neuropathy, are insensate and increase the risk of disrupting the fixation construct.

Diabetic Ankle Fracture Fixation Principles

As there is limited literature available discussing the efficacy and outcomes of minimally invasive fixation of ankle fractures that have a syndesmotic component, Ebraheim et al. sought to provide data regarding this topic through a retrospective case-control study. Authors examined patients treated by traditional open reduction-internal fixation versus percutaneous cannulated screw fixation for Danis-Weber C fractures, in the setting of either diabetes or obesity with a BMI 30 kg/m^2 compared to patients without comorbidities.[9] Results showed that those in the comorbid group were at greater risk for Weber C pattern fractures.

Minimally invasive fracture fixation management is an alternative; an additional finding of complication rates showed a reduction in infectious complications with minimally invasive percutaneous pinning fixation

technique.[9] As patients with diabetes mellitus statistically have more complications, both perioperatively and post-operatively, minimally invasive fracture fixation management is an alternative but has a higher learning curve. Manway et al. advocates for practice of the Sammarco Superconstructs in the surgical management of diabetic ankle fractures, principles that facilitate a more rigid hardware construct for patients with neuropathic complications.[10]

Some seasoned surgeons have used multiple syndesmotic screws for neuropathic ankle fractures, regardless of the presence of true syndesmotic injury. This preserves the integrity of the ankle joint and prevents both diastasis and possible fixation failure from microtrauma in an insensate foot.[10] Meyr et al. provide a curious perspective on guidance for fixation constructs in diabetic ankle fractures, alluding to the reasonable expectation that stronger fixation constructs have the potential to reduce postoperative complications and failure rates.[11] A surgeon should at least double the usual amount of fixation, period of non-weight bearing and number of office visits expected for nondiabetic patients.[4, 12]

The goal of using additional fixation is to of joint collapse given the higher risk of progression to Charcot in the setting of diabetic peripheral neuropathy.[5] Lavery et al. conducted a retrospective study that included 439 patients who experienced ankle fractures. Of those patients, 31.7% patients had diabetes mellitus at the time of fracture.[13] The authors found that there was a 7.61 times increased risk of developing Charcot arthropathy in patients with diabetes mellitus compared to those without diabetes mellitus after sustaining an ankle fracture.[13] The trauma of an ankle fracture in the setting of diabetic neuropathy can trigger the osteolytic cascade that predisposes patients to the degenerative and fragmentary changes associated with Charcot neuroarthropathy.

Syndesmotic Fixation Principles

The indications for syndesmotic screw implementation have developed over time, and are described early on by Boden et al. in a cadaveric study that examined the mechanical need for screw fixation based on the ankle fracture pattern.[14] The authors established a model for pronation-external rotation injuries, which included syndesmotic disruption by creating different levels of fibular fractures in the clinical setting.[14] Through this examination, authors determined specific criteria that indicate need for a rigid syndesmotic fixation with screws: fibular fractures past the "critical transition zone", located 3-4.5 cm proximal to the distal fibula in a region where rigid fixation is not achievable, as well as fracture patterns where syndesmotic integrity is weakened by other ligamentous injuries such as deltoid disruption.[14]

Multiple syndesmotic fixation options exist, including bioabsorbable screws, syndesmotic screws, ring fixators, flexible implants such as suture buttons, Kirschner wires, syndesmotic hooks, trans-syndesmotic bolts, cerclage wires and ligamentoplasties.[6] Although there is no consensus in the literature regarding a standardized approach to syndesmotic fixation, particularly in the setting of a diabetic ankle fracture, rigid internal fixation with syndesmotic screws is generally supported compared to more flexible fixation. Rigid internal fixation with syndesmotic screws maintains a plantigrade foot and a stable construct. Most often, 3.5mm and 4.5mm screws are used for syndesmotic fixation, however, there is no consensus on the number of screws or the orientation of screws, aside from anecdotal evidence.[15] Hansen et al. determined that 4.5mm diameter screws are better able to resist shear stress across the syndesmotic joint with simulated weight bearing following syndesmotic injury.[16] Research has also shown increased rotational stability against external rotation stress with a two-screw fixation technique rather than single-screw fixation.[17] It is beneficial to employ the practice of multiple syndesmotic screws rather than single screw fixation in diabetic ankle fractures with syndesmotic injury.

In recent years, decision-making between syndesmotic screw fixation (SF) versus the use of suture buttons (SB) has been debated. Recent literature has been published providing long-term outcomes of screw fixation versus suture button in the treatment of acute syndesmotic injury.[18] Altmeppen et al. (2022) conducted a prospective, randomized, monocentric study comparing 21 patients treated for acute syndesmotic injury with SB to 20 patients treated with SF.[18] Patient-reported outcomes including the Olerund-Molander Ankle Score (OMAS), Foot and Ankle Disability Index Score (FADI-Score), activities of daily living and sports activity showed no statistically significant difference ($p>0.05$) between the SF and SB groups. The OMAS score is a self-reported patient questionnaire on a scale of 0 to 100 that examines nine different elements including pain, swelling, stair climbing, stiffness, jumping, running, supports, squatting, work and activities of daily living. The FADI-Score is a self-reported patient questionnaire consisting of 34 questions that ask questions related to pain, activity and tasks related to sports. The authors did note the benefit of suture button fixation in athletes, allowing a quick return to athletic activity due from dynamic, flexible fixation.[18] Naqvi et al. used postoperative CT imaging to determine the incidence of syndesmotic malreduction, which was defined as 2 mm of widening of the syndesmosis compared to contralateral ankle following SF and SB in 46 patients, with 23 patients in each group.[19] Results showed a 21.7% rate of malreduction in the SF group and a 0% rate of malreduction in the SB group per CT

examination, however the patient-reported AOFAS scores did not exhibit a statistically significant difference.[19] While dynamic and flexible fixation via suture buttons is an option for some patients, in the setting of a diabetic ankle fracture with notable syndesmotic stability, the literature supports the use of rigid fixation with a larger hardware construct to increase stability and reduce risk of complication and failure in the short and long-term postoperative period.

CONCLUSION

The diabetic ankle fracture provides a unique challenge for management due to the pathogenesis of diabetes mellitus and the impact that the condition has on orthopedic surgical intervention. As presented in this paper, there are different decisions the surgeon may make when surgically repairing a diabetic ankle fracture with syndesmotic disruption, including the type, volume, orientation and size of fixation. A review of the literature provides a deeper understanding of the best way to provide a patient with a stable construct for the future, while reducing the risk of well-documented complications associated with comorbid diabetes mellitus. Further studies examining outcomes following diabetic ankle fracture fixation with different numbers of screws, directional orientations and sizes would be valuable. Unstable fractures with a syndesmotic component in the setting of diabetes mellitus should be addressed surgically to provide stability and rigidity, as well as to prevent future complications.

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National Foot & Ankle Review

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A Systematic Review on Minimally Invasive Foot and Ankle Surgery for ATFL repair - Looking at Outcomes and Return to Activity

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ABSTRACT

This systematic review looks at outcomes comparing minimally invasive surgery to open surgery for anterior talofibular ligament (ATFL) repair. Search methods used include PubMed, Google Scholar, Cochrane Library and NIH databases for relevant studies. We analyzed American Orthopedic Foot & Ankle Society (AOFAS) scores, visual analog scale (VAS) scores, functional outcomes, complication rates, patient outcomes, and return to activity. The benefits of minimally invasive foot surgery of the anterior talofibular ligament (ATFL) include cost-effectiveness, less injury to soft tissue, reduced pain, and shorter surgery time.

INTRODUCTION

The pathophysiology of lateral ankle instability is known whereas the ideal surgical treatment is less understood. Is it better to surgically treat this condition with an open procedure or with a minimally invasive approach? This uncertainty is due in part to the complexity of the ankle joint and the factors that allow for dynamic stabilization. The ankle complex consists of 3 articulations: talocrural, tibiofibular syndesmosis, and subtalar joint. The talocrural joint receives ligamentous support from a shared joint capsule and several ligaments, including the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL), and the deltoid ligament.[1]This review focuses on the lateral aspect of the ankle and the three ligaments that support and stabilize it: ATFL, PTFL, and CFL.

The ATFL is one of the three ligaments that make up the lateral collateral ligaments of the ankle. The ATFL is a short ligament that originates from the anterior edge of the lateral malleolus of the fibula and attaches to the neck of the talus anterior to the lateral malleolar facet. It functions to resist inversion and plantarflexion of the ankle joint. Injury to the ATFL usually occurs with sudden inversion-type movements. The ATFL is the weakest of the lateral collateral ligaments and, therefore, is most often injured.

Lateral ankle instability arises from recurrent ankle sprains with persistent symptoms lasting a minimum of one year. Symptoms include pain, instability, weakness, poor function of the ankle joint, altered gait kinematics, impairment of reflexes, and a loss of neuromuscular control.[1] With such injuries, the lateral ankle ligaments are stressed and become lax over time.

Lateral ankle sprains can be broken down into grades one to three based on the degree of injury: (I) small tear of ATFL, minimal swelling, and point tenderness directly over the ATFL, little to no instability; the patient can ambulate with little to no pain; (II) large tear of the ATFL, broader region of point tenderness over the lateral aspect of the ankle, painful gait or inability to ambulate, bruising and localized swelling from tearing of the anterior joint capsule, ATFL, and surrounding soft tissue structures; (III) complete rupture of the ATFL with possible involvement of the CFL, diffuse swelling that obliterates the margins of the Achilles tendon, inability to ambulate, and tenderness on the lateral and medial aspects of the ankle joint.[1]

To evaluate ankle pathology, weight-bearing bilateral foot radiographs with standard anteroposterior and lateral views are obtained. Radiographs allow other pathologies to be ruled out.[1] Further, stress radiographs such as an anterior drawer or talar tilt can help diagnose ligamentous injury, as can MRI and diagnostic ultrasound due to high specificity and sensitivity of the imaging technique.[1]

Surgical management and repair of ATFL injuries can be anatomic or non-anatomic. Non-anatomic procedures stabilize and repair the ligaments indirectly. Non-anatomical procedures such as Evans repair, Watson Jones, and Chrisman-Snook stabilize the ankle joint by excising a portion of the peroneal tendons and surrounding tissues and use those structures to create a new stabilizing structure. For example, the peroneus brevis may be moved and re-attached perpendicular to

the injured ligament. Non-anatomical methods are more technically difficult, require a longer non-weight bearing recovery and may be associated with future osteoarthritis of the ankle joint. Anatomic repairs, such as the Brostrom or the Brostrom-Gould, are more frequently used than non-anatomical repair. The Brostrom procedure is a direct repair of the ATFL that brings the edges of the ligament together with sutures.[2] The Brostrom-Gould, a modified version, incorporates the inferior extensor retinaculum which is sutured to the distal end of the fibula. This increases the stability and strength of the ATFL repair by up to 50%.[2] Because the Brostrom-Gould procedure is relatively fast, straightforward and effective, it is considered the "gold standard" for treating chronic ankle instability.

The Brostrom-Gould procedure can be performed as an open procedure or it can be performed arthroscopically. With the arthroscopic technique, the surgeon can visualize the site through a scope and work via 2 portals, located anteromedially and anterolaterally.[3] The Brostrom-Gould technique is then applied similarly to the open procedure. The arthroscopic approach is less invasive, with smaller incisions which allow for quicker healing and the potential for overall improved recovery.[3]

OBJECTIVE

To compare functional outcomes, return to activity, patient-reported satisfaction scores, and complication rates between arthroscopic and open surgery for anterior talofibular ligament repair.

MATERIALS/METHODS

Literature review

This review followed PRISMA guidelines. Studies were obtained through a search of the following databases: PubMed, Google Scholar, Cochrane Library, and NIH. The following search terms and Boolean operators were used: "Open" OR "invasive" AND "MIS" OR "minimally invasive surgery" AND "ATFL" OR "anterior talofibular ligament." There was no date range limitation applied, and texts printed in the English language were used. Four independent reviewers assessed the abstracts of the articles individually for relevancy. Articles that fit the topic were then read in their entirety. Inclusion and exclusion criteria were applied to the articles to determine their relevance.

Inclusion criteria

The following inclusion criteria were used in selecting our studies (1) Comparative studies looking at arthroscopic procedures compared to open procedures. (2) patients that received anterior talofibular ligament repair, (3) skeletally mature patients, (4) follow-up for six months or more.

Exclusion criteria

Exclusion criteria were (1) additional procedures performed other than arthroscopic repair of the anterior talofibular ligament, (2) incomplete data sets (3) non-comparative studies.

Observational Indexes

The four reviewers independently collected data from studies that fit the inclusion criteria. This included sample size, age, sex, average follow-up, technique,i intervention, functional outcomes, and complications. Patient-reported outcomes were compared between groups. American Orthopedic Foot and Ankle Society (AOFAS) scores were analyzed. AOFAS scores range from 0-100 with 100 indicating no pain, fully functional, and achievement of good alignment. Karlsson Ankle Functional Scores (KAFS) were also used. KAFS range from 0-90 with a 90 indicating no pain, swelling, or instability, and no problems with stair climbing or running. A higher KAFS also indicates that return-to-work activities are the same as before surgery and that no ankle support is needed. JSSF scores were calculated and have a range from 0-100 with 100 indicating no pain, fully functional, and achievement of good alignment. A higher JSSF score indicates better clinical conditions. The data was pooled for all patients and displayed in Table 1.

Statistical Analysis

Measurement data were expressed as mean +- standard deviation. $P < .05$ was defined as statistically significant.

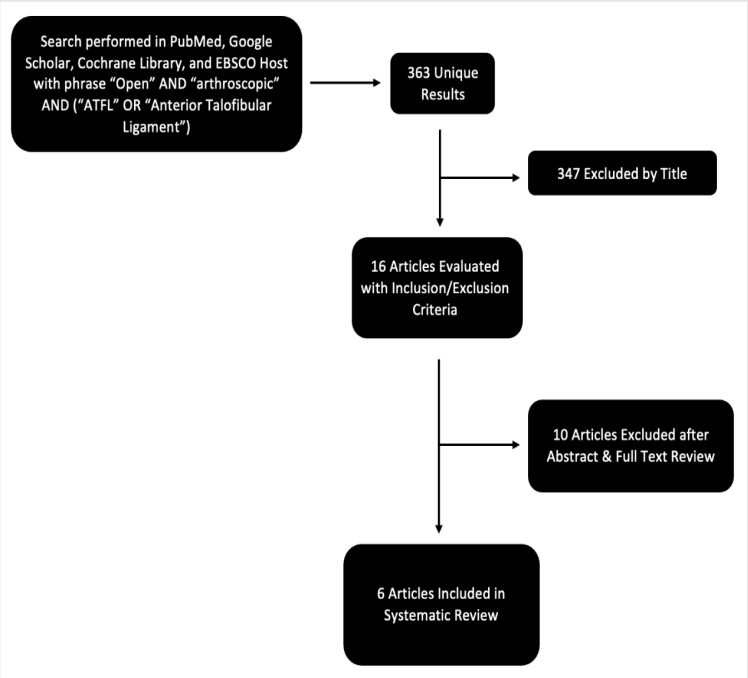

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram

Table 1 Demographics of reviewed studies

Author, Year	Journal	Level of Evidence	N° Ankles	Gender (M:F)	Mean Age (y)	Injured Side (R:L)
Su et al. (7) 2021	Medical Science Monitor	RCS, III				
Open			40	23:17	38.68±14.23	22:18
Arthroscopic			40	18:22	34.27±15.73	16:24
Zhou et. al. (8) 2021	The Journal of Arthroscopic and Related Surgery	RCS, III				
Open			31	23:13	31.36±7.79	23:13
Arthroscopic			36	20:11	33.42±6.40	12:19
Zeng et. al. (5) 2020	American Orthopaedic Foot & Ankle Society	RCS, III				
Open			10	7:3	27.7±9.7	N/A
Arthroscopic			17	15:2	30.9±6.0	N/A
Li et. al. (4) 2017	The American Journal of Sports Medicine	RCS, III				
Open			37	29:8	28.7±8.7	N/A
Arthroscopic			23	18:5	30.3±10.1	N/A
Yeo et. al. (9) 2016	American Orthopaedic Foot & Ankle Society	RCT, I				
Open			23	12:11	34.3±14.1	12:11
Arthroscopic			25	7:18	35.2±11.8	8:17
Matsui et. al. (6) 2015	Archives of Orthopaedic and Trauma Surgery	RCS, III				
Open			18	8:10	24 (13-56)	10:8
Arthroscopic			19	12:7	28 (8-59)	13:6

Table 2 Post-Operative Protocol

Author, Year	Post-Operative Protocol
Su et al. (7) 2021	Non-athletes wore boots and walked with weight-free plaster/fixed support for 4-6 weeks. Patients walked with crutches for 2 weeks, followed by walking normally with plaster/support. At 3 months they could exercise, at 6 months they could jump, and gradually resume pre-injury activities. Athletes could wear walking boots and walk with weight-free plaster/ fixed support for 2 weeks. followed by walking boots, after 2 months they could run, after 3 months they could jump, and after 6 months they gradually resumed pre-injury activities
Zhou et. al. (8) 2021	Short cast applied to fix ankle in neutral position. Isometric contraction of muscle groups around the ankle and flexion-extension of hip/ knee joints encouraged 1st postoperative day. At 2 weeks cast could be replaced by an ankle brace. 2 weeks post-op ROM & strength exercises encouraged. Partial WB 4 weeks after surgery, and progressive WB was allowed thereafter. Heel-lifting, ankle flexion-extension, and inversion-eversion exercises started 6 weeks. If pathologic features were addressed during surgery rehab process was postponed slightly. Patients were asked to see outpatient service at 2, 4, 8, and 12 weeks, 6 months, and 1 year after surgery, and every year thereafter
Zeng et. al. (5) 2020	Short leg cast removed within 2 weeks of surgery, flexion & extension of the hip and knee were encourages. At 3-6 wks. after surgery patients began walking in a boot, and strengthening exercises of the whole lower extremity were started. The flexion and extension of the ankle joint were passively performed. At 6-12 weeks post-op balance training and full WB was performed
Li et. al. (4) 2017	Postoperative protocol guided by PT. Rehab exercises including isometric contraction of muscle groups around ankle were started the day after surgery. Ankle was immobilized in a neutral position by means of short leg cast. 2 weeks post surgery cast was changed to an ankle brace and PROM encouraged, WB permitted after 4 weeks
Yeo et. al. (9) 2016	Patients placed in well padded posterior splint with foot in slight dorsiflexion and kept NWB until 2 week follow up. At 2 weeks placed in short-leg walking cast for additional 2 weeks; progressive WB was then allowed. During weeks 4-6 patients placed in half-removed cast or splint and started on gentle active-assisted ROM of ankle and peroneal strengthening exercises. By 8 weeks post-op patients were instructed to begin straight running and functional activities. Cutting and sport-specific drills started by week 12 post-op. Shortly after 12 weeks patients were allowed to return to previous sports without limitations
Matsui et. al. (6) 2015	Compressive bandage & splint with ankle in neutral position applied for several days. Followed by soft ankle brace for 6-8 weeks. WB and AROM permitted day after surgery. PT began 1-2 weeks after surgery. Endurance training and training to improve balance 2-3 weeks post surgery. Resumption of full sports activity at 6 weeks if patient didn't feel uneasy while performing sports specific drills

ROM, Range of Motion; PROM, Passive Range of Motion; AROM, Active Range of Motion; NWB, Non-Weight Bearing; WB, Weight Bearing; PT, Physical Therapy

RESULTS

The search strategy identified 363 articles, of which 347 were excluded by title and 16 were evaluated with inclusion/exclusion criteria. Ten articles were excluded after the abstract and full-text review. Six studies are included in the systematic review. Four studies compared the all-inside arthroscopic Brostrom procedure to the open Brostrom-Gould procedure. Two studies evaluated recovery time with an all-inside arthroscopic Brostrom procedure versus an open Brostrom-Gould procedure.

