TECHNICAL NOTE

First metatarsophalangeal joint percutaneous arthrodesis

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Summary The aim of this work is to describe a percutaneous technique of first metatarsophalangeal (MTP1) joint fusion and to assess its preliminary results. Thirty-two percutaneous MTP1 joint arthrodeses were analysed in a prospective continuous series including 30 patients of mean age 66 years old. The indications for arthrodesis of the MTP1 joint were symptomatic hallux rigidus or hallux rigido-valgus in most of the cases. All patients underwent the same percutaneous procedure, as a one-day surgery for 26 cases. Clinical results were assessed using the functional AOFAS forefoot scoring system both preoperatively and at last follow-up. Radiographical analysis was focused on positioning and quality of the arthrodesis. No patient was lost to follow-up and the mean follow-up was 18 months. The functional AOFAS score improved in all cases from a mean 36/100 preoperatively to a mean 80/100 postoperatively ($p = 0.02$). In 30 cases, patients were satisfied or very satisfied with their final outcome, one patient was disappointed and one was dissatisfied. Satisfied or very satisfied patients could wear normal shoes after a mean 50-day period. Fusion was radiographically obtained in 31 cases out of 32. The mean postoperative dorsi flexion of the MTP1 joint arthrodesis was $21^\circ$ (min: $15^\circ$, max: $35^\circ$). One patient developed a deep surgical site infection, 3 weeks after the procedure. Percutaneous MTP1 joint fusion is a simple surgical technique that can achieve similar results to open techniques for MTP1 fusions, with very simple postoperative care requirements. Indications for percutaneous MTP1 joint arthrodesis are large and only major bone defects or severe osteoporosis can be considered as contraindications.

Level of evidence: Level IV.

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Introduction

Arthrodesis of the first metatarsophalangeal (MTP1) joint has a major place in the surgical treatment of the hindfoot and remains the reference technique in the management of painful and advanced stages of hallux rigidus. Arthrodesis of
the first metatarsophalangeal joint allows patients to return to normal walking since mobility is mainly promoted by the interphalangeal joint with compensating hypermobility in dorsiflexion [1—4]. The main difficulty of this procedure lies in the three-plane positioning of the arthrodesis which should be adapted to each patient’s anatomy, level of activity and shoe wearing habits [5—9]. The other difficulty lies in the primary stability of the arthrodesis which depends on the chosen bone-surface preparation technique and on the selected osteosynthesis [8—15]. Various open or arthroscopic-assisted techniques were described and reported healing rates varying from 90 to 100% according to the series [2,16—20]. The authors present a percutaneous technique for arthrodesis of the first metatarsophalangeal joint with description of the operative technique, analysis of the first results and discussion regarding the interest of this new technique.

Operative technique

Material

The material used for percutaneous arthrodesis of the first metatarsophalangeal joint is similar to that used for any percutaneous surgery of the hindfoot and included a large conical reamer, a Beaver blade©, strippers and rasps, a low-speed motor (up to 5000tr/mn) and a fluoroscopic system. Diameter compression cannulated screws (3.0 mm) were used for fixation of the arthrodesis in the present technique but different cannulated screw systems are available.

Patient positioning

The patient was placed in the supine position under local anaesthesia (metatarsal conduction block) with a pneumatic tourniquet applied above the maleoli and inflated to 250 mm Hg, the foot being placed out of the operating table to facilitate AP and lateral fluoroscopic control.

Surgical approach

The main surgical approach was medial, facing the metatarsophalangeal joint line and was used for bone-surface preparation (Fig. 1). Two accessory surgical approaches were necessary in some cases: a plantar and medial proximal approach facing the first metatarsal head (this surgical approach is identical to that used in hallux valgus percutaneous exostosectomy) and a lateral and dorsal distal approach at the level of the first phalanx. The accessory medial proximal approach was used for the resection of medial and dorsal osteophytes and the accessory lateral distal approach for the resection of dorsal and lateral osteophytes and in case of lateral metatarsophalangeal joint capsular-ligamentous release.

