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Mid-term functional outcome of a total arthroplasty of the first metatarsophalangeal joint

Corina Nüesch, PhD [a,b,*], Annegret Mündermann, PhD [a,b], Monika Horisberger, MD [a]

[a] University of Basel, University Hospital, Orthopaedics and Traumatology, Switzerland
[b] University of Basel, Department of Biomedical Engineering, Switzerland

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ABSTRACT

Background: Arthroplasty of the first metatarsophalangeal joint is an alternative treatment option for end-stage hallux rigidus to the current gold standard of arthrodesis. The aim of this study was to investigate the mid-term functional outcome of an anatomically shaped prosthesis for the first metatarsophalangeal joint using pedobarography.
Methods: Ten patients (12 affected feet; age at surgery: 62.1 (SD: 7.2) years) were investigated preoperatively and 52 (SD: 3) months postoperatively using pedobarography (EMED, novel GmbH, Munich, Germany). Two patients were excluded at follow-up because their prosthesis was converted to an arthrodesis. Peak force and plantar pressure under the five metatarsal heads and the hallux were analyzed and correlated with the clinical outcome (pain, American Orthopaedic Foot and Ankle Society forefoot score and radiographic maximum first metatarsophalangeal dorsiflexion). Differences between pre- and postoperative data were analyzed using paired *t*-tests (alpha = 0.05).
Findings: Postoperatively, forefoot peak forces under the fourth (+40.9%; P = 0.018) and fifth metatarsal (+54.9%; P = 0.037) and plantar pressures under the fifth metatarsal (+38.7%; P = 0.027) increased significantly, while peak plantar pressures and forces under the hindfoot, medial forefoot and hallux did not change. While maximum passive dorsiflexion was not significantly greater at the 4-year follow-up compared to preoperatively, overall greater passive dorsiflexion was associated with higher first metatarsal peak pressure.
Interpretation: Despite of patients reporting less pain, the functional results indicate an altered and potentially non-physiological postoperative gait pattern with a lateralization of the load during walking, especially in patients with limited passive dorsiflexion.

1. Introduction

Hallux rigidus is associated with decreased mobility of the first metatarsophalangeal (MTP-I) joint, especially in dorsiflexion. Dorsiflexion in the metatarsophalangeal joints is important for propulsion in walking because it provides stability during toe-off (Bojsen-Møller and Lamoreux, 1979) and facilitates the windlass effect that tightens the plantar aponeurosis (Kappel-Bargas et al., 1998). Moreover, the highest pressures during the physiological push-off phase of walking occur in the hallux, the first and the second metatarsal regions (Hayafune et al., 1999). In patients with hallux rigidus, this normal function of the MTP-I joint during walking is impaired and their gait patterns are altered. Besides a smaller MTP-I plantarflexion/dorsiflexion range of motion (RoM) (Canseco et al., 2009; Kuni et al., 2014), a smaller forefoot pronation/supination RoM was observed in patients during walking (Kuni et al., 2014). Patients with radiological MTP-I osteoarthritis without pain had higher peak force and peak plantar pressure in the hallux area than healthy people (Zammit et al., 2008). However, the study investigated only pain free subjects and it remains unclear whether similar results would be observed in patients with symptomatic MTP-I osteoarthritis.

Arthrodesis is the standard surgical treatment for end-stage osteoarthritis of the MTP-I joint (Deland and Williams, 2012; McNeil et al., 2013; Vanore et al., 2003). While clinical studies showed pain relief and improved function (DeFrino et al., 2002; Gibson and Thomson, 2005), pedobarographic studies reported no changes in the peak plantar pressure in the forefoot (DeFrino et al., 2002; Gibson and Thomson, 2005) and increased peak pressure and peak force in the hallux segment after arthrodesis (DeFrino et al., 2002). Moreover, gait analysis studies reported, for instance, that ankle power generation from the plantarflexors during push-off remained altered with lower postoperative ankle power on the operated than on the healthy side (DeFrino et al., 2002), and increased ankle power compared to preoperative values

* Corresponding author at: Clinic for Orthopaedics and Traumatology, University Hospital Basel, Spitalstrasse 21, 4031 Basel, Switzerland.
E-mail address: corina.nueesch@usb.ch (C. Nüesch).

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(Brodsky et al., 2007). Among other factors, these remaining differences in postoperative gait patterns contributed to the development of MTP-I prostheses. Recent clinical results showed improved pain and functional scores after surgery for some prosthesis designs (Gibson and Thomson, 2005; Unger et al., 2013; Wetke et al., 2012). However, compared to arthrodesis, more complications and only limited RoM gain have been reported (Gibson and Thomson, 2005). While some clinical data on the outcome of MTP-I prosthesis are available, little is known on the function of MTP-I replacements during walking. Gibson et al. compared peak plantar pressures in the first and fifth metatarsal between MTP-I arthrodesis and arthroplasty in a randomized controlled trial and found indications for an increased lateral load 2 years after MTP-I arthroplasty (Gibson and Thomson, 2005). However, another study with a different prosthesis design reported a postoperative decrease of the lateral peak force and no changes on the medial side (Wetke et al., 2012).