Open procedures

Five of the included articles were comparative studies with level of evidence III, and one was a randomized control trial with level of evidence I. The open Brostrom-Gould procedure was used in all six studies with one or two suture anchors. A total of 159 patients received ankle surgery 102 males and 62 females. There were a total of 67 right ankles and 50 left ankles. Two studies did not report the right-to-left injured ankle ratio.[4,5] The average age was 30.8 years old. The mean follow-up from the time of surgery was 22.9 months with a range from 12 to 35.5 months.[4,6-9] Time from injury to the surgical procedure ranged from 3 to 6 months. [5,7,9]

The preoperative and postoperative mean AOFAS score was reported to be 66.3 and 89.5.[4,5,6-9] Su et al. reported a p-value of 0.657 preoperatively and 0.366 postoperatively. Zeng et al. reported a p-value of 0.579 pre-op and 0.605 post-op. Yeo et al. reported a p-value of 0.11 pre-op and 0.062 post-op. The remainder of the studies did not report a p-value for the AOFAS scores. (Table 3 outcomes)

The same five studies also used the Karlsson ankle functional score preoperatively and postoperatively with the mean score of 58.9 and 84.3. [4,5,7-9] In the same order of the AOFAS p-value scores, Su et al. reported 0.895 pre-op and 0.432 post-op. Zeng et al. reported 0.816 pre-op and 0.713 post-op. Yeo et al. reported a p value of 0.096 pre-op and 0.099 post-op. A JSSF score was determined preoperatively and postoperatively with a mean score of 70.45 and 91.3.[6,7] Su et al. was the only study to report a p value score of 0.833 preoperatively and 0.809 postoperatively (Table 3 outcomes).

The degree of talar tilt had a mean of 8.2° preoperatively and 3.3° postoperatively.[6,7,9] One study only reported the postoperative talar tilt, which resulted in an overall mean of 4.4°.[5] The preoperative anterior displacement of the talus had a mean of 8.4 mm and 4.4 mm postoperatively.[6,7,9] One study reported only the postoperative talus displacement, resulting in an overall mean of 5.9 mm.[5] (Tables 2 and 5).

Table 3 Outcomes

Author, Year	AOFAS			KAFS			JSSF		
	Open	Arthroscopic	P-value	Open	Arthroscopic	P-value	Open	Arthroscopic	P-value
Su et al. (3) 2021									
Pre-Operative	65.0±13.13	64.2±11	**0.657**	68.2±12	68.0±12.3	**0.895**	70.1±15	70.8±14	**0.833**
Post-Operative	84.4±3.6	86.3±3.9	**0.366**	79.2±3.4	83.4±4.8	**0.432**	87.1±3.5	88.9±4.5	**0.809**
Zhou et. al. (4) 2021									
Pre-Operative	61.92±7.11	60.13±8.05	**n.s.**	57.36±7.26	54.61±9.41	**n.s.**	N/A	N/A	N/A
Post-Operative	90.67±5.59	91.71±5.46	**n.s.**	88.75±5.56	87.52±7.59	**n.s.**	N/A	N/A	N/A
Zeng et. al. (6) 2020									
Pre-Operative	65.4±9.1	63.4±9.1	**0.579**	60.5±9.8	59.6±9.7	**0.816**	N/A	N/A	N/A
Post-Operative	91±6.2	92.4±5.9	**0.605**	90.5±8.8	89.2±8.4	**0.713**	N/A	N/A	N/A
Li et. al. (1) 2017									
Pre-Operative	69.2±13.2	69.3±11.8	**n.s.**	59.7±13.4	61.8±16.5	**n.s.**	N/A	N/A	N/A
Post-Operative	92.4±8.6	93.3±8.9	**n.s.**	89.4±10.6	90.3±12.5	**n.s.**	N/A	N/A	N/A
Yeo et. al. (5) 2016									
Pre-Operative	69.9±2.1	67.5±2.0	**0.11**	48.6±2.4	45.0±2.3	**0.096**	N/A	N/A	N/A
Post-Operative	89.2±2.3	90.3±2.4	**0.062**	73.5±2.8	76.2±2.8	**0.099**	N/A	N/A	N/A
Matsui et. al. (2) 2015									
Pre-Operative	N/A	N/A	N/A	N/A	N/A	N/A	70.8 (44-87)	69.9 (47-79)	**n.s.**
Post-Operative	N/A	NA	N/A	N/A	N/A	N/A	95.4 (82-100)	98.0 (87-100)	**n.s.**

AOFAS, American Orthopedic Foot and Ankle Society; KAFS, Karlsson Ankle Functional Score; JSSF, Japanese Society for Surgery of the Foot Ankle-Hindfoot; n.s., not significant

Arthroscopic procedures

Five comparative studies were identified with level of evidence III, and one, a randomized control trial, was level of evidence I. An arthroscopic repair of the ATFL for five studies used two portals with an anteromedial and anterolateral approach.[4-7,9] One study

included an additional portal, known as the accessory lateral approach.[8] A total of 160 patients received ankle surgery, 90 male and 65 female. There were 49 right ankles and 66 left ankles. The average age was 32 years old. Five studies' mean follow-up from the time of surgery was 23.1 months (range 12 to 39.7 months). The time from injury to the surgical procedure was the same as in the open procedures.

The preoperative and postoperative mean AOFAS scores for 5 studies were reported to be 64.9 and 90.8.[4,5,7-9] Karlsson ankle functional scores were assessed preoperatively and postoperatively, with a mean score of 57.8 and 85.3.[4,5,7-9] A JSSF score was determined preoperatively and postoperatively for 2 studies with a mean score of 70.4 and 93.45. [6,7] The degree of talar tilt had an average of 8.7° preoperatively and 3.5° postoperatively. [6,7,9] One study only reported the postoperative talar tilt resulting in an overall average of 4.8°.[5] Preoperative anterior displacement of the talus had a mean of 8.2 mm and 4.3 mm postoperatively. [6,7,9] One study reported only the postoperative anterior displacement result bringing the mean to a total of 5.7 mm.[5] (Refer to tables 2 and 5 for post-operative protocol and complications, respectively.)

DISCUSSION

All studies reported a significant decrease ($p < .05$) in talar tilt angle between preoperative and postoperative examinations, without any statistically significant difference t between open and arthroscopic techniques, . further suggesting either method can be used for ATFL repair. An argument for using an arthroscopic approach is shorter surgical time. Su et al., and Li et al. both reported faster surgery when using arthroscopy.[4,7] Zhou et al. and Matsui et al. stated using the arthroscopic technique had a longer learning curve, which resulted in the initial surgeries having a longer duration.[6,8] Overall, they reported a shorter surgical time for the arthroscopic repair. It is worth noting that Zeng et al. was the only article in our review that reported shorter surgery duration for the open technique.[5] Their reasoning for the longer duration while using the arthroscopic technique was it was necessary to explore the whole joint cavity to determine if other problems may be present.

Several studies mentioned early return to activity with arthroscopic repair. Su et al., Matsui et al., and Li et al. said daily functional activities began at an earlier stage with arthroscopic repair.[4,6,7] Zhou et al. discussed using the same rehabilitation protocol for both groups of patients because the stability ultimately was dependent on the strength of the ligament attached to the fibula, and this might require sufficient time for ligament-to-bone healing.[8] They conveyed how detrimental it could be to begin weight bearing or activity prematurely which led them to use the same protocol between the groups. They concluded that because of their favorable outcomes an earlier recovery protocol may be an option for arthroscopic patients in future studies.

The study by Zeng et al. was the only one that mentioned the cost of the open Brostrom technique versus the cost of the arthroscopic technique. As stated, the cost of repairing the ATFL with the

Table 4 Measurements

Author, Year	Talar Tilt, deg			Anterior displacement of talus, mm		
	Open	Arthroscopic	P-value	Open	Arthroscopic	P-value
Su et al. (3) 2021						
Pre-Operative	9.3±3.7	8.9±2.6	**0.363**	8.3±2.7	7.9±2.3	**0.63**
Post-Operative	3.1±0.2	3.3±0.4	**0.246**	3.4±0.2	3.3±0.5	**0.346**
Zhou et. al. (4) 2021						
Pre-Operative	N/A	N/A	N/A	N/A	N/A	N/A
Post-Operative	N/A	N/A	N/A	N/A	N/A	N/A
Zeng et. al. (6) 2020						
Pre-Operative	N/A	N/A	N/A	N/A	N/A	N/A
Post-Operative	7.7±3.1	8.8±2.8	**0..4207**	10.3±3.8	10.1±3.1	**0.9794**
Li et. al. (1) 2017						
Pre-Operative	N/A	N/A	N/A	N/A	N/A	N/A
Post-Operative	N/A	N/A	N/A	N/A	N/A	N/A
Yeo et. al. (5) 2016						
Pre-Operative	5.4±4.2	7.3±4.3	**0.365**	7.8±1.9	8.4±2.9	**0.311**
Post-Operative	3.8±3.6	3.9±1.5	**0.91**	6.8±2.1	6.7±1.3	**0.246**
Matsui et. al. (2) 2015						
Pre-Operative	9.9 (3-15)	10.0 (4-14)	**n.s.**	9.1 (2-12)	8.4 (3-12)	**n.s.**
Post-Operative	2.9 (1-4)	3.2 (2-4)	**n.s.**	2.9 (1-5)	2.8 (1-4)	**n.s.**

n.s., not significant

Table 5: Complications:

Author, Year	N° of patients	N° of complications (%)	Type of complications
Su et al. (3) 2021			
Open	40	4	2 cases of temporary numbness of ankle and foot, 2 cases of thread reaction
Arthroscopic	40	4	2 cases of temporary numbness of ankle and foot, 1 case of thread reaction
Zhou et al. (4) 2021			
Open	36	4	1 case of sensory disturbance of lateral ankle, 1 case of mild knot irritation, 2 cases of recurrent ankle instability
Arthroscopic	31	2	1 case of superficial peroneal nerve neuritis, 1 case of recurrent ankle instability
Zeng et al. (6) 2020			
Open	10	3	2 cases of poor healing, 1 case of painful nodules
Arthroscopic	17	2	1 case of poor healing, 1 case of nerve injury
Li et al. (1) 2017			
Open	37	2	2 cases of osteochondral defect in medial talus
Arthroscopic	23	1	1 case of osteochondral defect in medial talus
Yeo et al. (5) 2016			
Open	23	3	2 cases of superficial peroneal nerve injury, 1 case of an abscess
Arthroscopic	25	5	2 cases of superficial peroneal nerve injury, 2 cases of knot pain, 1 case of sural nerve injury
Matsui et al. (2) 2015			
Open	18	4	3 cases of wound irritation, 1 case of superficial peroneal nerve temporary numbness
Arthroscopic	19	2	2 cases of superficial peroneal nerve temporary numbness

Brostrom technique is more expensive when done arthroscopically. This is from equipment cost, specifically the scope and the use of the radiofrequency knife.[5] Also in this study, the arthroscopic approach took more time than the open procedure which contributed to its increased cost. If it becomes more widely used, the cost may decrease with time but currently, it presents as a more expensive approach than the open Brostrom repair.

Overall, all the studies presented similar limitations. Such limitations included a small number of participants and a lack of prospective studies.[4,6-8] This may be due to MIS and the arthroscopic technique for ATFL repair being a newer approach with limited studies. Another limitation was that the studies focused on ATFL repair only, not CFP repair.

CONCLUSION

In conclusion, this study showed that both arthroscopic and open Brostrom techniques for anterior talofibular ligament repair provide satisfactory outcomes. However, arthroscopic surgery results in an earlier return to activity, and shorter surgical time compared to traditional open techniques for ATFL repair.

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National Foot & Ankle Review

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College of Podiatric Medicine

The Effects of PRP Therapy in Osteoarthritis and Tendinopathy

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ABSTRACT

Osteoarthritis and tendinopathy are disabling conditions that involve the deterioration of joints, cartilage, tendons, and surrounding tissues. Globally, there are gaps in therapies that can introduce strategies for tissue repair, leaving a need for treating different musculoskeletal, spinal, osteoarthritic, and complex wound disorders. Platelet Rich Plasma (PRP) therapy is a strategy that works with the healing process throughout its three phases: inflammation, proliferation, and remodeling of tissues. The question of whether PRP therapy could help promote bone and tendon regrowth will be further investigated in this paper by analyzing previous case reports, literature reviews, and studies of patients diagnosed with osteoarthritis and tendinosis who have received PRP therapy as their treatment. The platforms being used for this literature search include PubMed, and Google Scholar. This report will help further assess whether Platelet-Rich Plasma Therapy is worth considering in patients diagnosed with osteoarthritis and tendinosis.

Keywords: Platelet-Rich Plasma Therapy, Osteoarthritis, tendinosis

INTRODUCTION

Both osteoarthritis and tendinopathies are debilitating, progressive disease states that can affect an individual's gait and activities of daily living.[1] Devastating pathologies may cause pain, discomfort, and impaired daily functions of living.[2] Fortunately, many treatment options are available to manage these conditions. One promising treatment is Platelet Rich Plasma (PRP) therapy. Platelet-rich plasma is thought to contain growth factors that can aid in or lead to regenerative processes and may include immunomodulatory responses through cytokine signaling.[3] There is also the possibility that PRP injections have a role in initiating the processes of hemostasis, connective tissue synthesis, and revascularization, which may be able to "jump-start" the healing process for both chronic and acute injuries at all stages of tissue repair. The extent of PRP response creates a broad clinical application profile. This profile has a high safety margin from the autologous nature of the product.[4] In fact, a previous meta-analysis comparing steroid injections and PRP injections suggested that PRP therapy has greater long-term efficacy than corticosteroids with less pain.[5]

METHODS

This meta-analysis review of literature examines the differences between PRP injections and other modalities (including surgical intervention), assessing their effectiveness and efficacy. Two platforms were used for the literature search: PubMed and Google Scholar. Articles were selected if they had PRP as a therapy modality and focused on conditions including osteoarthritis, tendinopathies, and other tendinous inflammatory conditions. Ten articles were selected and evaluated with different sample sizes. Results were assessed based on alleviation of symptoms, and imaging results (MRI, Xray, ultrasound) to evaluate the structural integrity post-treatment.

PERTINENT SECTIONS

Rahimzadeh et al. conducted a double-blinded randomized study with a sample size of 42 patients suffering from knee osteoarthritis (OA) to determine if PRP therapy was more effective at treating this condition, compared to Prolotherapy (PRL) therapy. PRL therapy involves the injection of an irritant solution, such as hypertonic dextrose, into a damaged joint space to promote the healing process. Outcomes were measured via assessment of the Western Ontario and McMaster Universities

Osteoarthritis Index (WOMAC), which evaluates several items regarding pain, stiffness, and functional limitations. Results from the study

demonstrate that PRP therapy is more effective than PRL in the long-term treatment of symptoms. This was evidenced by a significant decrease in the WOMAC index, strongly suggesting that PRP therapy may have a positive impact on the quality of life for patients living with knee osteoarthritis.[6]

Regarding radiographic evidence of PRP treatment outcomes, Buendía-López et al. used MRI to compare different treatment methods for knee OA. Treatment methods included PRP injection, hyaluronic acid (HA) and NSAIDs. 98 patients were followed, of which 33 subjects received NSAID, 32 subjects HA, and 33 subjects PRP. The subjects were evaluated over 52 weeks, and each received one X-ray and MRI.[7] Although no significant differences in cartilage thickness were observed in the femoral or tibial joints, Buendía-López et. al discovered that PRP therapy reduced discomfort and improved physical function. Moreover, subjects who received a single dose of PRP had significant clinical improvement over subjects who received a single dose of HA or NSAIDs. PRP subjects had less pain and stiffness than subjects who received HA or an NSAID. [7]

With Achilles tendinopathy, Filardo et al. injected 27 subjects with PRP, with seven subjects receiving bilateral injections. Follow-up was performed at two, six, and up to 54 months following ultrasound guided PRP injection. The Victorian Institute of Sports Assessment Achilles (VISA-A) and Tegner scores were used to measure tendon functionality and level of sporting activity, respectively.[8] Results showed that VISA-A and Tegner Activity scores significantly increased throughout follow-up periods, indicating improved functionality and decreased time to return to sporting activities following PRP injection. These outcomes favor the use of PRP therapy in treating chronic Achilles tendinopathy. On the other hand, subjects who experienced a longer duration of Achilles tendinopathy before PRP therapy experienced more difficulties The positive clinical outcomes from this study could be attributed to platelet-derived growth factors, which are highly concentrated in PRP. Platelet derived growth factors are responsible for stimulating collagen production and tenoblast proliferation.[8]

In a randomized control trial, Jian et al. used surgical and non-surgical techniques to treat 36 subjects with acute Achilles tendon ruptures. The subjects were mostly male athletes who were divided into two groups: one group underwent surgery and non-PRP therapy, while the other group underwent surgery and received PRP therapy.[9] Both groups had postoperative follow-ups, where range of motion and muscle strength were examined. An ankle joint range of motion was assessed by measuring dorsiflexion and plantarflexion at six months, then 1-year, and 2-year postoperatively.[9] According to Jian et al., subjects in the PRP group had better ankle joint range of motion compared to the control group. At the 3-month follow-up, the isokinetic muscle strength of the calf muscles was measured for all subjects. Isokinetic muscle strength was expressed as percentages of dorsiflexion and plantarflexion strength at 60, 120, and 240 degrees respectively.[9] During this time, it was determined that the PRP group had higher percentages in all ranges of motion measured compared to the control group.[9] Results from this study suggest that PRP therapy may improve ankle joint range of motion and muscle strength following operative repair of acute Achilles tendon rupture.

