CLINICAL RESEARCH ARTICLE

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Minimally invasive surgery for diabetic plantar foot ulcerations

Fábio Batista, MD, PhD[1]*, Antonio Augusto Magalhães, MD, PhD[2], Caio Nery, MD, PhD[2], Daniel Baumfeld, MD[2], Augusto César Monteiro, MD[3] and Fabíola Batista, RN[4]

[1]Department of Orthopedics and Traumatology, Federal University of São Paulo, Brazil; [2]Department of Orthopedics and Traumatology, Federal University of São Paulo, Brazil; [3]Brazilian Foot and Ankle Society, Federal University of São Paulo, Brazil; [4]Department of Orthopedics and Traumatology, Federal University of São Paulo, Brazil

Complications of diabetes mellitus constitute the most common indications for hospitalization and non-traumatic amputations in the USA. The most important risk factors for the development of diabetic foot ulcerations include the presence of peripheral neuropathy, vasculopathy, limited joint mobility, and pre-existing foot deformities. In our study, 500 diabetic patients treated for plantar forefoot ulcerations were enrolled in a prospective study from 2000 to 2008 at the Federal University of São Paulo, Brazil. Fifty-two patients in the study met the criteria and underwent surgical treatment consisting of percutaneous Achilles tendon lengthening to treat plantar forefoot ulcerations. The postoperative follow-up demonstrated prevention of recurrent foot ulcerations in 92% of these diabetic patients that maintained an improved foot function. In conclusion, our study supports that identification and treatment of ankle equinus in the diabetic population may potentially lead to decreased patient morbidity, including reduced risk for both reulceration, and potential lower extremity amputation.

Keywords: *foot ulceration*; *diabetic neuropathy*; *equinus*; *amputation*; *Achilles tendon lengthening*

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Complications of diabetes mellitus (DM) are responsible for a substantial number of hospital admissions, consume a great deal of medical resources, and have a profound negative impact on the lives of individuals with DM. Over 40% of diabetic patients develop renal insufficiency and many are prone to cardiovascular disease at about 2–6 times more than non-diabetic patients (1, 2). The heterogeneous nature of DM produces the variable course of diabetic foot disease. Presence of sensory alterations and foot deformities are principal risk factors for the development of complications. Approximately 25% of hospital admissions in diabetic individuals are directly related to foot problems. DM is the leading cause of non-traumatic lower extremity amputations. Amputation risk in diabetic patients is about 15–40 times higher than in non-diabetic patients (3–8).

There are many known pathways to amputation in diabetic patients. The most common problems are related to foot ulcerations, peripheral neuropathy, neglected foot deformities, infection, and vascular disease (8). Diabetic patients have a risk of 15% for development of foot ulcers in their lifetime with 20% of treatment failure. In most cases, these patients are not aware of their neuropathic state (9, 10). A program for effective prevention and treatment of foot lesions is necessary to avoid risk of major amputation.

The primary objective of our study was to demonstrate that minimally invasive surgery for diabetic plantar foot ulcerations in patients with decreased range of motion at the ankle joint can contribute to wound healing and also keep the foot in a plantigrade position, thereby avoiding reulceration and improving overall functional status.

Materials and methods

After approval by the Institutional Review Board of the Federal University of São Paulo, Brazil, 500 patients with DM from the Diabetic Foot Outpatient Clinic of Orthopaedic Department of the Federal University of São Paulo were enrolled in a prospective study to evaluate the results of minimally invasive surgery to treat forefoot ulcerations. All subjects underwent clinical evaluation

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and were followed from 2000 to 2008. The mean follow-up was 24 months.

Patients were included for surgery in the study if they had a history of DM type 2 for at least 5 years duration, decreased plantar sensation (detected with 10 g Semmes–Weinstein monofilament), dorsiflexion range of motion of the ankle equal to or less than 10° measured via goniometer (Fig. 1), palpable distal pulse, and history of forefoot ulceration healed with proper treatment (10, 11). Patients were excluded from surgery if they had an infected ulceration, dorsiflexion of the ankle greater than 10°, and absent distal pulse on clinical examination. Fifty-two patients met the study criteria and the average age was 66.4 years.

Operative technique and postoperative care

A modification of White's surgical technique was performed to address the equinus contracture with three hemisections of the Achilles tendon, with specific configuration according to the clinical presentation of the hindfoot and ankle (10). The proximal and distal hemisections were made at the same side of the Achilles tendon, and the intermediate cut was performed at the opposite side. A valgus hindfoot received proximal and distal hemisections at the lateral side of the tendon, whereas a varus hindfoot was addressed with medial side hemisections (Fig. 2). The postoperative care included plaster short-leg cast immobilization to maintain maximal dorsiflexion. After 1 week, a total contact cast with full weight bearing as tolerated was applied for 6 weeks. Physical therapy was then initiated to maintain ankle position, calf strengthening, proprioceptive improvement, and gait training in an accommodative walking boot for an additional 6 weeks (8, 12).