Bone-surface preparation

Bone-surface preparation started with resection of the metatarsal and phalangeal osteophytes if necessary. This resection was performed using two accessory surgical approaches (medial proximal and dorsal distal) after capsular-periosteal stripping by means of a large conical reamer. Bone debris were carefully removed and the resection area was thoroughly cleaned with a physiological saline solution. The metatarsophalangeal joint line was prepared through the main medial surgical approach (Fig. 2). The large conical reamer was placed at the joint line by applying traction in the axis of the first-ray. Cartilage resection and bone-surface preparation were performed using the reamer.
The amount and quality of bone resection were evaluated under fluoroscopic control. In the present technique, the arthrodesis site was prepared by realizing two flat surfaces extending parallel to each other in the AP and lateral planes under fluoroscopic control. Once bone-surface preparation was completed, bone debris were removed with a rasp and the arthrodesis site was thoroughly cleaned with a physiological saline solution to prevent any prolonged inflammation.

**Arthrodesis positioning**

The phalanx was placed in contact with the metatarsal head using compression and held in position by means of an oblique phalangometatarsal pin. Positioning was clinically and radiographically assessed:

- in the horizontal plane (Fig. 3): the aim was to achieve alignment or slight valgus of the first ray, the length of the first ray relative to the lateral rays was checked to prevent any excessive shortening. Proper metatarsophalangeal contact and the absence of subluxation (lateral or medial) were fluoroscopically controled;
- in the sagittal plane (Fig. 4): the position of the first phalanx was assessed relative to the floor plane which was represented by a radio-opaque support applied to the sole of the foot. Therefore, the orientation of the first phalanx parallel to the floor plane, the quality of the metatarsophalangeal contact and the absence of subluxation (usually plantar) were controled;
- in the coronal plane: the position of the phalanx in pronation and supination was assessed using the nail plane relative to the other toes.

**Fixation of the arthrodesis**

The arthrodesis was secured using two compression-cannulated screws (Fig. 5). The first phalangeo-metatarsal pin was oblique and medio-lateral and the second one was metatarsophalangeal and crossed the first one ideally at the level of the metatarsal head and not at the previous joint line. The two-bicortical screws were inserted and
compression was applied alternatively on both screws. Primary stability in flexion-extension was clinically assessed and the wounds were closed (Fig. 6).

Specific gestures

Lateral arthrolysis of the metatarsophalangeal joint was not systematically performed. Traditionally, this procedure was performed for cases of severe hallux valgus to achieve correction of the deformity and proper metatarsophalangeal alignment. It could also be performed in advanced stages of hallux rigidus without deformity, to facilitate joint decapsulation during bone-surface preparation. Avancement of the first metatarsal head was very limited when arthrodesis was performed in patients with rheumatoid arthritis (risk of loss of bone substance induced by osteoporosis with poor primary stability) and in case of Greek forefoot type and Greek index minus foot (to prevent excessive shortening of the first ray).

Associated gestures: postoperative care

A moderately compressive dressing was applied and left in place for 15 days after which a simple dressing with cohesive elastic bandages was placed and changed twice a week up to complete healing. Immediate full weight-bearing wearing a rigid flat-bottom orthopaedic shoe was allowed. No antithrombotic prophylaxis was administered except in specific cases (history of deep venous thrombosis, blood coagulation disorders, anticoagulant treatment). The first radioclinical assessment was performed at 10 days during the first dressing change. The second radio-clinical assessment was carried out at one postoperative month, the date from which normal shoes could be worn depending on the clinical and radiographic results. An assessment was then performed at 3, 6 and 12 postoperative months.

Preliminary series

Patients

It is a prospective continuous monocentre mono-operator series of 32 percutaneous arthrodeses of the first metatarsophalangeal joint performed in 30 patients of mean age 66 years (range, 44 to 86 years) between January 2007 and August 2008. Arthrodesis was performed for hallux rigidus or advanced stages of hallux valgus rigidus (stage 3 or 4), stiff and symptomatic in 18 cases, for revision surgery of the first ray in six cases, for symptomatic rheumatoid forefoot in five cases and for hallux varus in three cases.

All first MTP joint arthrodeses performed during the inclusion period were carried out using the percutaneous technique. In 19 out of 32 cases, percutaneous gestures on lateral rays were associated during the procedure (distal metatarsal osteotomies, percutaneous management of claw toe deformities). In all cases, patients presented with preoperative over load bearing of central metatarsal heads or symptomatic claw toe deformities. Twenty-six out of 32 patients underwent surgery with one-day hospitalization.

