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Original Research

Medial Displacement Calcaneal Osteotomy for Unilateral Adult Acquired Flatfoot: Effects of Minimally Invasive Surgery on Pain, Alignment, Functioning, and Quality of Life

Q1 Ottorino Catani, MD[1], Giovanni Cautiero, MD[1], Fabrizio Sergio, MD[1], Alessandro Cattolico, MD[2], Dario Calafiore, MD[3], Alessandro de Sire, MD[4,5], Fabio Zanchini, MD[6]

[1] Foot and Ankle Surgeon, Department of Orthopaedic and Traumatology, Casa di Cura S. Maria della Salute, Santa Maria Capua Vetere, Caserta, Italy
[2] Resident in Orthopaedics, Clinical Orthopaedics, Department of Medical and Surgical Specialties, University of Campania “Luigi Vanvitelli”, Naples, Italy
[3] Physiatrist, Neuromotor Rehabilitation Unit, Neuroscience Department, Azienda Socio Sanitaria Territoriale di Mantova, Bozzolo, Mantova, Italy
[4] Assistant Professor of Physical and Rehabilitative Medicine, Department of Health Sciences, University of Eastern Piedmont “A. Avogadro”, Novara, Italy
[5] Physiatrist, Rehabilitation Unit, "Mons. L. Novarese" Hospital, Moncrivello, Vercelli, Italy
[6] Assistant Professor of Orthopaedics, Clinical Orthopaedics, Department of Medical and Surgical Specialties, University of Campania “Luigi Vanvitelli”, Naples, Italy

A R T I C L E   I N F O

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A B S T R A C T

We aimed to assess the effects of medial displacement calcaneal osteotomy (MDCO) through a minimal skin incision in terms of pain, function, and alignment in patients with unilateral adult acquired flatfoot. American Orthopedic Foot and Ankle Society (AOFAS) hindfoot scale and Numeric Pain Rating Scale (NPRS) were assessed as outcomes at the baseline (T0), at 6 months (T1), and at 1 year (T2) from surgery. We analyzed data of 20 patients (7 male and 13 female), mean aged 46.6 ± 5.34 years, showed significant differences after 6 months in terms of AOFAS total score (44.30 ± 7.39 vs 96.50 ± 4.89; $p = .0001$), AOFAS subitems ($p < .001$), and pain (NPRS: 7.95 ± 1.36 vs 1.05 ± 1.05; $p = .0001$). At 1 year after surgery (T2), all outcome measures still significantly differ from baseline ($p < 01$). Therefore, percutaneous MDCO through a minimal skin incision seemed to be safe and effective in the middle and long term in reducing pain and improving function and alignment in patients with unilateral adult acquired flatfoot.

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Adult acquired flatfoot is a pathologic condition characterized by valgus alignment of the hindfoot, abduction of the midfoot, loss of longitudinal arch, and alterations of foot soft tissues such as spring ligament complex, tibialis posterior tendon and deltoid complex (1). A flatfoot could result in a less efficient biomechanics and can lead to chronic mechanical and degenerative overload (2). It can be classified into 4 stages according to Johnson and Strom (3): stage 1, normal alignment and swelling and pain of tibial posterior tendon; stage 2, flexible valgus hindfoot, loss of degrees in medial longitudinal arch, variation of hindfoot supination and abduction; stage 3, similar to stage 2 but alterations are more rigid than the previous one; stage 4, a fixed rigid deformity and valgus hindfoot. Another classification, proposed by Bluman et al (4), divides adult acquired flatfoot in 4 stages: stage I with no preexisting deformities; stage II, divided in IIa with mild deformity, minimal abduction through talonavicular joint and less of 30% of talonavicular coverage and IIb including severe flexible deformity with either abduction deformity through talonavicular joint or subtalar impingement; stage III, with fixed deformities; and stage IV, divided into stage IVa with hindfoot valgus and flexible ankle valgus without significant ankle arthritis and stage IVb with hindfoot valgus with rigid ankle valgus or flexible deformities with significant joint arthritis.

According to these classifications, there might be different therapeutic options including conservative treatment aimed to alleviate patients' symptoms and surgery that might be performed to correct the deformity (5,6). The first attempting of calcaneal osteotomy for pes planus has been performed by Gleich in 1893 (7). Nowadays, the usual surgical procedures include lateral column lengthening, modified triple arthrodesis, flexor digitorum longus transfer, and medial displacement calcaneal osteotomy (MDCO) (6,8). MDCO is a minimally invasive surgery (MIS) technique, commonly performed for mild flexible deformities, although timing and indications are still debated (9-12). A recent Consensus Statement of the American College of Foot and Ankle Surgeons affirms that MDCO should be considered in case of flexible adult-acquired flatfoot correction (13). This procedure allowed a greater correction and

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Q2 Address correspondence to: Alessandro de Sire, MD, Department of Health Sciences, University of Eastern Piedmont “A. Avogadro”, Viale Piazza d'Armi, 1 – 28100, Novara, Italy
E-mail address: alessandro.desire@gmail.com (A. de Sire).