To date, data on the functional outcomes such as the dynamic plantar pressure distribution is limited and dependent on the MTP-I prosthesis. The purpose of this prospective study was to test the hypotheses that an anatomically shaped MTP-I prosthesis improves both the clinical and functional mid-term outcome. Specifically, we hypothesized that the peak plantar pressure and peak force in the forefoot increase, especially in the medial forefoot and hallux. The second aim of this study was to test the hypothesis that patients with better clinical results have higher peak pressure and force in the forefoot.

2. Methods

2.1. Patients and procedures

Ten patients (7 males, 3 females; 12 affected feet; age at surgery: 62.1 (SD: 7.2 years)) were included in this prospective pedobarographic study. All patients suffered from end-stage hallux rigidus and had undergone MTP-I arthroplasty. These patients were all part of a larger cohort where the clinical outcome of MTP-I arthroplasty with the same anatomically designed 3-component MTP-I prosthesis (Metis, Newdeal SA, Integra Life Science ILS, New Jersey, USA) was studied (Horisberger et al., 2016) and some of the patients had undergone pedobarography preoperatively. Postoperatively, the patients wore a stiff hallux shoe for 6 weeks and were allowed full weight bearing if tolerated. All patients received physiotherapy during the first 6 to 12 weeks after surgery, where active and passive motion and lymphatic drainage were performed to support soft tissue healing and to regain MTP-I mobility (Horisberger et al., 2016). At the pedobarographic follow up measurement (52 (SD: 3) months after surgery), two patients were excluded because their MTP-I arthroplasty had been converted to an MTP-I arthrodesis. Therefore, pre- and postoperative clinical and pedobarographic data were available for eight patients (6 males, 2 females; 10 affected feet; age at follow up: 65.7 (SD: 7.1) years). The study was approved by the local ethics committee and conducted in accordance with the Declaration of Helsinki.

Plantar pressure distribution parameters were assessed pre- and postoperatively using dynamic pedobarography (EMED, Novel GmbH, Munich, Germany, 4 sensors/cm^2) during walking at self-selected speed. For each patient five dynamic trials of the left and right foot were recorded facilitating a sufficient reliability (Hughes et al., 1991).

The clinical assessment included pre- and postoperative radiological measurements of passive MTP-I RoM using fluoroscopy. For both maximal plantarflexion and dorsiflexion, the angle between the long axis of the first metatarsal and the proximal phalanx was measured (Fig. 1). Furthermore, the pain level was assessed using a visual analogue scale (VAS; 0 – no pain to 10 – worst pain) and the clinical functional outcome using the American Orthopaedic Foot and Ankle Society (AOFAS) forefoot score (Kitaoka et al., 1994).

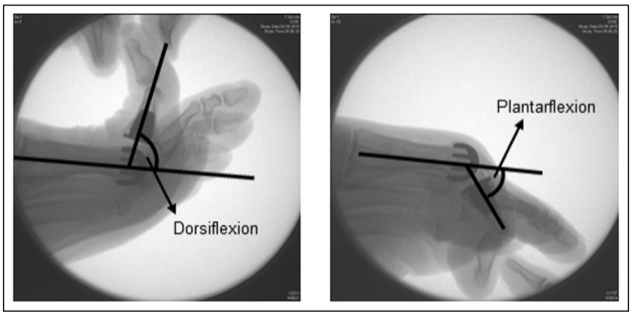

Fig. 1. Measurement of the maximal first metatarsophalangeal joint dorsiflexion (left) and plantarflexion (right) angle using fluoroscopy.

2.2. Data analysis

The EMED software (novel GmbH, Munich, Germany) divides the foot into ten regions according to the manufacturer's software – hindfoot, midfoot, first to fifth metatarsal, hallux, second toe, lesser toes – and provides peak pressure, peak force, contact time and contact area for each of these segments. To assess the load distribution between the medial and lateral aspect of the foot, we defined a mediolateral forefoot index for both peak pressure and peak force:

$$\text{mediolateral forefoot index} = \frac{\max(\text{first metatarsal}, \text{second metatarsal}, \text{hallux})}{\max(\text{third metatarsal}, \text{fourth metatarsal}, \text{fifth metatarsal})}$$

A mediolateral forefoot index >1, indicates that the highest forefoot pressure or force occurs on the medial side and an index smaller than 1, indicates that the highest forefoot pressure or force occurs on the lateral side.

2.3. Statistics

Only the affected feet were included in the analysis. Pre- and postoperative group means and standard deviations of all pedobarographic parameters were calculated from the averages of five steps of the respective measurement. Differences between the two measurements were analyzed with paired *t*-tests. Effect sizes for the differences were calculated using Cohen's d = (mean, post − mean, pre) / pooled standard deviation (Cohen, 1992). To assess the relationship between clinical and pedobarographic results, the Pearson product moment correlation coefficient was calculated. All statistical analyses were performed using MATLAB (MathWorks, Natick, MA, USA) and the significance level was set a priori to alpha = 0.05. A post-hoc power and sensitivity analysis for the correlation coefficients showed that for 80% power the absolute values of the correlation coefficient needed to be >0.53 (Faul et al., 2007). This value was subsequently used as a threshold for relevant correlations.

3. Results

3.1. Clinical results

Compared to the preoperative measurement patients had significantly less pain and higher AOFAS forefoot scores at follow-up. Postoperatively, the MTP-I passive RoM was on average smaller than preoperatively but the difference was not statistically significant. Specifically, patients had significantly less MTP-I plantarflexion after surgery, while the amount of MTP-I dorsiflexion tended to be higher (Table 1).