It is also thought that PRP therapy may affect gait progression for those receiving treatment for osteoarthritis. Mirza et al. collected responses to PRP therapy in horses with osteoarthritis. The researchers used 12 horses to perform kinetic gait analysis and study after and before intra-articular anesthesia (IAA). Results showed that 10 out of 12 horses responded positively to IAA. Of the 10 horses that responded, 3 reacted positively to PRP within 6 and 16 weeks of administration. Moreover, the researchers found no correlation between IAA and PRP therapy. The study also found variable changes in kinetic gait following the application of IAA and PRP therapy in horses with OA.[10] This finding suggests that PRP therapy may have an impact on gait progression.

While there are many options to treat osteoarthritis and tendinopathy, the introduction of activated PRP following surgery has reduced pain, and decreased use of opioid-based medications.[1] For tendinosis, a surgical release is often performed. In a study by Ford et al., a comparison of residual pain in subjects with tendinosis had no statistically significant difference between the surgical and PRP injection groups. Additionally, corticosteroid injections have been linked to suppressed tendon healing and collagen synthesis and are shown to be effective only in the acute stages of healing to modulate the inflammatory response.[5] Overall, it has been found that PRP therapy significantly improved the quality of life for patients living with knee osteoarthritis[6] and was better at relieving pain, stiffness, while improving physical function over HA and NSAID usage.[7] PRP therapy has also been found to significantly increase the VISA-A and Tegner Activity scores in patients with chronic

Achilles tendinopathy,[9] as well as improving gait progression.[10]

CONCLUSION

The most common limitations noted in these studies include inadequate control groups and small sample sizes.[2-10] PRP therapy has been shown to effectively alleviate osteoarthritic pain and stiffness.[6,7] Moreover, PRP therapy may also help improve Achilles tendon functionality and ankle joint range of motion following post-operative repair of Achilles tendon rupture.[9] It may also improve gait progression.[10] While PRP treatment may be beneficial postoperatively, it can also be a suitable alternative possibly reducing the need for operative intervention.[5] These findings favor the use of PRP therapy as a first-line treatment for multiple disorders, including tendinopathy and osteoarthritis. Furthermore, PRP is a relatively low-risk option that has shown significant promise. Therefore, its potential healing and regenerative properties warrant further investigation.

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National Foot & Ankle Review

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Viscosupplementation in the Ankle: A Literature Review

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ABSTRACT

Viscosupplementation is a widely used treatment for osteoarthritis in proximal joints, such as the hip and knee. This literature review explores the use of viscosupplementation for osteoarthritis (OA) of the ankle joint. The PubMed database was searched using keyword terms "viscosupplementation in the ankle," "Synvisc, Hylan G-F 20," and "osteoarthritis in the ankle." Limited studies on viscosupplementation in the ankle required researchers to expand dates from 2000 to 2022. Several studies using hyaluronic acid (HA) injections for relief of ankle pain secondary to OA revealed a maximum of six months of benefit. When comparing the patient-perceived outcomes and adverse effect profiles of viscosupplementation and corticosteroid injection, both were found to have similar patient benefits. However, viscosupplementation has a minor side effect profile of arthralgia, injection site pain, and joint swelling. In contrast, corticosteroid common side effects include injection site reaction, skin atrophy, septic arthritis, and post-injection flare. This literature review highlights the benefits of incorporating viscosupplementation for treatment of ankle OA.

INTRODUCTION

Symptomatic relief of ankle joint osteoarthritis (OA) includes NSAIDS, corticosteroids, physical therapy, weight loss, and bracing.[1] However, conservative treatment does not always adequately relieve symptoms. Viscosupplementation with intra-articular hyaluronan GF- 20 may provide symptomatic relief of ankle OA to the 8.8% of the population afflicted.[2]

Injectable hyaluronan GF-20, a more potent viscosupplementation, is generated by chemically modified, cross-linked rooster comb.[3] Its proposed mechanism cushions the joint by acting similarly to the body's native synovial fluid.[4]

Viscosupplementation with Synvisc™ is FDA-approved for use in the treatment of knee pain caused by OA; however, use in the ankle joint has not been as well studied. Most studies on viscosupplementation in the ankle joint were conducted outside of the United States. This literature review highlights the use, safety and efficacy of viscosupplementation for ankle joint OA.

MATERIALS & METHODS

A search of literature published prior to October 14, 2022 for studies related to Synvisc treatment was performed. The PubMed database was examined with the search terms "Synvisc for ankle," "Synvisc," "osteoarthritic ankle," "osteoarthritic ankle treatment," and "steroid injections for osteoarthritis in ankles." Inclusion criteria were studies discussing Synvisc, osteoarthritis ankle modalities, and studies analyzing the efficacy and patient satisfaction of HA injectables in the ankle. The studies analyzed within this paper used several measurement methods, including the Ankle Scale (AOS), American Orthopedic Foot and Ankle Score (AOFAS), and Visual Analogue Score (VAS). Fifteen publications reporting systematic and literature reviews, retrospective and prospective studies, randomized clinical trials, and case reports were included in this review. Non-English language articles were excluded. With limited research conducted in the United States, the location was not an exclusion factor, with seven of our referenced research articles performed outside of the United States.

RESULTS

Recent studies reported high efficacy for viscosupplementation in the ankle joint with decreased pain related to ankle joint osteoarthritis.[3,4,6,8,11,15] Witteveen et al. found that 56% of their cohort experienced a 42.5 mm decrease in the Visual Analog Score (VAS) with minimal side effects after a single injection. [6] This figure improved by a further 23.5 mm VAS decrease after patients received a second injection and were assessed at a six-month follow-up.

Lee et al. also found success with their injection protocol.[7] As the number of injections increased, there was an overall decrease in pain.[7] Their therapeutic model resulted in 80.6% of patients experiencing a remarkable decrease in pain and improvement in patient reported joint function after having at least two

injections. This study used an injection regimen of three per week in early to intermediate ankle OA that was intractable to traditional medications and modalities.[7]

Luciani et al. analyzed outcomes 18 months post treatment.[8] This study used a three injection protocol in patients categorized with grade II ankle OA. Perceived pain scores decreased well after six months in 81% of their cohort, with 48% experiencing excellent results.[8]

Other studies have compared hyaluronic injections to placebo. Brander et al. compared hyaluronic injections vs. a saline placebo for hip OA.[9] They found no difference between the saline placebo and HA for painful hip OA.[9] Two other studies examining the effectiveness of HA injection found that HA was comparable to saline placebo. Zammit et al. used two groups, one received a saline placebo, and the other received HA injection for the first metatarsophalangeal joint arthritis, not the ankle.[10] This study did not provide an interproduct difference in relief; however, both provided symptomatic relief after one injection, effectively improving the patient's foot pain and foot function testing. Jantzen et al. investigated various grades of ankle OA and the effectiveness of a single injection of HA for the ankle joint.[11] The study found that one injection effectively improves VAS scores for patients at rest from 4 to 3 and during activity from 7 to 6.[11] However, the study concluded that one injection is insufficient and a second injection should be considered during a six-month period.

A meta-analysis by Legre-Boyer et al. found that HA may have a more favorable risk-to-benefit ratio compared to some common analgesics used to treat OA pain, such as paracetamol.[12] The route of administration bypassing the first-effect phenomenon of liver metabolism was potentially significant. Pekarek et al. reviewed corticosteroid usage for ankle OA, and found significant side effects, including tendon rupture, atrophic changes of surrounding ligaments and skin, and cartilage changes.[13] The standard HA protocol of at least three injections decreased VAS numbers well after the course of treatment ended. In addition to efficacy, multiple studies' data suggest that HA injections were safer than corticosteroid injections in terms of patient tolerability and adverse effect profile. For knee OA, HA lasted longer than corticosteroids which lasted four weeks on average.[14]

Rezende et al. studied hemophilic arthritis of the ankle joint and other proximal joints.[15] A joint lavage was performed with HA and a glucocorticoid at all affected joints, not just the ankle. Function and quality of daily life improved; however there was no significant improvement in pain using the VAS criteria, no matter what joint was affected. In another study, Gomes et al. combined HA with a corticosteroid to determine the efficacy of pain relief at the subtalar joint.[16] In this study, VAS scores for pain improved with the combination therapy at 12 and 24 weeks.[16]

Migliore et al. found that in three studies using HA, two using HA alone, and one study that incorporated ankle arthroscopy pain improved.[17] Carpenter et al. compared ankle arthroscopy to HA injections as an adjuvant procedure.[4] Even though the arthroscopic procedure led to statistically significant decreases in both groups' perceived pain scores, the experimental group that underwent three HA injections as an adjuvant procedure ($p < 0.0014$), was found to have less pain.[17] After treatment with HA injection, the average decrease in pain was 6.27, with only 15% of total cases not experiencing any decrease.

DISCUSSION

Benefits and Usage of HA

Osteoarthritis is a chronic, degenerative disorder associated with joint pain and loss of joint function. It is the most common disease to affect synovial joints.[6] OA can affect any synovial joint, but most commonly affects the knee, hip, and hand. Treatment of OA typically starts with low risk conservative measures. Current nonoperative treatment includes physical therapy, bracing, medications, and intra-articular corticosteroid injection. HA is an effective treatment for OA of proximal joints such as the hip and knee. HA injection provides multiple benefits, including intra-articular lubrication, inflammation reduction, analgesia, and chondroprotective effects. However, for patients with ankle joint OA, HA treatment is neither recommended nor discouraged due to the inconsistencies of clinical studies. For example, Bowman's meta-analysis comparing ankle joint HA injection for OA pain demonstrated pain improvement,[5] while other studies did not demonstrate any significant improvement.[1,9,14,16] However, HA therapy does offer long-term improvement of pain, Luciana et al. demonstrated that HA injection relieved symptoms for more than six months.[8]

Corticosteroids vs. HA Injection

This review demonstrates that HA injections can relieve OA ankle and HA may be a safer alternative to intra-articular corticosteroid injection.

Corticosteroids have fast pharmacokinetics but may not provide long term pain relief [14] and they have a cytotoxic effect on chondrocytes.[17] Additionally, side effects of corticosteroids include tendon rupture, atrophic changes in surrounding ligaments and skin, and cartilage disruption.[17]

Lee et al. demonstrated that three weekly intra-articular injections of HA could improve clinical outcomes without severe complications in patients with

Figure 1

Study Name	Area	One injection effect	Two injections effect	Three injection effect	Notes
Witteveen et all	Ankle joint	56% of cohort experienced a 43.5 mm decrease in VAS with minimal side effects	Improved by a further 23.5 mm VAS decrease		
Korea by Lee et. al	Ankle		83% VFAS decrease		
Lucinai et al	Ankle joint			81% had decreased perceived pain scores	
Brander et al.	Hip	No difference between HA and saline			
Zammit et. al	1st MTPJ	Symptomatic relief with HA and saline			
Jantzen et al.	Ankle joint	Improved VAS scores for patients at rest from 4 to 3 and during activity from a 7 to 6			
Legre-Boyer et al.					Synvisc more efficient than other common analgesics
Pekarek et al.	Ankle				Significant side effects of corticosteroid usage in ankle
Rezende	All affected joints				Function and quality of life improved
Migliore et. all	Ankle	Each measure of pain resulted in pain improvement			
Carpenter et. al	Ankle			Greater positive impact on perceived pain scores	

primary ankle OA.[7] In addition, intra-articular HA injections can be performed safely to reduce pain and improve function in early or intermediate-grade ankle OA when patients inadequately respond to medication.[7] Witteveen et al. demonstrated that HA injection of the ankle in patients with OA provided six months of benefits after a single injection.[6] However, Jantzen et al. found no significant effect after a single HA injection.[11] Both Zammit et al. and Jantzen et al. suggest positive outcomes for patients with more severe OA. Jantzen et al. suggest that one HA injection may not be sufficient for a 6-month period for higher grades of OA in the ankle.[11]

Side Effects and Limitations of Synvisc Injection for Ankle Osteoarthritis

Adverse effects from ankle joint injection include arthralgia, injection site pain, and joint swelling.[7] No major side effects were reported in any of the studies reviewed.

This study's limitations and areas of contention include studies that use different formulations of HA and varying dosing and injection intervals. This literature review did not focus on the combination therapy of corticosteroids in conjunction with hyaluronic acid. However, it may be another area of study for the change in efficacy when used together or alternatively for pain management.

CONCLUSION

HA injection into the ankle joint can provide symptomatic relief of pain with minimal side effects. While this paper is limited in its exploration of the topic due to studies being performed outside of the United States and research including HA products other than Synvisc, it provides the basis for the need to increase research on HA use for treatment of ankle OA.

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National Foot & Ankle Review

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A Literature Review: Managing Plantar Fasciitis with Platelet Rich Plasma

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ABSTRACT

Introduction: Plantar fasciitis (PF) is a common multifactorial degenerative tissue condition that affects various demographics, especially overweight individuals. It significantly impacts work and quality of life. Recently, platelet rich plasma (PRP) injections have been used to treat PF. Studies have shown that PRP injections have fewer side effects compared to corticosteroid injections (CS). This systematic literature review aims to educate healthcare professionals and podiatric physicians about the efficacy of PRP in the treatment of PF as compared to other injections, such as corticosteroids.

Methods: A literature search was conducted using the PubMed database with the following keywords: "Platelet-rich plasma, plantar fasciitis, plantar, amniotic fluid, amniotic fluid versus platelet rich plasma." Non-English language articles were excluded. 15 published articles were used in this systematic literature review including three systematic and literature reviews, one narrative review, four randomized clinical trials, one comparative study, one cross-sectional study, three case series, one cohort study, one animal research study.

Conclusion: This literature review examined the efficacy of PRP injections as a therapeutic option for treating plantar fasciitis. Based on this review, PRP injections are an option for treatment of plantar fasciitis and produce significantly less side effects than steroid injections.

INTRODUCTION

Plantar fasciitis (PF), a common diagnosis, is a self-limiting pathology usually treated with conservative measures. Such as, plantar fascia stretching, heel lifts, night splints, icing, resting, physical therapy, orthotics, and NSAIDs. Platelet rich plasma (PRP) injection, a procedure that accelerates the healing of tendons, ligaments, and bones through concentration of the patient's platelets has been used to treat plantar fasciitis. To perform a PRP injection, the provider extracts blood from a peripheral venipuncture, and a laboratory certified for processing blood products like a centrifuge is sued to spin down the plasma and platelets. The resulting product is a plasma solution with a higher concentration of platelets than is normally physiologically present. The platelet rich plasma is then injected into the site of injury.[1] This causes an acute inflammatory reaction which attracts healing factors to the site of injury, increasing tendon regenerative abilities. When compared to steroid injections, the standard injectable treatment, PRP has significantly fewer side effects.[1] When compared to amniotic fluid allografts and corticosteroid injections, PRP had greater angiogenesis effects and allowed for easier extraction methods.

The purpose of this systematic literature review is to educate healthcare professionals about the efficacy of PRP treatment for plantar fasciitis while discussing the advantages of utilizing it compared to other injectables such as cortisone and amniotic fluid.

DISCUSSION

Platelet Derived Plasma (PRP)

PRP is a therapeutic modality that has been used for the treatment of chronic plantar fasciitis. Due to its novelty, there are limited studies on its efficacy. However, of the studies that have been published, there has been a high patient satisfaction regarding the heel pain improvement, overall function, and reduction of plantar fascia thickness.[1]

Another benefit to PRP therapy is the lack of allergic side effects.[1] Kantrowitz et. al. reported no serious adverse events associated with PRP treatment, including allergic reactions. Wilson et al. reported no adverse events associated with PRP treatment. In addition, scores used to track patient outcomes improved. One metric, the foot and ankle ability measures-activity and daily living subscale (FAAM-ADL) scores improved by 32.4%. The FAAM-ADL is a self-reported outcome used in many studies to assess physical function in individuals with foot and ankle-related impairments. The scale is from 4 to 0 (4=no difficulty at all and 0=unable to perform). The FAAM-sports subscores improved by 82%. The change in sub scores all

show clinically significant improvement.[2] In a randomized clinical trial performed by Vahdatpour et al., no systemic or local complications were reported ten months after PRP injections. In a year, nearly 85% of participants reported "excellent/good" results.[3]

Moreover, PRP has become popular with some professional and collegiate athletes. For instance, Vahdatpour et al., found greater success using PRP than other treatment modalities six months after treatment.[3] In a cross-sectional study by Kantrowitz et al., collegiate , NFL and NHL physicians successfully used PRP to treat various soft tissue pathologies despite a lack of consensus on the timing of treatment and exact formulation. More specifically, physicians treating high-level athletes have seen a benefit in using PRP to treat hamstring injuries, lateral epicondylitis and patellar tendonitis.[4]

Platelet Derived Plasma versus Corticosteroid Injections

Corticosteroid (CS) injections have been a standard treatment for PF. CS injections reduce inflammation, but at a cost of potential adverse side effects, including the risk of fat pad atrophy and plantar fascia rupture.[5]

Previously, PF was once believed to be an inflammatory condition. However, research has shown the pathophysiology is now thought to be degenerative in nature. Grasel et al. studied MRI images of patients with PF; based on the findings there was no significant evidence to support the claim that PF was due to an inflammatory cause.[6]

PRP may be advantageous over CS injections due to its regenerative characteristics. For example, PRP contains growth factors and bioactive cytokines, which are thought to contribute to cellular healing. Additionally, PRP releases vascular endothelial growth factor which contributes to neovascularization.[7]

When assessing pain improvement, studies have shown that PRP injections have better long-term effects compared to CS injections. For example, Yang et al. reported a significant 6-month follow-up improvement in the PRP group.[8] The results demonstrated that at the 4-week follow up there was no significant difference in the visual analogue score (VAS), a measure of the efficacy and reality of clinical practice, between the two groups. [8] However, during the 1-year follow-up, the PRP group had significantly improved VAS scores. [8] Kowshik et. al, states that PRP is significantly a more "durable injection" than cortisone, having longer symptom relief 12 months post-injection compared to cortisone.[9] This finding also supports the hypothesis that PRP is a better long-term therapeutic agent for plantar fasciitis.