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stability, providing a viable alternative to triple arthrodesis, restoring the physiological alignment of the foot and the normal structure of foot tripod in order to balance weightbearing forces (12,14-15). Some authors perform calcaneal osteotomies with procedures that involve soft tissues such as ligaments repair and tendon transfer (10,11); however, its use for painful flatfoot is still debated in terms of successful outcomes, for example, pain, functioning, X-ray images (16,17).

In our clinical practice, we commonly perform a percutaneous surgical approach through a minimal skin incision to treat symptomatic adult acquired flatfoot, according to international literature; indeed, it has been showed that a percutaneous approach might provide a minor risk of infections, saving the soft tissues (18-20).

In this retrospective study, we aimed to evaluate the effects of percutaneous MDCO through a minimal skin incision in terms of pain, function, and alignment in patients with unilateral adult acquired flatfoot.

Patients and Methods

Participants

We analyzed data of subjects referred to an Orthopaedics and Traumatology Unit over a 12-month period (from May 2018 to April 2019), satisfying the following inclusion criteria: (1) adult age (>18 years); (2) diagnosis of acquired flatfoot; (3) valgus hindfoot and variable alterations of medial arch height according to stage 2 of the classification of Bluman et al (4); (4) pain at skin pressure of medial longitudinal arch in the last 3 months; (5) no responsive to conservative treatment in the last 3 months. Exclusion criteria were: (1) presence of osteoarthritis: (2) patients who underwent surgery before; (3) patients with rheumatoid, neurologic, or post-traumatic acquired flatfoot.

The institutional review board approved the study. All the procedures were conducted according to the principles of the Declaration of Helsinki and the authors were instructed to protect the patients' privacy.

Intervention

The percutaneous MDCO was performed under spinal anesthesia. The patients were positioned in lateral position on the operating table. Prophylactic antibiotics were instilled intravenously prior to operative incision. The limb was prepped and draped until knee level. As showed by Fig. 1, the incision point was drawn with a sterile pen on lateral surface of calcaneus from the origin of the plantar fascia extending to posterosuperior aspect of the tuberosity, area corresponding to calcaneus safe zone (Fig. 1*A*). Moreover, a fluoroscopy was performed to determine the intended osteotomy and to avoid injury to neurovascular structure (Fig. 1*B*). Before performing the osteotomy, one or two 2-mm Kirshner wires were inserted at posteroinferior portion of calcaneus and push forward for 1 to 2 cm. These wires will be used as joysticks to shift medially the back-heel portion at the end of the osteotomy. Another Kirshner wire is passed through the skin on lateral-calcaneus surface with a 45° angle to plantar surface and used as a guide for the osteotomy. An incision of 5 mm was made on lateral side of calcaneus in the calcaneus safe zone. A small rasp was used to remove the fibrous tissue and periosteum from surface. A 3-mm wide and 20-mm long Shannon burr was inserted and advanced across the calcaneus perpendicular to its long axis following the Kirshner wire, previously passed through the skin (Fig. 2). Fluoroscopy was used to control the trajectory of osteotomy.

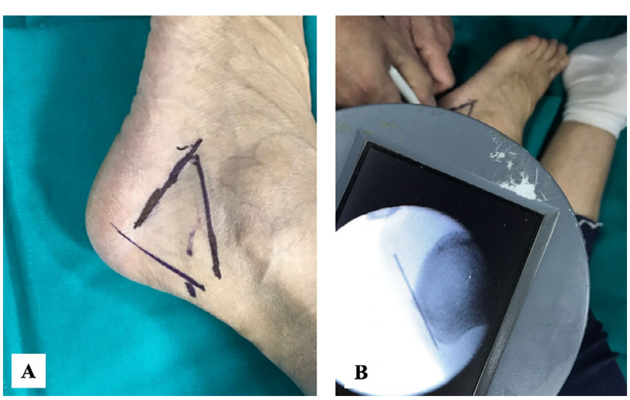

Fig. 1. . (*A*) Incision point drawing. (*B*) Fluoroscopy performed to assess the calcaneus safe zone.