Methods

All patients were reviewed at 10 days, 1 month, 3 months, 6 months and one year by the main operator. The AOFAS score for all patients was calculated preoperatively and at last follow-up [21]. The subjective patient satisfaction was assessed at last follow-up (very satisfied, satisfied, disappointed, dissatisfied). The date at which patients were allowed to wear normal shoes was noted in all cases. The metatarsophalangeal valgus angle (M1P1 angle) and the intermetatarsal angle (M1M2) were measured preoperatively and at last follow-up on AP weight-bearing foot radiographs. Healing of the arthrodesis was assessed on AP and lateral radiographs (complete fusion, partial healing, persistent joint line). The position of the arthrodesis in dorsiflexion was measured at last follow-up on the weight-bearing lateral radiograph from the angle formed by the axis of the first metatarsal bone (parallel to the dorsal cortical) and the axis of the first phalanx. Statistical analysis of the results was performed using the Student t test for quantitative variable comparison.

Results (Figs. 7 and 8)

All patients were reviewed. The mean follow-up period was 18 months (range, 10 to 30 months). The functional AOFAS score improved in all cases, from 36/100 (range, 10 to 59) preoperatively to a mean value of 80/100 (range, 59 to 90) postoperatively (p = 0.02). The functional score items (pain, function, alignment) all improved (p < 0.05). The postoperative mobility score was 0/10 in all cases and the maximum overall score could only be 90/100 postoperatively. Thirty out of 32 cases were satisfied or very satisfied, one patient was disappointed (AOFAS score: 68/100) and another one was dissatisfied (AOFAS score: 59/100). All satisfied or very satisfied patients could wear normal shoes after a mean period of 50 days (range, 35 days to 4 months). Radiographic healing was achieved in 31 out of 32 cases. A persistent joint line was reported in one case at 2-year follow-up. Complete healing was achieved after a 6-week to 3-month period in 26 cases, at 4 months in two cases and at 6 months in three cases. The mean metatarsophalangeal joint valgus was 23° (range, −16° to 60°) preoperatively and 11° (range, 0° to 19°) postoperatively. The mean metatarsus...
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Figure 7  Hallux rigidus. a: preoperative aspect. b and c: at 2-year follow-up.

Figure 8  Hallux rigido-valgus. a: preoperative aspect. b: at 1-year follow-up.

varus was 11° (range, 5° to 25°) preoperatively and 9° (range, 5° to 16°) postoperatively. The mean arthrodesis position in dorsi flexion was 21° (range, 15° to 35° in a patient with pes cavus deformity of the foot). No significant difference could be found between the arthrodesis position in dorsi flexion measured at 10 postoperative days (mean value 19°, range, 15° to 35°) and that observed at last follow-up (N/A).

The dissatisfied female patient reported the only severe complication of the series: she developed surgical site infection on the third postoperative week, managed with local and antibiotic treatment, and later developed pseudarthrosis with persistent pain. At 2-year follow-up, pain had decreased without completely disappearing, the AOFAS was 59/100, there was no evidence of focal mobility and despite the lack of healing of the arthrodesis, the patient refused to undergo any further surgery. In one patient, screws had to be removed at 7 months since they induced pain.

Discussion

Percutaneous arthrodesis of the first MTP joint is an easy and rapid surgical procedure which functional results are similar to those obtained with an open arthrodesis technique, and reports over 90% of satisfied patients, with significant improvement of the functional AOFAS score [2,9,15–19].

In conventional open arthrodesis procedures of the first MTP joint, bone-surface preparation sometimes require an extensive surgical approach which may induce postoperative pain and improper healing [8]. One of the advantages of the percutaneous technique for arthrodesis of the first MTP joint is the immediate decrease in postoperative morbidity (limited pain and rare wound healing problems) which allows ambulatory surgery and immediate full weight-bearing with a rigid flat-bottom shoe.