Platelet Derived Plasma versus Amniotic Fluid Injections

Amniotic fluid (AF) is a rich source of stem cells that can be used for a wide range of clinical applications, including plantar fasciitis. It is collected via amniocentesis between the 15th and 19th week of gestation.[10] AF is used as an innovative allograft and injected along the dorsal and plantar surfaces of the plantar fascia.[11] Nutrients and growth factors that aid in tissue repair in AF include carbohydrates, proteins and peptides, lipids, lactate, pyruvate, electrolytes, enzymes, hormones, transforming growth factor alpha, transforming growth factor beta 1, and fibroblast growth factor.[11] Hyaluronic acid found in AF also prevents scarring by inhibiting collagen deposition and fibrotic tissue formation.[11]

On the other hand, PRP accelerates wound healing. This occurs via induction of migration of various cell types such as endothelial cells, mesenchymal stem cells, and skin fibroblasts.[12] Wound healing is highly dependent on neovascularization, and PRP has high levels of growth factors and molecules related to angiogenesis. These molecules include angiopoietin-1 (ang-1), angiopoietin-2 (ang-2), and vascular endothelial growth factor (VEGF).[12] Ang-1 and ang-2 pathways initiate angiogenesis.[13] VEGF is involved in extracellular migration, mitogenesis, angiogenic sprouting, and tube formation.[13]

While PRP and AF both contain growth factors and mesenchymal stem cells that accelerate the healing process, PRP can act as a stimulator and regulator of cell migration. PRP enhances the secretion of local growth factors that increase cell migration and proliferation of the target cells when applied to the wound site.[12] In a study by Ghaffarinovin et. al, PRP had more significant angiogenesis properties compared to AF mesenchymal stem cells.[14]

CONCLUSION

Chronic PF is a painful condition that impacts quality of life. Although CS has been the most common therapeutic injection for PF, studies have shown that PRP is an effective alternative treatment. CS injections only address the inflammatory properties associated with PF to allow short-term pain relief while bearing negative consequences with chronic usage.[17] These consequences include the risk of fat pad atrophy and plantar fascia rupture.[5] Systemic consequences from chronic use of steroids also include alteration of adaptive immunity post-vaccination, menstrual irregularities, glucocorticoid-induced osteoporosis, and a multitude of other adverse effects.[15,16] Collins et al. and Williams et al. have shown that there are no associated allergic side effects nor any other adverse events with PRP treatment for PF. In addition, PRP

provides better long-term effects in terms of pain and healing. [5, 8, 9]

In comparison to AF treatments for PF, PRP contains growth factors, migration factors, and neovascularization factors that makes it overall superior to AF. Because PF is a multifactorial degenerative condition, PF would be treated more effectively with PRP because it will address underlying factors that cause PF, not just the pain associated with it. AF and PF may share similar growth factors and molecules that assist in wound healing, however, PRP accelerates wound healing by being a stimulator and regulator of cell migration that is associated with healing.[12] Also, PRP contains more angiogenic properties than AF mesenchymal cells which promotes healing of PF.[14] The ease of collecting PRP from a patient makes it a very attractive treatment as well. To extract amniotic fluid via amniocentesis, there is a specific time frame, 15-19 weeks gestation, that must be followed.PRP may be a great alternative and minimally invasive treatment of PF, but it is not without its limitations. When researching this topic, there is a lack of research and peer-reviewed articles discussing the efficacy of PRP versus AF treatments of PF. Also, due to its novelty, there is a lack of established preparation protocols for PFP. When reviewing the research articles for this study, the method of PRP collection from patients differed for each study. With that said, there is a lack of regulation in terms of dosing, timing and frequency of PRP injections, techniques and location of PRP injection delivery, and optimal dosing and conditions for PRP injections.[18] The novelty status of PRP treatments, despite established studies and research since its documented first use, also contributes to the disapproval of coverage from most medical insurances, making it expensive and difficult to access for the majority of patients.[19] More studies should be done to show possible PRP adverse effects in relation to AF with chronic treatment, PRP overall long-term efficacy and side effects, and PRP cost-effectiveness for different socioeconomic backgrounds in relation to other regenerative and/or minimally invasive treatments for PF.

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National Foot & Ankle Review

The Impact of Vitamin C on the Treatment of Lower Extremity Ulceration: A Systematic Review

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OBJECTIVE

To evaluate the impact of vitamin C on the healing of the common ulceration types affecting the lower extremity: diabetic (neuropathic), pressure, and venous.

ABSTRACT

A cutaneous ulceration is the breakdown of the skin with potential complications ranging from persistent pain to life-threatening infection. Common ulceration types affecting the lower extremity include diabetic (neuropathic), pressure, venous and arterial. Treatment of ulceration can be difficult and novel therapies that reduce ulceration volume and facilitate dermis regeneration are the subject of substantial research. Vitamin C, an antioxidant, aids tissue regeneration by increasing collagen synthesis, enhancing the tensile strength of new collagen, and activating the proliferation of dermal fibroblasts. Its antioxidant quality also increases wound healing by dampening inflammation. A literature search was conducted on PubMed for relevant studies on the impact of vitamin C on tissue regeneration in common ulcerations of the lower extremity. Inclusion criteria were defined as human studies published in English with full-text availability. Secondary sources (systematic reviews, literature reviews) and studies that did not pertain to ulcerations of the lower extremity were excluded. As a result, 15 relevant articles were included in this review. The results of this search suggest that vitamin C is likely to enhance the healing of pressure, diabetic (neuropathic), venous, and necrotic ulcers, supporting its therapeutic effect in patients with ulceration of the lower extremity.

INTRODUCTION

Vitamin C, or ascorbic acid, plays a significant role in different phases of wound healing. During the inflammatory phase, its antioxidant properties control tissue injury from free radicals by regulating neutrophil apoptosis and upregulating angiogenesis, a crucial component of wound healing.[1,2] In the inflammatory state, angiogenesis is impaired by high serum levels of oxidized low-density lipoprotein (LDL) through cholesterol loading and inhibition of endothelial growth.[3,4] Vitamin C can prevent LDL oxidation, which enhances wound healing.[1,3] Subsequently in the proliferative phase, vitamin C promotes the maturation of dermal fibroblasts and increases collagen synthesis.[1,5] In the remodeling phase, vitamin C enables extracellular matrix deposition, creating collagen with higher tensile strength and improved quality for an efficient scar formation.[1,2,5,6,7] This review examines the current literature on the impact of vitamin C on ulceration of the lower extremity.[9]

METHODS

A literature search was conducted on the PubMed database using the search terms, (ascorbic acid) AND ((venous ulcer) OR (arterial ulcer) OR (diabetic foot ulcer) OR (pressure ulcer) OR (plantar ulcer)), which yielded 85 studies. Inclusion criteria were defined as human studies published in English with full-text availability. After applying the inclusion criteria, 23 studies were identified. Exclusion criteria were defined as secondary sources, such as systematic reviews, literature reviews, and studies that did not pertain to ulceration of the lower extremity. After applying the exclusion criteria, 15 studies were identified and included in this systematic review (Figure 1).

RESULTS

Of the 15 studies on the effect of vitamin C on ulceration healing, 10 were randomized controlled trials (RCTs), three were prospective observational studies, one was a case series, and one was a case report. Seven studies pertained to pressure ulceration, three on foot ulcers, one on diabetic (neuropathic) ulcers only, one on venous and diabetic ulcers, two on venous ulcers, and one on necrotic ulcers secondary to scurvy (Table 1).

Pressure ulcers

Two RCTs examined the independent effect of vitamin C on pressure ulceration healing. Taylor et al. reported that a twice-daily administration of vitamin C 500 mg for one month significantly reduced the wound area compared to the placebo (treatment 84% vs. placebo 42.7%, $p<0.005$).[10] Next, Ter Riet et al.

compared the effect of 500 mg and a control of 10 mg vitamin C over 12 weeks and reported that the mean wound area reduction per week was not statistically significant in the higher dose group (treatment 13.88% vs. control 22.85%, adjusted difference -3.13%, PI-13.66-7.39).[11] Additionally, the Kaplan-Meier wound survival curves did not show a significant difference between the two groups (p=0.84), and the adjusted hazard ratio for wound survival was 0.78 (PI 0.44-1.39), indicating the intervention was not associated with a higher wound closure rate. A prospective interventional study by Frias Soriano et al. reported an association between vitamin C and reduction in the wound area of pressure ulcers.[12] Vitamin C 250 mg was administered to supplement a diet high in energy, protein, and carbohydrate with 9 mg of zinc and 38 mg of vitamin E daily for three weeks. At the end of the intervention, the median wound area reduced significantly (29%, $p<0.001$), translating to a healing rate of 0.34cm^2 per day (two days to heal 1cm). Additionally, the amount of exudate in infected ulcers and necrotic tissue was significantly reduced ($p<0.05$).

Similarly, four RCTs examined the effect of vitamin C in combined treatments on pressure ulcer healing.[13,14,15,16] In a study by Desneves et al., subjects were randomized to three groups of varying diets A-C for three weeks.[14] Diet A consisted of the standard hospital diet, while diet B consisted of diet A supplemented with additional protein, calories, 72 mg of vitamin C, and 7.5 mg of zinc. Diet C was the same as diet B, with a higher amount of protein, 500 mg of vitamin C, 30 mg of zinc, and 9 g of arginine. Pressure Ulcer Scale for Healing (PUSH) scores were taken at baseline and then in weeks 1, 2 and 3 to assess the change in pressure ulcer severity. In week 2, the diet C group was associated with a significant change in the PUSH scores compared to baseline ($p<0.05$), which persisted in week 3. Additionally, Diet C reported a significant change compared to Diet A or B ($p<0.05$) in week 3. In a separate study by Cereda et al., the effect of vitamin C combination therapy was observed on the healing of acute pressure ulcers of less than one-month history.[13] Subjects were randomized to the standardized hospital diet or intervention diet, which consisted of the standard hospital diet plus additional proteins, 500 mg of vitamin C, 18 mg of zinc, and 6 g of arginine. Both groups were orally fed for 12 weeks. At week 12, the treatment group was associated with a significant reduction in the PUSH score (-6.1, $p<0.02$) and a change in pressure ulcer area (-1,450mm^2, $p<0.005$) compared to baseline. However, there was no difference observed between the groups in the ulcer area at any time point throughout the 12 weeks. In contrast, van Anholt et al. compared a noncaloric diet with a combination diet consisting of high energy, protein, vitamin C 250 mg, zinc 9 mg, arginine 3 g supplemented with vitamin A, vitamin E, carotenoids, selenium, copper, and folic acid.[15] Subjects were randomized into either group for 8 weeks and were assessed for the mean change in wound surface area, the number of wound dressings, and PUSH scores at baseline, weeks 4 and 8. The treatment group reported a significant reduction in pressure ulcer size at week 8 ($p=0.016$) compared to the control, which was also true for within-group changes when compared to baseline at week 3 ($p=0.019$) and week 8 ($p\leq0.012$). In the control group, a significant reduction in ulcer size was observed from weeks 5 and onwards ($p<0.05$). The treatment group had a significant reduction in the number of dressings throughout the observation period ($p < 0.05$ throughout at weeks 3-7, $p=0.003$ at 8 weeks). PUSH scores also improved significantly in the treatment group ($p=0.011$), mostly attributable to fewer ulcers of the "granulated or necrotic" subtype and more "closed or epithelial" subtype compared to the control group ($p=0.037$). Theilla et al. evaluated the effects of a combination diet of vitamins C, A, E, eicosapentaenoic acid, and gamma linoleic acid on the incidence of pressure ulceration in subjects with acute lung injury.[16] These nutrients supplemented a high-fat, low-carbohydrate enteral formula, and the number of ulcers was compared to those of the control group without the supplementation over seven days. Subjects who were randomized to the treatment group experienced a smaller increase in the number of new ulcers on days 4 and 7 compared to the control group (treatment group 12 and 15 vs. control group 23 and 24, all $p<0.05$).

Diabetic (neuropathic), Venous, and Necrotic Ulcers

Gunton et al. focused on the independent effect of vitamin C on the change in ulcer size and healing rate in subjects with vascular disease, diabetes, neuropathy, or deformed foot architecture.[17] The study showed that the administration of vitamin C 500 mg for 8 weeks resulted in a significant reduction in ulcer size (treatment 100% vs. placebo -14%, $p<0.05$) and 50% ulcer healing rate (treatment 20 days vs. placebo 48 days, $p<0.05$). A case report examined the effect of vitamin C treatment on a subject with scurvy.[18] Secondary to poor wound healing, the patient's rash had evolved into a necrotic ulceration at the medial malleolus. After 5 months of vitamin C supplementation, the rash had resolved, and his plasma vitamin C level and anemia were normalized.

An RCT by Yarahmadi et al. explored the effect of platelet-rich plasma-fibrin glue dressing taken with oral vitamin E (200 IU/2 Day) and C (250 IU/2 Day) on subjects with diabetes mellitus with a non-healing ulceration for at least four weeks.[19] The intervention group with platelet-rich plasma-fibrin glue (PRP-FG) dressing and oral vitamin E and C had a significant

increase in complete closure of the ulcers (treatment 6 of 13 vs. placebo 2 of 12, $p<0.02$) compared to the control group with PRP-FG dressing and placebo. Another study by Salgado et al. used a topical agent composed of Maltodextrin and vitamin C powder and compared its effect on venous ulceration in lower limbs with zinc oxide ointment for control.[20] After 12 weeks, it was found that there was a significant increase in wound closure rate among the treatment group compared to the control (treatment 57.4%+/-39.9 vs. control 16%+/-41.6, $p = 0.034$). Silvetti et al. used a three-step treatment of saline solution of pH 6.5 followed by an aqueous solution of amino acids and vitamin C/ D-glucose polysaccharide powder on open wounds resulting from trauma, ulcers, and second/third-degree burns.[21] Chronic small and medium-sized wounds were closed completely, and large wounds were reduced enough to apply grafts. An observational study by Chudek et al. investigated the effect of *Ruscus aculeatus* + hesperidin methyl chalcone (HMC) + vitamin C on subjects with active or healed venous ulcers. The resultant reduction in ulcer areas was on par with that of known venoactive drugs taken by subjects with chronic venous disorders.[22] Prakoeswa et al. compared the reduction in size and depth of plantar ulcers among subjects with Hansen's disease after administration of human amniotic membrane-mesenchymal stem cell-conditioned medium (hAMMSC) only (control), hAMMSC + vitamin E, and hAMMSC + vitamin C every 3 days for 8 weeks.[23] All treatments resulted in a significant reduction in ulcer size and depth ($p<0.005$), with the intervention group treated with hAMMSC + vitamin E showing the best results.

Conversely, Bauer et al. showed that standard oral nutrition supplement resulted in a greater reduction in Pressure Ulcer Scale for Healing (PUSH) of chronic wounds compared to wound-specific oral nutrition supplements (ONS) enriched with arginine, zinc, and vitamin C (treatment -0.1, $p>0.05$ vs. control -3.6, $p=0.006$) and between week 8 to baseline (treatment -0.6, $p>0.05$ vs. control -4.8, $p=0.017$).[24]

DISCUSSION

While there are many studies on the effect of vitamin C on wound healing, there are a limited number of studies on its effectiveness on ulceration of the lower extremity. Fifteen studies included in the present systematic review were categorized into three groups: positive (13), uncertain (1), and negative (1) wound healing outcomes. Of the seven studies on vitamin C administration for subjects with pressure ulceration, six showed effective wound healing. Our finding supports the current literature on the positive role of vitamin C in ulcer healing.

Ten out of 11 studies also showed positive wound healing outcomes when vitamin C was used in combined therapy. Along with vitamin C, common micronutrients given to treat ulcers were vitamin E, zinc, arginine, protein, and essential amino acids. Currently, multistage combined therapy is recommended for chronic wounds.[25] Our findings suggest that the therapeutic effect of vitamin C may be maximized through combined therapy, especially with zinc and arginine.[2]

Two studies in the present systematic review required further examination for proper categorization. While Prakoeswa et al.'s study concluded that the subjects administered with hAMMSC-vitamin E showed the best results compared to hAMMSC-vitamin C and hAMMSC only, it should be noted that all treatments showed significant wound healing. Another study by Chudek et al. concluded an insignificant difference between the decrease in ulcer area in subjects treated with vasoactive drugs and *Ruscus aculeatus* + HMC + vitamin C. Vasoactive drugs are used to increase venous wall tonus, capillary resistance, lymphatic drainage, and protect the microcirculation in patients with chronic vascular disease,[22] hence they were selected as the positive control. Given that the treatment and control groups demonstrated similar levels of wound healing, it was concluded that *Ruscus aculeatus* + HMC + vitamin C was just as effective in wound healing as those vasoactive drugs.

The study by Ter Riet et al. demonstrated that both vitamin C 500 mg and vitamin C 10 mg groups exhibited positive wound healing. However, it was placed in the uncertain category due to possible confirmation bias that may have produced results that were inconclusive of the definitive effect of vitamin C. The researchers may have designed the study with an expectation for large doses of vitamin C to produce compelling results compared to small doses of vitamin C, and therefore failed to include a placebo to test the actual effect of vitamin C on wound healing. Because a placebo group was absent in this study, the effect of vitamin C remains a question.