Results

Fifty-two patients in the study underwent surgical treatment consisting of percutaneous Achilles tendon lengthening through a modified White's technique to treat forefoot ulcerations. Forty-eight patients (92%) had no recurrence of ulcerations during the follow-up and

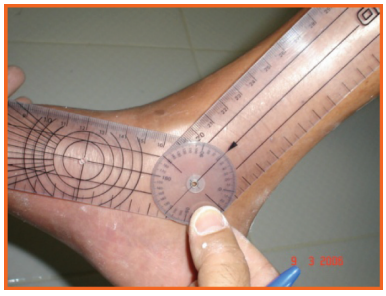

Fig. 1. Ankle goniometer showing the measurement of ankle equinus in the diabetic study population.

Fig. 2. Percutaneous Achilles tendon lengthening: Three hemisection technique.

demonstrated improved foot function. Follow-up was performed through a multidisciplinary team to maintain metabolic and glycemic control, provide education strategies to prevent recurrence of lesions, and also physical therapy for adequate function and protection. Patients with recurrent forefoot ulcerations ($n=4$ feet), which occurred in the same location as the original ulcer, also underwent a percutaneous distal metatarsal osteotomy (Fig. 3) of the associated metatarsal and were permitted full weight bearing in a total contact cast for 4 weeks. Thereafter, walking boots and custom shoes were prescribed. During the study, none of the patients presented with infection, pain, or necrosis.

Discussion

Diabetes mellitus is a chronic disease with potential complications that are responsible for high rates of morbidity and mortality. The presence of plantar foot ulcerations in these patients increases the risk of

Fig. 3. Percutaneous distal metatarsal osteotomy.

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infection, sepsis, and amputation. Early detection, multidisciplinary treatment, and education are critical for preventing any related lower extremity amputations. Our study demonstrated success in 92% of patients for prevention of recurrent forefoot ulceration in patients with ankle equinus, suggesting the usefulness of a minimally invasive approach for percutaneous lengthening of the Achilles tendon in these patients. Risk factors are well established in the literature regarding development of plantar ulcerations. DM can affect all components of the nervous system, including light touch sensation, motor control, pain recognition, proprioception, and autonomic function. Absence of protective sensation and the presence of foot deformities are the clinical factors with the highest correlation for the development of foot ulcerations and eventual lower extremity amputation (8, 13–15).

In fact, 85% of lower limb amputations are preceded by plantar ulcerations (16). Prevention and early treatment of these lesions can maintain satisfactory biomechanical and functional longevity of the lower extremity. Longer duration of DM is associated with the development of calf shortening due to structural changes, glycated collagen of tendon fibers, and the presence of peripheral sensory neuropathy, contributing strong risk factors for forefoot ulceration. Harmful load distribution contributes to hyperkeratosis and presence of plantar ulcerations. Clinical and imaging assays demonstrate that these patients often present with heterogeneous patterns of tendon fibers and sometimes contain internal calcifications. Anatomic physiologic patterns show significant modification within the calcaneal tendon that becomes a solid tendon (12, 17–19). As a consequence, patients present with limited range of motion of the ankle, physiologic loss of collagen elasticity, gait alterations, and inability of the foot to act as an energy absorber leading to elevated forefoot pressures (9, 18, 19).

Diabetic prophylactic foot surgery plays an important role in establishing optimal biomechanical function as well as preventing and treating foot ulcerations (8, 11, 12, 17). Our study illustrates that percutaneous Achilles tendon lengthening with a modification of White's original technique constitutes an important mechanism to restore appropriate range of motion to the ankle, improving gait quality, and preventing recurrent forefoot ulcerations. When necessary in cases of ulcer recurrence after Achilles tendon lengthening, the percutaneous distal metatarsal osteotomy has been recommended (9). We believed that the ulcer recurrences were associated with anatomic disturbance of the involved metatarsal such as elongation and plantar flexion (9). This study also highlights successful treatment of forefoot ulcerations and prevention of recurrence during a follow-up period in a large cohort of subjects via a multidisciplinary team approach.

Conclusion

Prophylactic surgery of the diabetic foot is a viable option in advanced treatment clinics to avoid foot complications and treat forefoot ulceration in diabetic patients. In an effort to reduce forefoot pressures and subsequently prevent ulcer recurrence, our study demonstrates an effective, reproducible surgical technique for percutaneous Achilles tendon lengthening with good tolerance by patients, and minimal complications.

Conflict of interest and funding

The authors have not received any funding or benefits from industry to conduct this study.

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***Fábio Batista**
Department of Orthopedics and Traumatology
Federal University of São Paulo, Brazil.
Email: dr.fabiobat@terra.com.br

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