Fig. 2. A 3-mm wide and 20-mm long Shannon burr insertion. Q3

The trajectory of the osteotomy was performed typically 45° to plantar surface. The burr was carefully advanced through the far cortex. Fluoroscopic controls were made in different times during the osteotomy procedure. Burr speed should be approximately from 2000 to 6000 rpm. Physiological solution was used to irrigate the site of osteotomy constantly in order to avoid damages or necrosis to tissues. When the osteotomy was completely performed, as depicted by Fig. 3, the Kirshner wires were used as joysticks to shift medially the back part of the bone (Fig. 3*A*). The degrees of translation were evaluated by fluoroscopy (Fig. 3*B*). A Howarth elevator might help operator in the procedure. After the operator reached the desired degree of translation, Kirshner wires were pushed forward in the bone to fix temporarily the osteotomy. Drill was used through Kirshner wires to prepare the fixing and 2 cannulated screw were inserted through the wire until calcaneus tuberosity. Different projection fluoroscopic controls were made to ensure the results of osteotomy. Irrigation was performed to remove bony debris and a single suture was used to close the percutaneous access. Intravenous antibiotics were administered for 2 days followed by oral antibiotics for 10 days. After 10 to 14 days suture used to close the percutaneous incision is removed. Patients wore a pinstriped boot for 30 days after surgery and then observed at 20 days for partial weight bearing. At 50 days after surgery, full weightbearing is allowed and all patients were instructed to perform a patient-oriented rehabilitation program consisting of exercises to restore ankle range of motion, ankle strengthening exercises in order to have posterior tibial tendon strength enough to support the plantar arch and to control the motion of ankle during ambulation, and proprioceptive exercises.

Outcome Measures

At the baseline, we collected demographic and anthropometric data. Primary outcome measure was the American Orthopedic Foot and Ankle Society (AOFAS) hindfoot scale with its subitems: pain, function, and alignment (21-23).

As secondary outcomes we assessed: Numeric Pain Rating Scale to evaluate pain (24), and EuroQol 5-Dimension 3-Level (EQ-5D-3L) and EuroQol Visual Analogue Scale (EQ-VAS) for health-related quality of life (HRQoL) (25). All these evaluations were performed at the baseline (T0), the day before the surgical intervention, at 6 months (T1), and at 1 year (T2) from the surgical intervention.

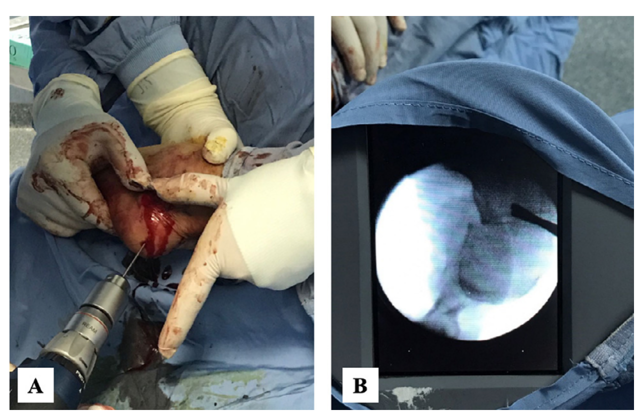

Fig. 3. . (*A*) Osteotomy execution. (*B*) Fluoroscopy performed to assess the degrees of translation.

Table
Differences in outcome measures from baseline (T0), the day before the surgical intervention, at 6 months (T1) and at 1 year (T2) from the surgical intervention (N = 20 patients)

	T0	T1	T1-T0 *p*Value	T2	T2-T0 *p*Value
AOFAS total score	44.30 ± 7.39	96.50 ± 4.89	.0001	97.25 ± 4.72	.0001
AOFAS pain score	2.00 ± 6.16	36.50 ± 4.89	.0001	38.50 ± 3.66	<.0001
AOFAS function score	40.55 ± 2.68	50.00 ± 0.00	.0001	49.00 ± 2.62	.0001
AOFAS alignment score	1.75 ± 2.45	10.00 ± 0.00	<.0001	9.75 ± 1.12	<.0001
NPRS	7.95 ± 1.36	1.05 ± 1.05	.0001	0.80 ± 0.70	.0001
EQ-5D-3L	0.76 ± 0.06	1.05 ± 1.05	.0008	0.92 ± 0.09	.0001
EQ-VAS	5.25 ± 0.95	8.25 ± 0.97	.0001	8.55 ± 0.60	.0001

Abbreviations: AOFAS, American Orthopedic Foot and Ankle Scale; EQ-5D-3L, EuroQol 5-Dimension 3-Level; EQ-VAS, EuroQol Visual Analogue Scale; NRS, Numeric Pain Rating Scale.
Continuous variables are expressed as means ± standard deviations. Wilcoxon matched pair test was performed as statistical analysis.