The study by Bauer et al. was an outlier. Their study concluded that wound-specific ONS enriched with vitamin C, arginine, and zinc was ineffective compared to the standard high protein, high energy ONS. A possible explanation for the conflicting study results is their small sample size. There were initially 24 subjects, but the sample size was reduced to 22 at week 4 (treatment: 10 vs. control: 12) and 19 at week 8 (treatment: 10 vs. control 9). Such a small sample size is prone to measurement errors and unreliable statistical significance. Additionally, the wound ONS group had acute GI problems immediately after the consumption of the supplement (3 of 10), but no issue was observed in the control group. This GI irritation may have resulted in malabsorption of the essential

nutrients for proper wound healing, therefore, underestimating the effect of wound-ONS. It should also be mentioned that there was no significant difference in nutritional status in either studied groups. The absence of statistical difference in nutritional status between the two groups does not explain the improvement in wound healing that was observed in the standard ONS group. Therefore, a solid conclusion may not be drawn from this study.

There are several limitations of this systematic review. Exclusive use of PubMed to achieve studies may have failed to include other relevant studies, resulting in a possible selection bias. Because most of the subjects in the examined studies were hospitalized, external validity is limited. Although a positive trend in wound healing with vitamin C administration was established, it should be mentioned that vitamin C was given at different dosages via diverse routes of administration. Because of this inconsistency, it is difficult to gauge the optimal method for vitamin C administration for ulcer healing. Additionally, the seven studies on pressure ulcers that were evaluated may not be enough to draw a conclusion about vitamin C and its effect on pressure ulceration.

CONCLUSION

With this review, we conclude that vitamin C administration is likely to enhance the healing of pressure, venous, diabetic (neuropathic), and necrotic ulcers. Vitamin C combination therapy should also be considered for patients with ulcers of the lower extremity. Possible future studies could investigate the effect of vitamin C independently with consistent dosage or explore the effects of different routes of administration of vitamin C administration.

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National Foot & Ankle Review

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Efficacy of Ultrasound as an Adjunct to Conventional Wound Care

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ABSTRACT

The management and care of chronic wounds can be both difficult and time consuming. The standard of care is to debride a wound of devitalized tissue and to perform regular dressing changes to promote healing. Several adjunctive modalities may also be incorporated into wound care, including non-contact ultrasound, a treatment modality that has not been well documented. This paper reviews the current literature to determine if ultrasound is beneficial in the treatment of chronic wounds when used as an adjunct therapy versus standard of care alone. The reported benefits of ultrasound therapy include reduced wound healing time, better patient tolerance of treatment, and a reduction in wound bioburden.

For this literature review, an analysis was conducted on studies that were previously published and reported. Search parameters for this study were "ultrasound" AND "high frequency" AND "low frequency" AND "venous ulcer." The search criteria for included studies were those published in peer reviewed journals, including randomized controlled trials (RCT) and case studies. The working hypothesis for this review was a significant improvement in wound healing would occur when using ultrasound as an adjunct therapy.

INTRODUCTION

Chronic lower extremity ulcers are those that do not progress through normal, orderly, and timely healing, and instead enter a chronic delayed healing stage. The prevalence of chronic ulcers in the United States is approximately 2.4 to 4.5 million people.[1] Ulceration may be classified by etiology and include pressure, arterial, venous stasis, and neuropathic. The standard wound treatment is debridement and dressing changes. To aid in wound healing, low-frequency ultrasound has been investigated for contact and non-contact debridement. This treatment helps debride the wound by loosening necrotic tissue, stimulating cellular repair signals, and promoting granulation tissue deposition. To properly use ultrasound, a 0.5 to 2.0 cm distance between the leading edge of the applicator and the wound should be incorporated to maximize the therapeutic effect.[2] According to clinical guidelines, debridement of necrotic tissue is important because necrotic tissue slows the healing process. To determine if low-frequency ultrasound is beneficial, a review and analysis of low-frequency ultrasound (contact and non-contact; high-intensity and low-intensity) was conducted. Multiple systematic reviews have investigated wound debridement techniques, the results of which are reported in this paper.[3] The effectiveness of low and high-frequency ultrasound as an additional treatment for chronic wounds is assessed in this literature review.

METHODS

Criteria for study inclusion

Studies selected for this review were published in peer-reviewed journals or articles. The studies involved patients with chronic ulceration of the lower limb, including but not limited to four ulceration etiologies: venous stasis, neuropathy, pressure, and ischemia. Studies must have incorporated high-frequency or low-frequency ultrasound in the treatment group to be included in this review. A total of eight studies which included RCTs and case studies were selected.

Search methods

The studies in this review were selected from four databases: PubMed, CINAHL Plus, Cochrane Library, and AccessMedicine. Search criteria included: (((therapeutic ultrasound) AND (low frequency)) AND (high frequency)) AND (lower limb)) AND (ulcer)).

Exclusion criteria

A total of fifteen studies were considered, and eight were selected. Studies were excluded if they did not report outcomes of treatment modalities. This review was also limited to reviews published or translated into English but not limited by country of

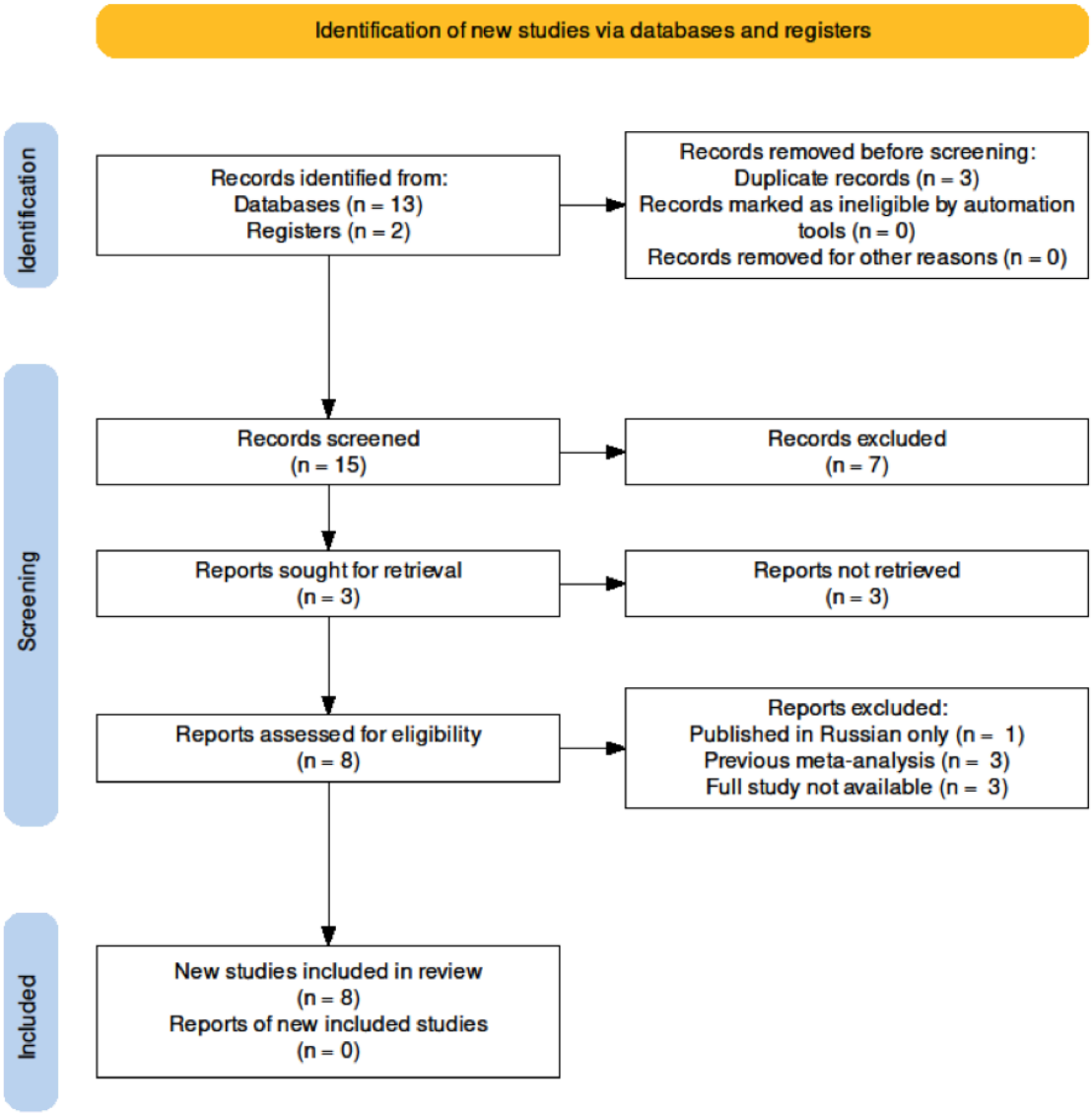
origin. Three of the studies were excluded from the data collection portion of our study as they were meta-analyses. Three studies were excluded due to unavailability.

Data interpretation

Differences were identified in the criteria used to determine the efficacy of ultrasound therapy. Some studies measured wound closure by physically measuring the wound bed, others used computerized photographic imaging analysis, and others assessed whether a wound fully healed by visual identification of a wound bed. The data were categorized into faster wound healing, complete versus incomplete wound healing, wound assessment via revised photographic wound assessment tool (revPWAT), and wound reduction per time. For ultrasound therapy to be considered successful, these measures had to show a significant difference in the metrics favoring the use of ultrasound.

RESULTS

A total of 274 patients were enrolled in the eight randomized controlled trials selected for this review. A presumed 311 wounds were studied; however, this number cannot be verified as some studies only reported patients treated and not wounds treated. One wound per patient was presumed unless otherwise stated. In a study by Ashu Rastogi, MD et al., a greater than 50% reduction in wound area was observed in 97.1% and 73.1% of subjects (P = .042) in ultrasound and sham groups, respectively.[4] In that same study, they also found a significant difference in complete wound closure in eight participants (23.5%) in the ultrasound group and three participants (11.5%) in the sham group (P =.033).[4] Christine Anne Murphy et al., found a statistically significant improvement in wound appearance for the low-frequency contact ultrasound



debridement (LFCUD) group assessed against usual care ($P < 0.01$).[5] They also found a greater reduction in wound surface area (WSA) after four weeks of treatment, but it was not statistically significant ($P = 0.48$). Wounds measured at the 12-week follow-up were smaller in the LFCUD group, but the difference was again not significant ($P = 0.16$). They also found that of the 47 patients who returned for the 12-week follow-up, there were significantly more healed wounds in the treatment group (33.3%) than the control group (8.3%), ($P = 0.03$).[5] A retrospective study by Charles A Messa et al. found that after ultrasonic debridement, 60% (n=49) of wounds improved, and 40% were non-improved (n=33).[6] In a Steven J. Kavros, DPM, et al. study, patients who were treated with a low-frequency (40 kHz) ultrasound energy via an atomized saline mist, achieved greater than 50% wound reduction at 12 weeks, compared to those treated with the standard of care alone ($P < .001$).[7] William J. Ennis, DO, et al., achieved a statistically significantly greater degree of reduction in wounds treated by atomized saline mist therapy alone than wounds treated with this therapy assisted by a secondary procedure ($P = .04$). That same study also found wounds achieving closure by atomized saline mist therapy alone were healed in an average of eight weeks compared with 18.71 weeks (Kaplan-Meier method) for those patients healed with this therapy followed by an additional modality ($P = .0005$).[8]

Based on the compiled data found among the eight studies that met our research criteria, ultrasound modalities, when provided as an adjunct therapy for wound healing, showed higher healing rates than the standard of care alone. The P-values that correlated with reduced wound volume in the ultrasound group were significant when compared with groups that used standard of care alone.

DISCUSSION

Based on the eight reviewed studies, ultrasound can help heal a chronic wound. A limitation of this review are the non-standard methods of measuring wound healing in the eight studies. Additional investigations with standard parameters would help compare conventional wound care to wound care that includes ultrasound therapy.

CONCLUSION

Low frequency ultrasound therapy may be an effective adjunct to conventional wound care. This is supported by data showing significant improvement in wound size, healing time, appearance, and cost compared to conventional treatment alone.

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The Use of Targeted Muscle Reinnervation in Lower Extremity Amputation

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ABSTRACT

A below-the-knee, transtibial amputation (BKA) is a major lower extremity amputation that results in the removal of the distal lower limb. A common side effect of BKA is phantom pain. To help prevent phantom pain, BKA's may be performed with targeted muscle reinnervation. Targeted muscle reinnervation is performed by taking a severed or affected nerve and coaptating it to a neighboring muscle. This literature review explains the background, methodology, and clinical outcomes of using targeted muscle reinnervation in a lower extremity amputation. This literature review was conducted between October and November 2022. Articles pertaining to BKA survivability, BKA outcomes, BKA with targeted muscle reinnervation methodology, BKA with targeted muscle reinnervation indications, and targeted muscle reinnervation pain outcomes were included. The introduction of targeted muscle reinnervation done concurrently with a BKA is a reliable surgical technique that may improve patient post-amputation quality of life.

INTRODUCTION

A below-the-knee amputation (BKA) is a major amputation of the lower limb which is non-viable from conditions including ischemia, infection, trauma, or malignancy.[1] BKAs are performed by transecting the tibia and removing all structures distal to the cut.[1] Complications of BKA include the need for surgical revision, increased mortality within five years of the amputation, phantom pain, and hospital readmission.[2] Wong et al. found that approximately 38% of patients who underwent a BKA needed a surgical revision within one year.[3] Within five years, patients that underwent major and minor amputations required contralateral major amputations 11.5% and 8.4% of the time, respectively. [4]

Phantom limb pain (PLP), also known as phantom pain, occurs when the patient perceives pain and discomfort at the previous location of the limb.[5] Patients describe PLP as a sharp, pins-and-needle pain. Currently, the standard of care for phantom limb pain is the use of analgesics such as NSAIDs or anticonvulsant drugs such as Gabapentin.[5] Current literature suggests that 60-80% of amputees live with phantom limb pain.[6] The introduction of targeted muscle reinnervation during the 21st century may prevent phantom limb pain. This paper analyzes and review targeted muscle reinnervation.

METHOD

A bibliographic study was conducted September 2022 through October 2022, with an additional search occurring prior to November 5, 2022. PubMed was used as a database, and the following terms were searched "below-the-knee amputations," "phantom pains," "targeted muscle reinnervation," "below-the-knee amputation with targeted muscle reinnervation," "targeted muscle reinnervation outcomes," "targeted muscle reinnervation amputation," and "below the knee amputation complications." The inclusion criteria for the study articles had to be a literature review, a systematic review, a meta-analysis, a randomized control trial, a retrospective study, or a prospective study originally written in English. In addition, articles were excluded if they were published prior to 2010, if no disclosures were mentioned, and if the article was not published in a peer-reviewed journal.

DISCUSSION

Targeted Muscle Reinnervation

Targeted Muscle Reinnervation Overview

Elsberg et al. in 1917 are credited for the first documented targeted muscle reinnervation (TMR).[7] The concept of target reinnervation, the transfer of a nerve from a severed limb to a target muscle, was developed by the Elsberg team who transferred a severed nerve to a new muscle.[7] The goals of TMR differ between the upper and lower limbs. In the upper limb, TMR is indicated for the prevention of neuromas and for patients unable to function with a standard prosthetic.[8–9] In the lower extremity, TMR is used to prevent neuroma and phantom limb pain.[8–10]

Table 1. Summary of the findings of Peters et al. and Francol et al. [10–12]

Nerve affected	Motor nerve branches/muscles being reinnervated
Posterior Tibial Nerve	Medial gastrocnemius, lateral gastrocnemius, tibialis posterior, lateral soleus, or medial soleus
Deep Fibular Nerve/ Deep Peroneal Nerve	Tibialis anterior, peroneus brevis, medial soleus, peroneus longus
Superficial Peroneal Nerve/ Superficial Fibular Nerve	Peroneus longus or peroneus brevis
Saphenous Nerve	Medial gastrocnemius, vastus medialis, or medial soleus
Sural Nerve	Soleus or Tibialis Posterior
Common Peroneal Nerve	Biceps Femoris
Tibial Nerve	Semimembranosus
Posterior Femoral Cutaneous Nerve	Tibial Nerve

Targeted Muscle Reinnervation in the Lower Limb

Surgical methods for TMR vary based on the surgeon performing the surgery. A TMR is performed by excising the affected nerve from the healthy nerve fascicle.[10] Next, the nerve is reattached to a surgically divided nearby motor nerve.[10] The nerves are then sutured together using 8-0 epineural sutures.[11] Should there be a size discrepancy with the nerves, the muscle surrounding the motor nerve recipient will be dissected.[10] The muscle will then act like a cuff and surround the coaptation.[10] In 2018, Francol et al.provided an anatomical road map to guide targeted muscle reinnervation of the lower extremity.[12] Within the anterior compartment of the leg, the tibialis anterior and extensor digitorum longus were defined as targets for reinnervation.[10] Within the lateral compartment of the leg, the peroneus longus was designated as the optimal muscle to be targeted.[12] If the saphenous nerve is affected, the medial gastrocnemius, medial soleus, and/or the vastus medialis all serve as viable targets for reinnervation.[12] When the sural nerve is affected, the tibialis posterior or soleus muscles are considered adequate targets for reinnervation. Table 1 summarizes the targets of all the major nerves within the lower extremity.

From the bibliographic study, the research group identified seven quantitative articles discussing targeted muscle reinnervation within the lower limb. Table 2 summarizes the findings of each article. While each study used a different approach to TMR, there was a consensus, that TMR improves pain following amputation. Patients treated with TMR overall had decreased phantom limb pain, decreased residual limb pain, and decreased neuroma formation. Because pain is a subjective, researchers used a pain , including the Patient-Reported Outcomes Measurement Information System (PROMIS), a scale used to evaluate different levels of health against the population norm in clinical research. Additionally, to assess functional outcome, researchers used the Orthotics and Prosthetics Users' Survey and Rasch analysis (OPUS Rasch), an instrument that measures patient functionality after surgery and with prosthetics.