Our technique is an easy and rapid one but some precisions need to be made. Osteophyte resection should be supervised and adapted to the symptomatology (dorsal
and medial osteophytes often result in painful shoe wear whereas lateral osteophytes are rarely symptomatic. Excessive resection should be avoided as it might lead to bone loss (commonly asymmetrical and at the expense of the first metatarsal head) which could compromise the arthrodesis primary stability. Bone-surface preparation is the most critical stage of the procedure and should be performed by an experienced surgeon familiar with percutaneous forefoot surgery. In the present technique, the flat bone surfaces should be cautiously prepared since any error will have an impact on the arthrodesis positioning. Actually, the amount of bone resection when using a reamer should be controled to avoid any loss of bone substance most commonly asymmetrical and associated with poor primary stability due to the absence of contact and shortening of the first ray. Some traps should be avoided:

- excessive metatarsal resection: the basis of the first phalanx usually has a more sclerotic and denser aspect than the metatarsal head, therefore the reamer will tend to spontaneously resect the metatarsal head. There is a risk of over-resection of the metatarsal head with associated shortening of the first metatarsal, loss of primary stability, positioning of the arthrodesis in metatarsus elevatus and a risk of transfer metatarsalgies due to the absence of first ray loading. Therefore, the reamer should be controled by applying a higher pressure on the phalanx than on the metatarsal and perform reamer positioning and bone resection under fluoroscopic guidance;
- excessive dorsal resection: the plantar region of the first MTP joint is less easily accessible than the dorsal part (particularly in case of hallux rigidus with major stiffness) and the reamer will tend spontaneously to resect the dorsal part of the joint line. This leads to the risk of asymetrical V resection at the dorsal basis with excessive dorsal resection, loss of primary stability and excessive dorsi flexion of the first phalanx. Bone-surface preparation should be performed by applying traction in the first ray axis for decoaptation of the first MTP joint to provide better access to the plantar region, good control of bone resection and parallel bone cuts on the lateral view.

Bone-surface preparation with concave convex cuts is a more reassuring procedure since it facilitates arthrodesis positioning, reduces first ray shortening and improves stability [12,15]. However, such method is hardly reproducible through the percutaneous technique since it requires a specific instrumentation.

Positioning of the arthrodesis is a critical stage of the procedure. The surgeon should not only take into account the positioning in varus-valgus, dorsiflexion-plantar flexion, pronation-supination but also the metatarsus varus, the metatarsal formula, the hindfoot morphology (valgus flat foot, pes cavus), the symptomatology (metatarsalgies of lateral rays, toe deformities) and shoe wearing habits (flat or high-heeled shoes) [5—9]. Good arthrodesis positioning is quite easy to achieve through the percutaneous technique and may be both clinically and radiographically assessed at any time. The use of a support simulating the bearing surface promote proper positioning of the hallux in the sagittal plane to obtain a good pulpar weight bearing whatever the hindfoot or midfoot morphology [8,9]. In our experience, tenotomy of the extensor hallucis longus was never performed.

Fixation of the arthrodesis using a dorsal plate seems to be the safest option and provide the highest healing rate even if it also depends on the amount of bone loss and of the aetiology (there is a higher risk of non-union in case of osteoporosis or failure of previous surgery) [12—14]. Plate osteosynthesis is only possible in case of percutaneous surgical approach. The use of cross-cannulated screws for the fixation of first MTP joint percutaneous arthrodesis is easy and the quality of contact and proper positioning of the arthrodesis may be assessed at any time which ensures precise screw placement under fluoroscopic guidance. Since the use of cross-cannulated screws is not the most stable fixation option, good control of screw positioning is essential to achieve the best compression and prevent the screws from crossing at the level of the joint line which could lead to excessive stress [8,9]. Axial screwing or parallel screw positioning may be easily performed with the percutaneous technique. However, in this series, no significant modification of the arthrodesis in dorsi flexion could be observed between the first control (at 10 post-operative days) and last follow-up, despite the immediate full weight bearing with a rigid flat-bottom orthopaedic shoe. The percutaneous surgical approach prevents massive capsulo-ligamentous detachment and devascularization for proper bone-surface exposure and preparation which may promote the intrinsic stability of the arthrodesis and healing but further studies should be conducted to confirm such hypothesis.

Conclusion

Percutaneous arthrodesis of the first metatarsophalangeal joint is an easy procedure which provides comparable results to those reported with conventional open arthrodesis techniques. Postoperative management is simple with immediate full weight bearing in a rigid orthopaedic shoe and return to normal walking within about 2 postoperative months. The bone-surface preparation is the longest stage of the procedure and should be performed by an experienced surgeon familiar with percutaneous surgery. Positioning and fixation of the arthrodesis using this technique are easy procedures which may be clinically and radiographically controlled at any time.

Conflicts of interest

None.

References

[1] Mann RA, Oates JC. Arthrodesis of the first metatarsopha-