Statistical Analysis

Statistical analysis was performed using STATA v.12 (StataCorp LP, College Station, TX). Study power 90% and the statistical significance was defined at 0.05 ($\alpha = 0.05$). We performed a statistical analysis using Wilcoxon matched pair test to evaluate intragroup differences of continuous variables. Statistical significance was defined at the 5% ($p \leq .05$) level.

Results

Twenty patients (7 male and 13 female), mean aged 46.6 ± 5.34 years, were analyzed. All subjects suffered unilateral symptomatic acquired flatfoot: 9 right and 11 left. From data analysis, we reported a statistically significant improvement in the primary outcome (AOFAS total score: 44.30 ± 7.39 vs 96.5 ± 4.89; $p = .0001$) and its subitems ($p <$ .001), at 6 months after surgical intervention (T1). Moreover, there was a significant reduction in terms of pain (Numeric Pain Rating Scale: 7.95 ± 1.36 vs 1.05 ± 1.05; $p = .0001$) an improvement in HRQoL, as depicted by EQ-5D-3L (0.76 ± 0.06 vs 1.05 ± 1.05; $p = .0008$) and EQ-VAS (5.25 ± 0.95 vs 8.25 ± 0.97; $p = .0001$). At 1 year after surgery (T2), all outcome measures still significantly differ from baseline ($p <$ 01), testifying the long-term outcome of the surgical intervention. Further details are described by Table. No skin or neurovascular complications were reported. No cases experienced that the tip of the burr broke and remained in the heel body.

Discussion

The adult acquired flatfoot is a complex, multifaceted pathology needing a full understanding of the anatomy involved and the biomechanics to be able to accurately perform adequate diagnosis and surgery plan (26,27). The accurate choice of osteotomy is an essential part of our current armamentarium and MIS as the MDCO might be preferred to reduce patient's complications. A recent consensus affirmed that there is evidence that the MDCP might be considered as effective in treating the progressive collapsing foot deformity (28); MDCO.

More in detail, MDCO is a delicate procedure that allows greater correction of the deformity, changing the calcaneal axis, protecting the soft tissue reconstruction, to prevent the heel from going into valgus, leading to a positive influence on walking dynamics (29). Moreover, MDCO offers a better outcome in reducing the contact stresses and restoring normal loading across the tibiotalar joint (15,30). Kendal et al (18) compared calcaneal osteotomy with a MIS procedure in patients with flatfoot, showing a minimal difference of the displacement (9.4 mm with MIS vs 10.2 with open procedure) but a great reduction of wound complications with MIS compared to open surgery (6.5% and 28.0%, respectively). Furthermore, Kheir et al (19) described MIS procedure in 30 cases: 29 surgery MDCO with posterior tibial tendon reconstruction and 1 case of nonunion calcaneal fracture. No major complications were reported in this study and all osteotomies lead to a bone union. The authors underlined that burr removed about 3 mm of bone more than a saw facilitating the calcaneal translation. A narrow burr used in MIS procedure had fewer risks to damage medial neurovascular calcaneal structures than saw utilized in open access. The use of physiological water and of a rasp can help to remove the bone pasta and the residues. Moreover, the X-ray images should control constantly the osteotomy; the use of a portable X-ray fluoroscopy as a useful equipment combined to the ability of the operator in order to reduce the radiation exposure. Recently, Saxena et al (31) performed a comparison study between MDCO with screw fixation and locking plate fixation in flatfoot deformity and affirmed that both techniques provide good results in terms of improvement of AOFAS without difference between approaches.

The present study has some limitations that should be highlighted. First, the lack of longer follow-up intervals that might not reveal more patients with symptoms from their hardware; second, the absence of a control group did not allow to compare MDCO with other approaches for the treatment of flatfoot, but only an intragroup difference; third, the lack of monitoring of radiographic parameters at more follow-up evaluations. However, despite our appreciation of the limitations of our investigation, we believe that the results of this study could be useful in the future development of randomized controlled trials that focus on functional recovery and quality of life after different surgical approach in adult flatfoot.

Taken all together, our real-practice findings suggested that MDCO through a minimal skin incision might be considered as an effective and safe surgical technique reducing, enhancing function and alignment, and improving HRQoL in the middle and long term in patients with unilateral adult acquired flatfoot. Future prospective controlled studies on larger samples could provide more data in order to confirm the effects of this MIS orthopedic technique.

Authors' Contribution

Study conceptualization and design: OC, AdS, FZ; Participants recruitment: GC, FS, AC; Intervention/surgery: OC; Iconography: GC, FS; Data acquisition: GC, FS; Data analysis and interpretation: AdS; Literature research: OC, GC, DC, AdS; Writing manuscript: OC, GC, AdS; Supervision: FZ; Revision and approval of the final draft by all the authors.

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