CONCLUSION

This review supports TMR as a method to prevent neuroma and to reduce phantom limb pain following major amputation. Currently, most TMR studies focus on the upper extremity. Podiatry would benefit from additional studies focused on TMR of the foot (i.e., in intermetatarsal neuroma excision). There also is a need for a longer follow-up on post-operative TMR patients.

Table 2 Targeted Muscle Reinnervation Clinical Studies:

Study	Author	Key Findings	Participants
Targeted muscle reinnervation and prosthetic rehabilitation after limb loss[13]	Mioton & Dumanian (2018)	TMR has improved functional outcomes in patients with upper extremity prostheses as measured by a box and blocks test. Functional outcomes improved by an average of 323% and patients showed enhanced prosthesis control. Therefore, TMR has been used for pain instead of increased prosthetic control in the lower extremity. The lower extremity follow-up after 18 months post-TMR showed improvement in residual and phantom limb pain. Patients that reported no phantom pain grew from 17.6% to 47.1%; however, mild residual limb pain increased from 5.9% to 58.9%.	Started with 43 patients; however, 10 did not follow up, so only had 33 patients for analysis
Targeted Muscle Reinnervation at the Time of Major Limb Amputation in Traumatic Amputees: Early Experience of an Effective Treatment Strategy to Improve Pain[14]	Frantz et al. (2020)	PLP and residual limb pain (RLP) decreased over time, with pain scores reported at lower values during the 2-year follow-up. Also, 92% of the patients reported no pain between PLP episodes.	25
Targeted Muscle Reinnervation Improves Residual Limb Pain, Phantom Limb Pain, and Limb Function: A Prospective Study of 33 Major Limb Amputees[10]	Mioton et al. (2020)	Amputees treated with TMR were followed up with a one-year post-operation to revisit pain scores. The average NRS scores for residual and phantom limb pain were reduced from 6.4 to 3.6 and 6.0 to 3.6, respectively. PROMIS scores showed decreased pain intensity, behavior, and interference for residual and phantom pain. Additionally, removing the neuroma during the procedure did not influence the pain scores. With a decrease in reported pain levels, OPUS Rasch scores showed improved functionality after targeted muscle innervation in the upper and lower extremities.	33
Targeted muscle reinnervation for the management of pain in the setting of major limb amputation[8]	Peters et al. (2020)	Patients reported that their PLP declined significantly post-operatively. 72% of the patients observed PLP in the first month, 19% at three months, and 13% at six months. Overall, the rates of neuroma pain and PLP improved over time.	22 BKA (18 primary and 4 secondary)
Preemptive Treatment of Phantom and Residual Limb Pain with Targeted Muscle Reinnervation at the Time of Major Limb Amputation[15]	Valerio et al. (2019)	Patients in the TMR group saw decreased median PROMIS scores. The TMR group for PLP pain intensity was a median of 36.3 compared to the control, and TMR PLP pain behavior was 50.1 compared to 56.5 of the control. The residual limb pain intensity was 30.7 for the TMR group versus the control's 46.8, and the residual pain behavior was 36.7 for the TMR group versus 57.3 for the control group. Lastly, pain interference was a median of 40.7 TMR versus 57.3 for the control.	51

Targeted Muscle Reinnervation Treats Neuroma and Phantom Pain in Major Limb Amputees A Randomized Clinical Trial[16]	Dumanian et al. (2019)	At one year post-surgery, patients who underwent TMR surgery reported reduced PLP– 72% of TMR patients reported either no PLP or mild PLP. Compared with the standard, non-TMR procedure, 40% of the patient population claimed to have PLP pain post-surgery.	28

Acknowledgments
All authors on this paper contributed equally.

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Maffucci Syndrome: A Literature Review

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ABSTRACT

Maffucci syndrome (MS), first described in 1881, is a rare non-hereditary congenital condition characterized by multiple enchondromas, chondrosarcomas, and spindle-cell hemangiomas. This literature review focuses on the history, histological, radiological, and clinical findings, diagnosis, and other pathological associations of MS. PubMed was used to search for relevant research articles regarding MS and its association. MS is clinically diagnosed through histology, radiology, and clinical presentation. It has been reported that mutations in somatic heterozygous IDH1 (R132C and R132H) or IDH2 (R172S) are found in 87% of enchondromas and 70% of spindle cell hemangiomas; however, the underlying mechanism of MS remains unclear due to the rarity of the disease. Previous studies demonstrate an increased incidence of fractures, limb length discrepancies, and malignancies in MS patients. Currently, there is no cure, but the treatment of MS includes surgery, although it depends on the severity and extent of the symptoms. Further research is needed to examine the genetic cause, manifestations, and management of MS.

INTRODUCTION

Angelo Maffucci first described Maffucci syndrome (MS) in 1881.[1] Since then, there have been about 200 cases of MS identified, many with associations to other pathologies. MS is described as a rare, congenital, non-hereditary disorder subtype of multiple enchondromas, chondrosarcomas, and hemangiomas with no sexual or racial predilections.[2] MS may often be confused with Ollier disease, a non-hereditary skeletal disorder; however, Ollier disease is only characterized by multiple enchondromas.[3] Enchondromas are benign and asymptomatic intramedullary cartilaginous tumors commonly present near the growth plate of small, long, and flat bones, which result from abnormal growth regulation and terminal differentiation of chondrocytes.[1,4] Hemangiomas are benign, asymptomatic vascular tumors. A specific type of hemangioma called spindle cell hemangioma (SCH) is commonly seen in MS and often described as painful and aggressive, leading to functional impairment.[5] A few complications associated with MS include fractures, limb length discrepancies, and vascular and skeletal malignancies; however, malignant transformation of enchondromas and hemangiomas is a prevalent complication seen in MS patients throughout their lifetime.[1]

Because MS is rare, the underlying mechanism is not well understood and effective treatment is unproven. But in 2011, Pansuriya et al. discovered the heterozygous somatic mutations in the gene encoding isocitrate dehydrogenase 1 and 2 (IDH1/IDH2) in enchondromas and spindle cell hemangiomas. The IDH1 R132C gene has been associated with bone tumors and several other tumors.[6] They reported that 77% of MS patients had IDH1(98%) and IDH2 (2%) mutations; however, the comprehensive genomic sequence remains incomplete.

METHODS

The PubMed database was searched with keywords "Maffucci Syndrome," "enchondromas," "spindle-cell hemangiomas," and "somatic IDH1/IDH2 mutations." Sources ranged from 1945 to 2022, with original research from 1881. The search was performed in October 2022. The inclusion criteria for this review is original research studies, case studies, literature reviews, or systematic/meta-analyses. Low-tier duplicative studies and case reports with limited references were excluded.

CLINICAL PICTURE

Histopathology

The affected tissue may be gray in color during histological observation of the nodules. Cutaneous or subcutaneous venous lesions may be present.[7] There may be enlarged vascular spaces representing hemangiomas.[8] The osseous tissue has a mineralized matrix, and the nodules of irregular overgrowth of cartilage suggest enchondromas.[8]

Radiology

Conventional radiographs show multiple bony radiolucencies with endosteal scalloping, bone malalignment and an increase in soft tissue volume and density.[6,8,9,10] Spindle cell hemangiomas appear as distinct round calcific phleboliths.[7,10,11]

Clinical Presentation

Maffucci syndrome is asymmetrically distributed and can be found in different sizes, numbers, locations, and ages. Most studies report that masses of

enchondromas are primarily seen in the metaphysis or epiphysis of long bones including the phalanges.[7,9] The hard painless masses gradually enlarge and several cystic, soft, and compressible reddish-blue subcutaneous nodules are presented with vascular lesions.[8,9,11] Patients report pain if they have chondrosarcoma, but pain alone does not imply the existence of chondrosarcoma.[12]

DIAGNOSIS

The diagnosis of Maffucci Syndrome is based on clinical, radiological, and histological evaluation. In some patients, the diagnosis could be mislabeled as Ollier disease because it has characteristics similar to MS. It may also be mistaken as Kast syndrome, a rare skeletal disorder with multiple enchondromas and vascular tumors.[13] The IDH1 p.R132C gene present in patients within enchondromatosis and hemangiomas may be useful for diagnostic confirmation of MS.[4]

POSSIBLE PATHOLOGIES ASSOCIATED WITH MAFFUCCI SYNDROME

Fibroadenomas

There have been a few case reports of breast fibroadenomas with limited evidence associated with MS. Fibroadenomas are solid benign tumors commonly found in women under 30 years of age. The case reports are of female patients with multicentric breast fibroadenomas with a history of enchondromas. Even though the typical genetic variants of MS, IDH1/IDH2, were not found in fibroadenomas in these patients, Canepa et al. and Mazingi et al. suspect these patients could have under-diagnosed MS since the patients had a history of enchondromas.

Endocrine pathologies

Previous studies have found abnormal growth of adrenal masses leading to autonomous secretion of cortisol, causing Cushing syndrome in some patients with MS.[16] They speculate that IDH1 R132C gene mutation could be implicated in patients with Cushing syndrome because this gene is physically close to the other genes involved in endocrine pathways.

Intrahepatic Cholangiocarcinoma

Although there have only been two cases of intrahepatic cholangiocarcinoma coexisting with Maffucci syndrome, it has also been revealed that IDH1 R132C mutation is also seen in intrahepatic cholangiocarcinoma in the tumor tissues, but not in the normal tissues.[6,17]

Intracranial Chondrosarcoma

Tibbs et al. described the case of intracranial chondrosarcoma being linked with MS because the histopathological tests revealed enchondromas with hemangiomas. The skull can be affected in patients with Maffucci syndrome, especially the sphenoid bone. Enchondroma leading to chondrosarcoma is seen; however, the brain remains unaffected.[2]

Other rare malignancies include mesenchymal ovarian tumors, gliomas and astrocytoma, acute myeloid leukemia, adrenal hyperplasia, and different types of sarcomas due to the IDH1 R132C gene mutation being near the associated genes of these conditions.[1,16]

TREATMENT AND MANAGEMENT

The main concern for patients with MS is the malignant transformation, not only to the skeletal system, but also to the pancreas, liver, ovaries, and brain.[1,9,17] In other studies, researchers reported no treatment for hemangiomas except for surgical intervention, but Lekwuttikarn et al. reported successful management of spindle cell hemangiomas using the mTOR inhibitor, sirolimus, in combination with surgery. Following two months of treatment at a therapeutic level of sirolimus, a patient observed her vascular tumors shrinking and softening. Post sirolimus treatment, she underwent surgery for tumor excision. She then continued sirolimus treatment for over a year at a maintenance dosage and reported no tumor recurrence or other side effects.[5]

MS patients can experience malignant transformation at a rate of 52-57% and chondrosarcomas account for 30% of these malignant transformations.[10] Thus, these patients require close monitoring for malignant degeneration.

CONCLUSION

Maffucci syndrome is a rare disease characterized by enchondromas and vascular lesions without racial or sexual predilections. Although surgery is a treatment option, tumor recurrence with malignant transformation remains a significant concern. Recent identification of the genes IDH1 and IDH2, seen in enchondromas and spindle cell hemangiomas has helped provide more details about this rare disease; however, future genome-wide association studies and clinical trials are needed to better understand the specific etiologies, associations with other pathologies, and treatment for Maffucci Syndrome.

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The Approach to the Pigmented Foot Lesion: A Case Report and Literature Review on Malignant Melanoma

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ABSTRACT

The incidence of cutaneous melanoma in the US has steadily increased, especially in the lower extremity, despite increased awareness and improved diagnostic instrumentation. Foot melanoma (FM), a subset of cutaneous malignant melanoma, has a poorer prognosis than melanoma diagnosed elsewhere in the lower extremity. Early diagnosis can be difficult because FM may be painless, mimic other ulcerative lesions, and may be hidden.

This report describes a 49-year-old female with no personal or family history of melanoma who presented with a large painful mass on the left plantar heel. Initial biopsy revealed malignant melanoma. Subsequent wide excision with sentinel lymph node testing was performed. Advanced stage melanoma diagnosis was made (pT4b, N1aMx) with Breslow thickness of 20.0mm with ulceration, mitotic rate 4mm^2, and left groin positive for metastatic disease. Special pathologic staining was positive for BRAF V600E mutation, and the patient was started on adjuvant Nivolumab.

FM can mimic several ulcerative conditions making early diagnosis and treatment difficult. A high index of suspicion is valuable when lesions are identified, and the threshold to biopsy should be lower when treating pigmented or non-healing lesions of the lower extremity.

INTRODUCTION

Skin cancer is a common malignancy, and according to the CDC, is the most common cancer in the United States.[1] The incidence of cutaneous melanomas diagnosed in the US has steadily increased over the past twenty years.[2] Despite advances in technology that aid in identification and increased awareness amongst patients and health care providers, one in five Americans will receive the diagnosis of a cutaneous malignancy in their lifetime.[1] Skin cancer can be thought of in several ways, and it is frequently categorized as non-melanoma or melanoma This case report focuses on malignant melanoma and explores the correlation between the BRAF V600E mutation and survival. Although malignant melanoma is not the most common of skin cancer, it is the most aggressive with high mortality as it quickly spreads and metastasizes. Thus, it is essential to recognize melanoma risk factors. Melanoma is seen more often in a patient with dysplastic or atypical nevi. It tends to present in patients of more fair complexions, such as the Caucasian populations.[3] There may be a correlation between increased exposure to UV light and the development of melanoma in sun-exposed regions of the body. However, the relationship between UV light and the plantar surface of the foot is still under investigation. Despite improved measures for prevention, the incidence of malignant melanoma of the skin has increased, with a 1.2% rise yearly.[2] Even though the incidence has increased, the mortality from this disease has diminished from improved public awareness, early diagnosis, and better therapeutics.

Foot melanoma (FM), a subset of cutaneous malignant melanoma, has a 5-year survival rate reported to be as low as 52% for patients with melanoma of the foot and ankle compared to 84% for patients with melanoma elsewhere on the lower extremity.[4] While the location of the primary lesion on the foot indicates poor prognosis, early diagnosis and improved therapeutic interventions can improve patient survival. Diagnosis starts with a careful visual inspection, followed by a biopsy and the histopathological examination. The visual inspection starts with the ABCDEs with features of asymmetry, an irregular border, variegated pigmentation, and a diameter greater than a pencil eraser (> 6mm).[3] Also, any recent change, such as growth, erosion, or pain, could indicate a more aggressive lesion. FM diagnosis can be challenging. FM is often painless, it may mimic other pigmented lesions and can be hidden. Pigmented lesions in the lower extremity do not always present as expected. Thus, a new criteria, the CUBED can help identify suspicious lesions more reliably. When broken down the CUBED protocol serves as an

acronym for identifying suspicious lesions as the protocol stands for colored, uncertain, bleeding, enlarged, and delay in healing. The CUBED protocol identifies lesions that possess different pigmentation than the surrounding skin and lesions with persistent bleeding or granular beds that resist healing or contraction in wound size.[3] This examination tool also helps to identify persistent lesions with delayed healing beyond two months, or continue to cause ulceration without any healing progression.[3] Here, we present the case of a patient who noticed a growth on the plantar surface of the left foot, which increased in size and spread to sentinel-draining lymph nodes.

CASE PRESENTATION

A 49-year-old female presented to the podiatry clinic with a lesion on the plantar surface near the heel of her left foot that she had noticed getting larger over the last five years. The patient has no personal or family history of melanoma. The patient had no interactions with any healthcare providers over the last five years and had no prior investigation of the lesion. Upon presentation, the lesion had started to cause pain and rapidly increased in size. An immediate biopsy was recommended; however, the patient deferred the biopsy for an additional two months. At the time of the biopsy, the lesion measured 2.4 x 2.5 x 1.8 cm. Two punch biopsies were performed, one proximal and the other distal. Histopathology diagnosed malignant melanoma with invasion involving the complete thickness of the biopsies. In addition to the histopathology analysis, special staining was done and showed the malignant melanoma tumor was positive for BRAF V600e, HMB-45, and negative for P16. The patient was referred to oncology, and the tumor was staged pT4b, N-aMX prior to surgery. The patient underwent comprehensive left superficial and deep inguinal femoral lymphadenectomy, which showed metastatic melanoma involving 1 of 3 lymph glands. The patient began Nivolumab and Ipilimumab. Unfortunately, the side effects became intolerable, and the patient paused active medical therapy.

DISCUSSION

Malignant melanoma of the foot can lead to significant mortality if not diagnosed early. In the case of this 49-year-old patient, the condition was diagnosed at an advanced stage. This is not unusual as the average time to diagnose has been reported to be 17 months with a median Breslow thickness of 1.75 mm.[5] With late diagnoses, the chance of metastasis is high, and the need for aggressive cancer treatment is often warranted.

BRAF V600e status is an important target for the treatment of melanoma. The mitogen-activated protein kinase signaling pathway is constitutively activated by the BRAF V600e tumor mutation which increases mitotic activity. It has been reported that approximately 50% of melanomas have BRAF mutations, and targeting these mutations with different pharmaceutical treatments increases the prognosis of patients with melanoma.[6] Vemurafenib and Nivolumab have been effective treatment for malignant melanoma.[7] Vemurafenib specificity targets the BRAFV600 mutation while Nivolumab has similar efficacy in patients with both the wild-type or mutant BRAF V600e.[7] BRAF V600e mutation promotes carcinogenic properties of the tumor, increases the immune modulating capacity of the tumor microenvironment, and predicts the effectiveness of the anti-PDL antibody Nivolumab.[8,9] While both agents are indicated for the treatment of some patients with FM, Nivolumab has significantly improved clinical outcomes, especially in combination with Ipilimumab.[10]

As with most malignant conditions, early detection and treatment are important. Several studies have shown that the location of melanoma has significant prognostic value, especially when the lesion is present in the lower extremity. Melanoma within the lower extremity is an independent risk factor for recurrence. [11] The reason FM has a worse outcome than other lower extremity lesions has not been clearly explained by anatomic, physiologic, or environmental studies. [12,13] Patients with a longer duration of active disease and a delay in diagnosis have been associated with melanomas located in the acral region.[12] Hsuech EC et al. primary melanoma of the thigh and calf with melanoma in the foot. Ten year survival rates were 71% in subjects with primary melanoma of the foot compared to 92% for those with calf melanomas and 95% for those with thigh melanomas.[13] Hseuch et al. also showed that foot melanoma has higher mortality and the highest risk of recurrence. These findings demonstrate how location within the lower extremity can alter the prognosis and outcome. A possible physiologic explanation has been suggested for the poor prognosis of pedal melanoma. Weight-bearing areas may have significant lymphatic drainage from the constant compression of the soft tissue. The pressure applied by an axial load, including body weight and gravity, facilitates increased lymphatic drainage.[14] If a melanoma is present, the high lymph flow related to pressure and ambulation may enhance the spread. [14]

The literature has shown that melanomas of the lower extremity often behave more aggressively and have higher mortality. [13,14] Our case highlights the implications of a late diagnosis. The patient, in this case, had no established dermatological, podiatric, or other medical care over several years. Thus, when she presented to the clinic after five years with the lesion,

it was large and had more invasive qualities. Additionally, the patient delayed the biopsy for two months after her initial medical encounter, which may have made the melanoma even more invasive and metastatic. The patient has since decided she doesn't want to continue with the current treatment course of Nivolumab and Ipilimumab, as the side effects have become intolerable. This case study highlights the need for prompt diagnosis and treatment of foot melanoma and the impact on prognosis when these lesions are untreated.

CONCLUSION

Melanoma can mimic several ulcerative conditions of the foot and ankle making early diagnosis and treatment difficult. A higher index of suspicion and a lower threshold for biopsy is necessary for pigmented lesions encountered in the lower extremity.

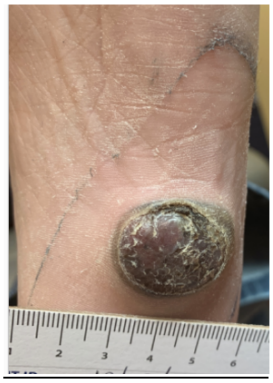

IMAGE 1. Pigmented Exophytic Nodule On The Sole of The Left Foot

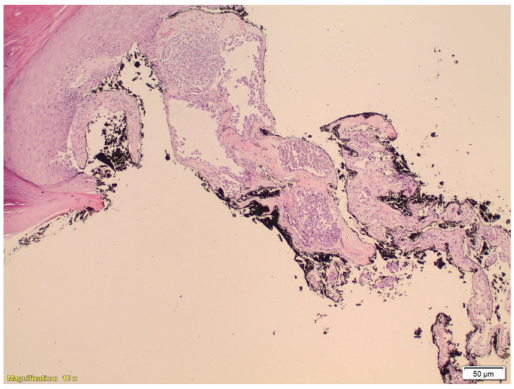

IMAGE 2. PHOTOMICROGRAPH 4X H&E STAIN

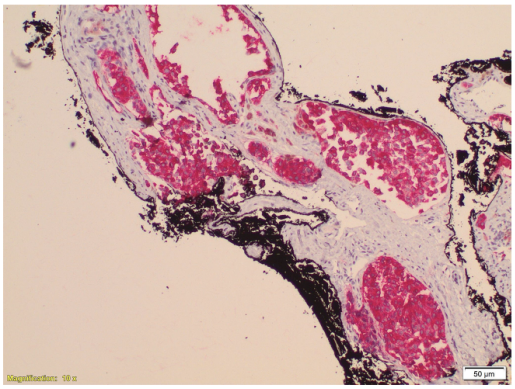

IMAGE 3. PHOTO 10X PAN MELANOMA HMB-45 STAIN

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KENT STATE UNIVERSITY
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Complication Rate Following in-Office Hardware Removal

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ABSTRACT:

Background: This study presents data about postoperative infection following hardware removal (HWR) procedures performed in a podiatric private practice office setting.

Methods: We conducted a retrospective review using Athenahealth of nine procedures of patients who had undergone elective hardware removal procedures done in private practice in Parma, Ohio from November 2nd, 2021 to July 26th, 2022. Patients were excluded if they had a previous or concurrent infection in the operative foot or if the hardware was exposed. Hardware removal involving only plates and/or screws was included in this study. Three patients were excluded due to having concurrent osteomyelitis.

Results: None of the nine patients in this study developed a surgical site infection between time of procedure and final follow-up.

Conclusion: Performing certain HWR surgical procedures in an office setting is an effective and safe means to treat patients with comparable infection rates when performed in an operating theater.

INTRODUCTION

Hardware removal (HWR) is a common procedure. Due to minimal subcutaneous tissue on the dorsum of the foot, internal fixation can become prominent and cause pain. Following a first tarsometatarsal arthrodesis for bunion correction, Peterson et al. found that 15.2% of all patients required HWR at a mean follow-up time of 65.9 weeks.[1] Fenelon et al. found that 12.5% of patients who underwent ankle ORIF following unstable ankle fractures required HWR. Sanderson et al. found that 14.6% of ankle fracture HWRs were complicated by infection. While infection is a top concern for both patients and surgeons, there is mounting evidence that shows there is no meaningful difference in infection rates in ambulatory settings compared to an operating room (OR) for hand surgery.[2] LeBlanc et al. reported a 0.4% superficial infection rate in a prospective study of more than 1500 carpal tunnel releases performed in a procedure room using sterile gloves and mask without a sterile gown.[3] This was in line with the infection rate of .47% of the same procedure using the main operating room sterility technique.[4]

The rate of surgical site infections (SSI) in foot and ankle elective surgeries is higher than in other elective orthopedic subspecialties.[5,6] During an elective foot and ankle surgery performed in a hospital or ambulatory surgery center, it has been shown that patients without comorbidities reported having surgical site infection incidence of up to 3.5%.[7] Meng, in 2020, evaluated over 1,200 elective foot and ankle cases and reported an overall incidence rate of soft tissue infections of 2.1% while stating that forefoot procedures have a higher predisposition to SSI than the rest of the foot.[8] Furthermore, these studies captured rates of surgical site infections where procedures were performed in a hospital or ambulatory surgery center and collectively revealed rates from 1.0-4.8%.[8]

While normally performed in the operating room under anesthesia, several techniques have been described to allow procedures under local anesthesia. Wide Awake Local Anesthesia No Tourniquet (WALANT) has been consistently used in elective and trauma upper extremity surgery with excellent results.[1] WALANT technique has been proven to be useful to patients and surgeons while having high patient satisfaction, decreased healthcare cost, and avoidance of preoperative clearance/fasting/cessation of medications/risks of monitored anesthesia care (MAC). This is particularly useful in patients with multiple comorbidities. Procedures done in the office setting under WALANT also minimize the need for OR and postoperative anesthesia care personnel. This became particularly important during the COVID-19 pandemic when many operating rooms and ambulatory surgical centers followed recommendations to postpone non-essential and elective surgeries.[10]

The current literature on WALANT in the lower extremities is limited and there are currently no reports on HWR using WALANT in an office setting. The purpose of this article is to present one physician's experience with nine HWRs in an office setting as a viable alternative to HWR in an operating room.

METHODS:

Data were collected on nine patients who, between February 2021 and June 2022, had hardware removed following the union of a fracture or arthrodesis site in

the foot by a single podiatric practitioner. The average age of patients when the implants were removed was 56.7 years.

Operative Technique

All procedures were done in a clinic room in a private practice setting. Patients were positioned supine in the clinic chair with the backrest lowered. Preoperative local anesthesia was performed using an equal combination of 2% Lidocaine plain with 0.5% Bupivacaine plain. At the surgeon's discretion,1% Lidocaine with epinephrine (1:100,000) was used along the planned incision line for hemostasis. Adequate anesthesia was verified before starting the procedure. Patients were not treated with preoperative antibiotics. The lower extremity was prepped with betadine solution unless an allergy prohibited the use, in which case chlorhexidine was used. Sterile draping, gloves, and instruments/materials were used. Incisions were dressed with betadine-soaked gauze, followed by the appropriate dressing for the surgery. The patient was instructed not to remove the dressing until seen for a first postoperative visit. All patients had a final follow-up visit four weeks following the procedure, where they were evaluated for complications.

A retrospective chart review for each patient was performed on all postoperative visits within four weeks of the procedure. The following information was gathered on each patient: age, sex, HWR site, type of hardware removed, exposure of hardware, history of diabetes mellitus, peripheral vascular disease, tobacco use, presence of postoperative infection, and follow-up time in weeks. Patients were excluded if they had a concurrent infection in the operative foot or if the hardware was exposed. 12 of the nine patients met the inclusion criteria, while three patients were excluded for having exposed hardware and osteomyelitis at the time of in-office procedure. The presence of superficial surgical site infection was evaluated according to the CDC/NHSN Definition of Healthcare-associated infection.[11]

RESULTS

In this small series of in-office HWR, zero incidents of SSI occurred as shown in **Table 1** according to the CDC definition of SSI. Although minor erythema and edema were noted in two cases, these were resolved at the 4-week follow-up visits with an antibiotic prescription. While these patients received prophylactic antibiotics, their presentations did not

Table 1. Initial procedure performed, type of implant removed, signs of infection, antibiotic prescribed and risk factors predisposing to infection.

Index Procedure	Hardware Removed	Signs of Infection	Antibiotics given	Risk Factor for Infection
1st MPJ Arthrodesis	Screw	None	None	None
1st TMTJ Arthrodesis	Screw	None	None	Diabetes
Subtalar Joint Arthrodesis	Screw	None	None	None
Lisfranc ORIF	Screw	None	None	Tobacco Use
Calcaneal Osteotomy	Staple	None	None	None
Talonavicular Arthrodesis	Wire	None	None	None
2nd Digit Hammertoe	Digital Implant	Erythema	Doxycycline	Diabetes Mellitus/Tobacco Use
2nd Digit Hammertoe	Digital Implant	Edema/Erythema	Doxycycline	Peripheral Arterial Disease
5th metatarsal ORIF	Screw (4) and Plate	None	None	None

qualify as a SSI according to the CDC definition. Both patients requiring antibiotics occurred following the removal of a hammertoe implant device. Two of nine patients had diabetes mellitus (22.2%). Two of nine patients had a history of smoking (22.2%). One in nine patients had a history of peripheral arterial disease. Both patients who required antibiotics had risk factors for developing SSI as seen in **Table 1**. This study shows that multiple types of internal fixation such as screws, staples, wires, digital implants, and plates can be removed in the office setting with minimal postoperative complications.

DISCUSSION

HWR is a common and necessary procedure following many foot and ankle surgeries. Most commonly done in an operating room, our series of patients suggest that HWR can be performed safely and effectively in an office with the use of local anesthesia and provides similar postoperative outcomes. Procedures done in an office-based setting have several advantages: shortened perioperative period, avoidance of risks associated with inhaled anesthetics, and reduction in cost/waste and healthcare resources.

In-office HWR provides many benefits to patients and surgeons, this technique has several considerations and contraindications. It is important that surgeons provide an accurate description of the procedure and ensure patients have an adequate understanding of what they will experience. Patients may experience nervousness, distress, or tremors during the anesthetic injection and procedure; thus patient temperament should play a role in assessing eligibility.

Depth of hardware should also play a role in operative setting selection. Patients with prominent hardware that requires minimal dissection are most amenable to in-office removal. Removal of hardware that requires extensive dissection and use of fluoroscopy is most effectively accomplished in an operating room.

Lastly, infection is always a concern when performing surgery and is dependent on several factors including preoperative skin antisepsis, wound closure, dressing selection, duration of operation, and operative setting. The operating room has historically been recognized as the most sterile location for procedures, our series shows that HWR performed in the office produces similar post-operative infection results.

CONCLUSION

Performing certain HWR surgical procedures in an office setting is an effective and safe means to treat patients with comparable infection rates when performed in an operating theater. Limitations of this study include the retrospective nature of the investigation as well as a small study cohort. Further research should be expanded to focus on large, randomized prospective studies examining the infection rate between the OR and the clinic room.

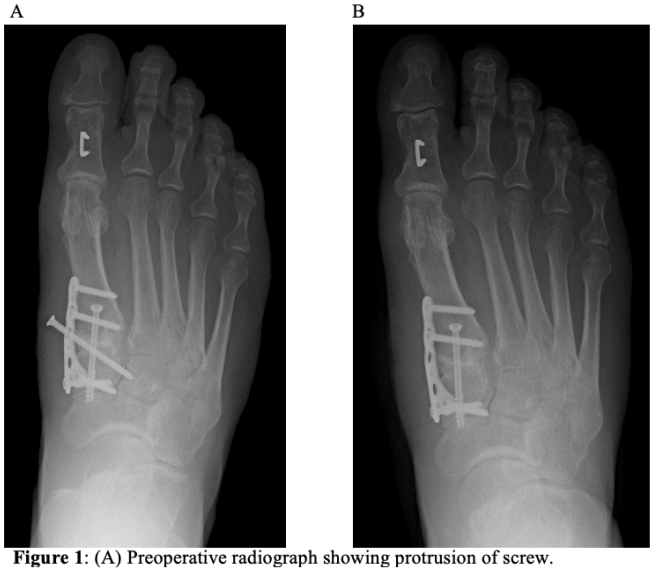

Figure 1: (A) Preoperative radiograph showing protrusion of screw. (B) Postoperative radiograph demonstrating removal of midfoot screw.

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Barry University
SCHOOL OF PODIATRIC MEDICINE

An Overview of Medical Malpractice in Podiatric Medicine

Azariya McClendon B.S, B. A, Zaria St. Lawrence B.S. , Jennifer Badette B.S., MHA

ABSTRACT: Medical malpractice arises when a physician's negligence results in injury to the patient. To determine negligence, one of four elements must be proven: duty owed to patient, breach of duty of care, breach of duty of care resulting in injury, or patient loss because of injury. The highest number of malpractice claims are from surgical error and most malpractice suits filed against podiatrists follow elective surgery. This article examines common causes of podiatric malpractice cases to help incoming practitioners improve. ProAssurance Insurance Company of America (PICA) was contacted in October 2022 about acquiring data concerning malpractice claims filed from 2017 to 2022. A 5-year period was chosen to review the most recent data surrounding podiatric malpractice litigation. A literature review was conducted. A broad search occurred using PubMed and Google Scholar. The terms searched for included, but were not limited to, "definition of medical malpractice", "foot infections", "bunionectomies", "ankle surgeries", "plantar fasciotomies", and "steroid injections in the foot and ankle". The articles were required to be an original research article, literature review, or meta-analysis, written in English. The authors independently reviewed each article for completeness and then cross-referenced the articles for conflicting information. All literature used was found to be congruent. Most malpractice claims were a result of alleged failure to provide sufficient care. Inadequacies of treatment include mismanagement of patient's complaints, inappropriate surgical procedures, and insufficient post-surgical care. Increased focus should be placed on pre- and post-operative care to help maximize patient outcomes.

INTRODUCTION

Legal action is brought against practicing physicians when there is a failure to provide satisfactory treatment. To determine negligence, one of four elements must be proven: duty owed to patient, breach of duty of care, breach of duty of care resulting in injury, or patient loss as a result of injury. [1] Duty requires that a physician-patient relationship be established prior to care and must remain throughout the duration of treatment. It must be proven that the practicing physician failed to provide sufficient care or directly breached medical practices. The injury, the primary reason for litigation, must be a direct result of the physician's negligence or breach of duty of care. Breach of duty of care can be defined as electing to provide care that is substandard or not evidence based. [1] For example, a doctor choosing to give a corticosteroid injection for a plantar plate rupture after a neuroma has been ruled as a direct breach of duty of care. The final element of negligence is direct loss as a result of injury. The plaintiff must be able to provide direct loss, such as injuries, medical bills, or illness, as a result of the care provided by the physician in question.

Most podiatric malpractice lawsuits arise after wound treatment, injections, and common elective surgeries, such as bunionectomies. Treatment involving ulcers, wounds, and diabetic foot infections rank number one amongst the most recent malpractice claims reported to PICA,[2] which provides insurance to podiatric physicians across all 50 states and the District of Columbia. PICA, which has provided insurance for 40 years, is a member of ProAssurance and the leading provider of podiatric malpractice insurance in the US. It is important to note that individuals with vascular disease or diabetes heal at a slower rate and are at higher risk of developing further complications. According to PICA, elective surgeries, such as bunionectomies, also rank high in malpractice claims, followed by plantar fasciotomies and steroid injection procedures. [2]

METHODS:

PICA was contacted in October 2022 about acquiring data concerning malpractice claims filed from 2017 to 2022. PICA was selected due to its role insuring the majority of podiatrists. Following the review of the PICA inquiry results, the researchers conducted a literature review pertaining to the complications of each procedure associated with dereliction of duty.

The focus of the review was on finding articles related to podiatric malpractice claims on the following topics: infections, bunionectomies, ankle surgeries, plantar fasciotomies, and steroid injections. A broad

search was conducted using PubMed and Google Scholar. The search terms included, but were not limited to, "definition of medical malpractice," "foot infections," "bunionectomies," "ankle surgeries," "plantar fasciotomies," and "steroid injections in the foot and ankle." To be included in this paper, the articles were required to be an original research article, literature review, or meta-analysis, written in English. The authors independently reviewed each article for completeness and then cross-referenced the articles for conflicting information. All selected literature was found to be congruent.

RESULTS

PICA reported approximately 1,700 malpractice claims between 2017 and 2022.[2] Procedures and treatments that led to the largest number of malpractice cases were:

1. Ulcer / Wound / Diabetic Foot Infections[2]
2. Austin and Austin-Akin Bunionectomies[2]
3. Other bunionectomies (involving proximal osteotomies and proximal fusions) [2]
4. Ankle Surgeries[2]
5. Plantar fasciotomies[2]
6. Steroid injections[2]

The number of cases per category was not disclosed during the data inquiry. The rankings provided were limited to the malpractice claims reported to PICA, which is not representative of the entirety of podiatric malpractice cases due to the exclusion of: podiatrists not insured by PICA, malpractice claims that were not filed, and claims handled via settlements.

DISCUSSION

Ulcer, Wound and the Diabetic Foot Infection

Podiatric physicians are well versed in treating and evaluating the diabetic foot. Treatment is common and there are many associated complications and risks for patients such as diabetic neuropathic foot ulcers, osteomyelitis, and Charcot arthropathy. Many patients with diabetes mellitus experience vascular complications that lead to ulceration. Diabetic neuropathic foot ulcers occur in approximately 15% of patients with diabetes mellitus; however, there is a 60% incidence of diabetic foot ulcers in patients with diabetic neuropathy. [3] Osteomyelitis is the most frequent complication associated with diabetic foot ulcers.[4] Patients with neuropathy have diminished protective threshold; the lack of sensation may result in an undetected foot wound. Once a foreign body penetrates the skin or bone, patients are exposed to pathogens leading to the development of soft tissue infection and osteomyelitis. Osteomyelitis is the most frequent complication associated with diabetic foot ulcers.[4] Osteomyelitis is found in 10-15% of moderate diabetic foot ulcer infections and 50% of severe diabetic foot ulcer infections.[5] Should osteomyelitis develop, the likelihood of lower extremity amputation increases. [6] Delayed wound healing and/or amputation can lead to decreased patient satisfaction, quality of life, and an increased likelihood of litigation due to the detrimental physical, mental, and emotional toll on the patient's overall health.

Nather et al. found the most important element of prevention of diabetic foot complications is to provide patient education.[7] Studies have demonstrated that the following topics provide the most educational benefit: selection of proper footwear, management of diabetes mellitus, and proper foot care.[7] Foot screenings and government supported long term intervention also play a role in the prevention of complications.[7] When conducting patient education, podiatrists need to ensure it is documented in the patient chart.

Austin and Austin-Akin Bunionectomies

Austin bunionectomies, also known as distal chevron osteotomies, are used to treat mild and moderate hallux valgus deformities. [8-10] The Austin bunionectomy is conducted by performing a "V" distal osteotomy at the level of the metaphysis of the first metatarsal. [8-10] The arms of the V are angled 60 degrees, making the head of the metatarsal half the width of the shaft. [8-10] By reducing the metatarsal head to half the width of the metatarsal shaft, the surgery corrects increased intermetatarsal angle.[8-10] Over the years there have been modifications to the Austin procedure; however, the basic principles remain the same.[8-10] Complications of Austin bunionectomies include: insufficient lateral release, an angle that is too large or too small, incorrect direction of the osteotomy, apex of the osteotomy being too distal, loss of the bone substance by saw, neuronal injury, hallux varus, joint stiffness, incorrect reception of the metatarsal shaft, joint pain, excessive capsular tightness, and osteonecrosis.[8-10] A complication of all bunion surgeries is a varus or valgus second digit leading to recurrence of the bunion. Proper patient education and management of patient expectations may help prevent a malpractice lawsuit and prevent dissatisfaction.

Proximal Bunionectomies and Proximal Fusions

Standard severe hallux valgus deformity treatment includes osteotomies of the proximal metatarsal. Proximal bunionectomy procedures include opening and closing wedges, crescentic osteotomies, proximal chevron, and Ludloff. A major benefit of proximal metatarsal osteotomies include correction of aggressive hallux valgus deformities that have large IM angles, with minimum shortening of the first metatarsal. Osteotomies occurring at the first metatarsal cuneiform joint are less stable and may often result in a

permanent dorsiflexed position of the hallux after healing, leading to metatarsalgia.[11] Because proximal osteotomies are more unstable, they have a longer healing time and require an extended period of non-weight bearing or partial weight bearing. Patients may become non-compliant and decrease the overall results of the osteotomy.

The Lapidus procedure is a proximal procedure that involves arthrodesis of the first tarsometatarsal joint for correction of hallux valgus. A Lapidus fusion allows for correction in the three cardinal planes: sagittal (correction of the hallux valgus angle), transverse (rotation of the first metatarsal), and frontal (plantarflexion of the first ray).[12] A fusion procedure allows for correction with a stable foundation and less risk of recurrence, but there is an increased risk of non-union, delayed healing, malunion, wound dehiscence, and excessive shortening of the first ray. Modifications have been created to increase the overall effectiveness of the surgery.[12] Arthroscopic fusion is a less invasive technique that reduces adduction and extension of the hallux, maintains the length of the first ray, protects the soft tissue, reduces postoperative pain results, and allows for a better cosmetic appearance. However, according to Cardoso et. al, although arthroscopic techniques result in a smaller, more manageable scar, open tarsometatarsal joint fusion procedures produce corrections with smaller intermetatarsal and hallux abducto valgus angles.[11]

Ankle Surgeries

Infections are a prevalent complication of surgery. Frederick et. al reported that almost 500,000 surgical site infections occur annually in the United States, with a 4% occurrence of surgical site infections in foot and ankle surgery. [13] Postoperative surgical site infections resulted in a patient being five times more likely to be readmitted to the hospital, resulting in increased medical costs. [13] According to Frederick et. al, the use of postoperative antibiotics did not prove to be beneficial in preventing infections after foot and ankle surgery unless the patient had pre-existing comorbidities. [12] Cherea et.al. established that postoperative complications, specifically reoperations and infections, resulted in reduced rates of patient satisfaction.[14] Individuals with postoperative complications were less likely to undergo another surgery, recommend surgery to other individuals, had less perceived improvement, and had lower activity and quality of life scores.[14] Infections following foot and ankle surgery can have negative effects on the patient's overall quality of life, resulting in increased hospital stays, non-healing wounds, increased medications, and increased mortality rates.

Plantar fasciotomies

Plantar fasciitis is a common foot abnormality in podiatric medicine. Highest incidences are seen between the 5th and 7th decades of life amongst athletic and non-athletic populations.[15] The cause of plantar fasciitis is multifactorial. Some risk factors include but are not limited to increased body weight, standing for long periods, aging, equinus and hallux limitus.[15] Conservative treatment such as steroid injections, orthoses, splints, strengthening and stretching exercises, physical therapy, platelet-rich plasma (PRP) injections, and extracorporeal shock wave therapy (ECSWT) are often successful in treating patients with plantar fasciitis.[15]

Plantar proximal fasciotomy is the most common surgical procedure for the plantar fascia and is typically recommended when conservative treatments and non-operative measures have been exhausted. A plantar proximal fasciotomy involves cutting the plantar fascia to reduce the tension, provide relief and an environment for healing to occur. Controversy regarding the best technique, such as open, endoscopic, or minimal incision is still a topic of discussion; however, the ultimate decision lies with the surgeon.[15] Influencing factors include the surgeon's preference and the patient's condition.[15] Complications such as instability of the lateral column should be considered prior to plantar fasciotomy surgery[14]. Lateral column instability can progress into metatarsalgia, sinus tarsi pain, and possible stress fractures leaving patients unsatisfied postoperatively. [15] Because 90% of plantar fasciitis cases are managed conservatively, plantar fasciotomies are not as prevalent as other surgeries.[14]

Steroid injections

Corticosteroid injections are often used to reduce pain and inflammation for a variety of foot and ankle conditions. Injections are commonly used for conditions such as plantar fasciitis, arthritis, Morton's neuroma, and ankle soft tissue impingement.[16] Corticosteroids also reduce the need for surgery by providing effective short-term relief lasting approximately 4-12 weeks.[17] Patients with plantar fasciitis given corticosteroid injections are encouraged to undergo physical therapy, stretching, and strengthening exercises. In rare instances complications such as heel fat pad atrophy, infection, nerve injury, and plantar fascia rupture can occur post-corticosteroid injection. Although relatively uncommon, to avoid malpractice, physicians should consider the treatment benefits against the risks. Patients should also be informed of long-term complications and risks associated with repetitive administration of corticosteroid injections.[17]

CONCLUSION

The most reported malpractice claims occurred following treatment for ulceration, wounds, diabetic foot infections, bunion correction procedures, plantar fasciotomies, and steroid injections. The data demonstrate that communication is an essential element to prevent malpractice litigation. To reduce malpractice in podiatric medicine, it is important to provide transparency regarding the limitations of a procedure, associated risks, patient's expectations, and practical recovery outcomes. It is also important for clinicians to document all communication in the patient's chart.

The study was limited to review the rankings of common malpractice claims as reported to PICA, the number of claims in each category were not disclosed. A second limitation was from the exclusivity of the data. Only data of malpractice claims covered by PICA were reviewed. Cases settled without a claim or covered by other insurance companies were excluded. Future studies would benefit from having proportional data on which surgeries contribute to malpractice claims and data including settlements and alternate insurers.

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First Generation

by Fatima Daknish

First generation student doc
Left her family behind,
State lines apart
First generation immigrant parents
Left their families behind,
Continents apart

First generation student doc
Without a charted path
Journey to medicine, nontraditional
First generation immigrant parents
Without a charted path
Journey to a territory, unfamiliar

First generation student doc
Striving to make her parents proud
First generation immigrant parents
Striving to do best for their kids

First generation student doc
To first generation immigrant parents
They work twice as hard
May take twice as long
Ultimately striving for success

First generations paving the way for the second
First generations with opportunities that beckon
Constantly inspiring one another
Cartographers, charting paths for future generations
Architects, building intergenerational social mobility
Pioneers, establishing long-lasting legacies

TEMPLE UNIVERSITY
School of Podiatric Medicine

POV of HPK

by Angel King, B.S.

It's really tough here.
External forces thicken me up where I lay is nothing but harsh wear and tear.
Who I am, well most don't care.
But once they've had enough, they bring in the big bucks.
"10 blade please?"…slash, slash, slash to my face and I then bleed.
Oh you thought I'd go quietly?
You start remembering "oh shoot she did have numbness , tingling, loss of protective sensation"
[ya know, neuropathy].

Thought you could get rid of me with no complication?
Like I wouldn't fight back, fight for my station!
As you debride me away sir you find I'm not alone in my disposition.
No longer just an ideation, but a physically new more horrific situation.
I fall to the ground, now my journey is over.
Who was I? Just an hpk or a pre ulceration?
Just behind me is a nasty ulcer …big bad full thickness!
Purulent discharge, odious smell…ou we you're gonna miss me, as God as my witness!

Samuel Merritt University
College of Podiatric Medicine

Where Have all the Creatives Gone?

by Rachel Zemble

Left brain mode activated
Analyze! Memorize! Criticize!
Right brain mode exhausted
Imagine? Create? Dream?

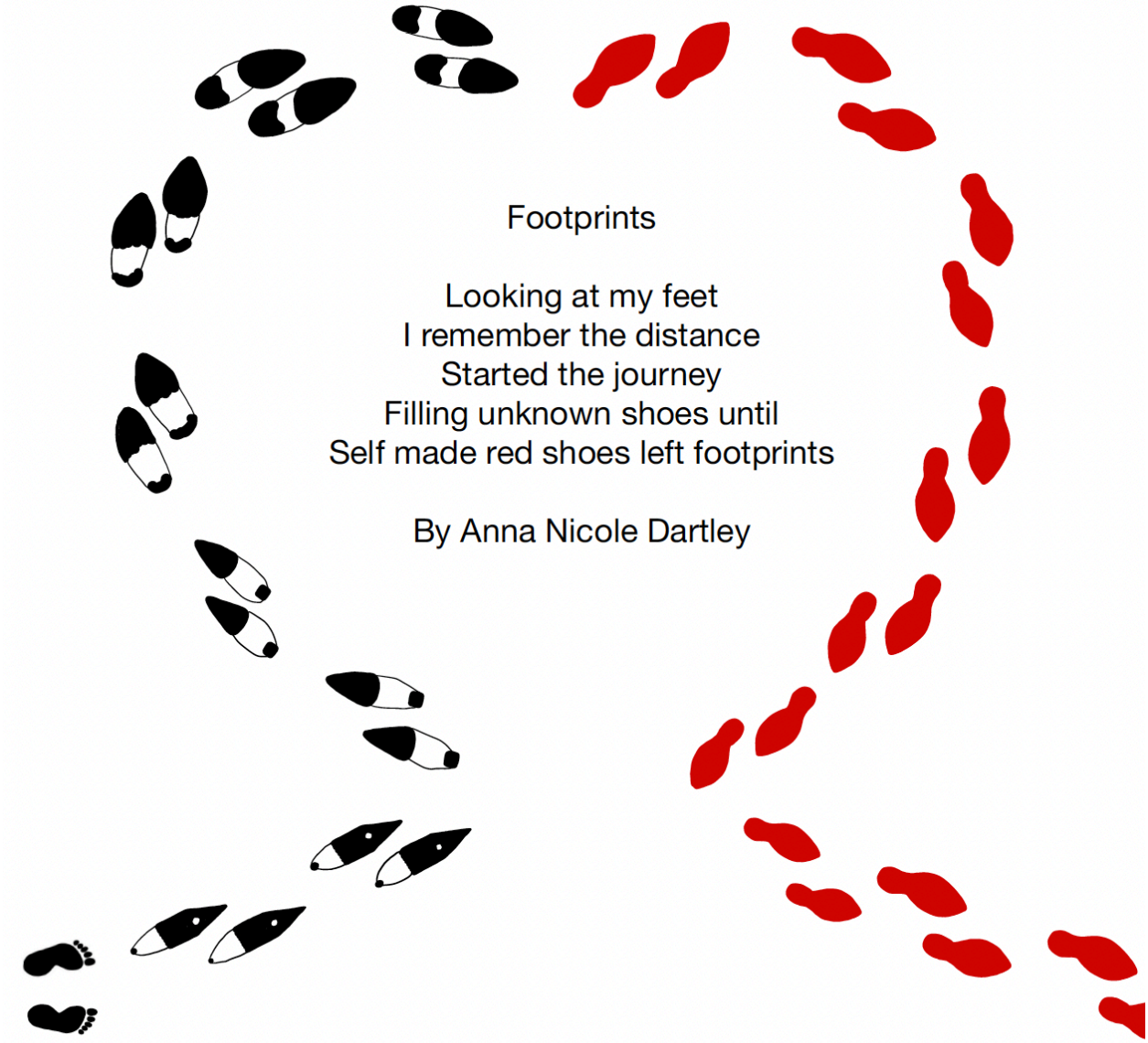
Where have all the creatives gone
Are we hiding behind our textbooks
Putting our poetic thoughts on trial
Arresting our feelings before they taste freedom

Are we measuring our value through letters and numbers
By the length of our CV
By only judging our logic and sense
Have our imaginations atrophied

Are we recalling all of the algorithms
Yet forgetting to consider zebras among the hoofbeats
Prescribing antibiotics like candy
And laughing at the holistics

Life begins outside the classrooms
Where reality strikes like a defibrillator
When your head hits the pillow at night
What is your identity beyond "student doctor"

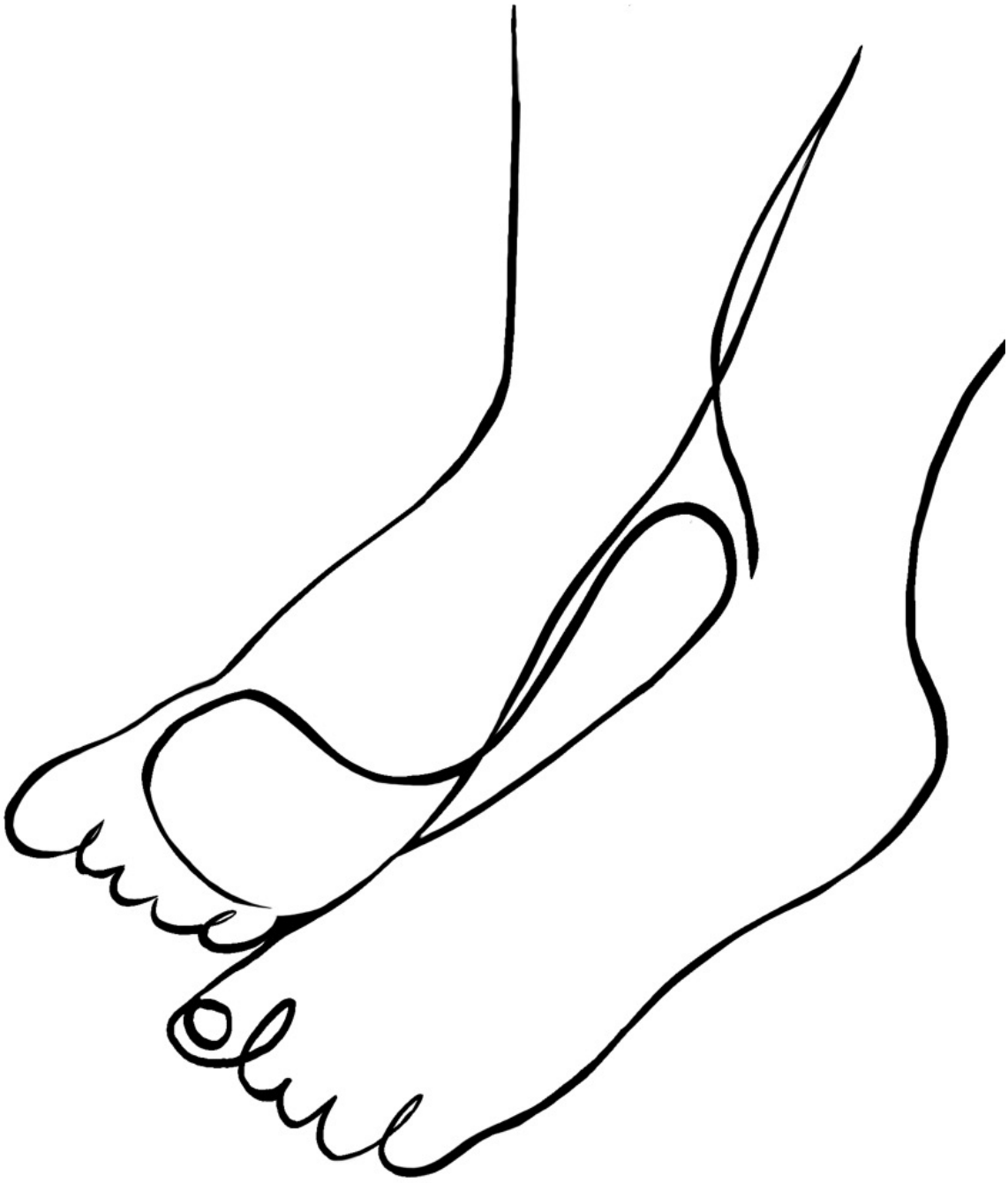
Barry University
SCHOOL OF PODIATRIC MEDICINE



Footprints

Looking at my feet
I remember the distance
Started the journey
Filling unknown shoes until
Self made red shoes left footprints

By Anna Nicole Dartley



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