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First metatarsophalangeal fusion using joint specific dorsal plate with interfragmentary screw augmentation: Clinical and radiological outcomes

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ABSTRACT

Background: This study reports the outcome of a plating system for arthrodesis of the first metatarsophalangeal joint (1st MTPJ) that incorporates a lag compression screw within a low profile titanium plate with a predetermined contour. This is the first report of the outcomes of this implant from a non-affiliated centre.
Patient and methods: This is a prospective cohort study of 40 consecutive primary 1st MTPJ arthrodesis procedures. The mean age of the cohort was 56 years (range, 20–74 years). The diagnosis was hallux rigidus in 31 patients and inflammatory arthropathy in 7 patients.
Results: All patients achieved clinical union at 6 weeks and radiological union was confirmed on plain radiographs between 6–16 weeks. One case of hardware removal was reported.
Conclusion: The cohort achieved consistently satisfactory results with a reliable and reproducible MTPJ position and a 100% union rate. There was a low rate of hardware removal.
Level of evidence: Level IV evidence. Prospective cohort study.

1. Introduction

Ankylosis of the first metatarsal phalangeal joint (MTPJ) had been described as early as 1887 by Kelikian [1] and later by Clutton in 1894 [2] who concluded that stiffness of the 1st MTPJ, in an optimal position, would produce a longstanding and satisfactory result for patients with degenerative arthritis and hallux valgus.

McKeever advocated the use of rigid internal and external fixation techniques for 1st MTPJ arthritis [3]. Numerous techniques have been used in both the preparation [4–6] and fixation of the articular surfaces [7–9]. Preparation options include; cup and cone shaping of the bone surfaces [4,5,10], that have the advantage of versatility in positioning of the fusion site and increases the stiffness at the fusion site, and flat cut surfaces [6,11] that increase the surface area for fusion [12]. Methods for fixation of the arthrodesis include interfragmentary screws (oblique single, parallel and cross configuration), dorsal plates and a combination of interfragmentary screw with a dorsal locking plate [7–9,13]. Despite the various joint preparation and fixation methods described, the objective is to achieve reproducible rigid fixation, high rates of fusion, reproduce anatomical position of the arthrodesed joint and reduce hardware related symptoms that may lead to metal work removal.

The rate of fusion reported varies between 77% and 100% [4,5,8,10,11,14–18] with an average of 90% [19] and is dependent on the operative technique and method of internal fixation. Malalignment of the arthrodesed MTPJ in any plane is poorly tolerated [5,19]. Accurate positioning has an important role on hallux function, generation of hallux interphalangeal joint arthritis and ultimately patient satisfaction [17].

Biomechanical studies report that fixation using a lag screw and a dorsal plate has the greatest mechanical stability when compared to other fixation methods with screws or plates alone [20]. Whilst reported fusion rates with dorsal plates have shown good success [5,10], larger and bulky small fragment compression plates have frequently required removal [19,21]. There has been an evolution of the dorsal plate, with low contour plates and first metatarsophalangeal joint specific plates with locking and non-locking options. There has been concern that these plates may not provide adequate compression, and may be augmented with an interfragmentary screw.

The new generation of low contour dorsal plates incorporate an interfragmentary screw, which can be in the shaft of the plate or within a phalangeal arm [18]. The Anchorage metatarsophalangeal

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cross plate system (Stryker®, Selzach, Switzerland) design positions the interfragmentary screw head in a counterbore within the shaft of the plate that is angled obliquely, from dorsal to plantar side, across the fusion site. This technology creates an interfragmentary lag and compression across the targeted fusion area. The prefabricated angulated dorsal plate has a landmark line to ensure correct positioning and an oblong hole in the plate to allow further compression. The plate design reduces the risk of malposition of the arthrodesis, whilst providing rigid fixation, with greater biomechanical advantage, and potentially lower rates of secondary hardware removal. To our knowledge, this is the first study to assess outcomes, clinical and radiological, of a consecutive series of patients using this implant.

2. Patients and methods

This was a prospective cohort study. A total of 40 cases (38 patients) underwent primary arthrodesis of the 1st MTPJ at our centre between August 2013 and November 2016. The procedures were performed by a Consultant foot and ankle surgeon. Patients were excluded from the study if they had previous failed 1st MTPJ arthrodesis, previous osteotomy to the hallux or previous open reduction and internal fixation for fracture of the hallux. All included patients had standardised antero-posterior and lateral weight bearing radiographs taken preoperatively. The mean age of the sample was 56 years (range, 20–74 years). The diagnosis was hallux rigidus in 31 patients and inflammatory arthropathy in seven patients.

Preoperative and postoperative Manchester Oxford Foot Questionnaire [22] (MOXFQ) and EuroQol EQ-5D [23] scores were obtained in 38 cases. Two patients were lost to follow up. Pre-operative scores were obtained at the time of attending the outpatient clinic prior to surgery. Post-operative scores were obtained by telephone and paper records were electronically scanned. A postoperative score was obtained at a mean time of 15 months (with a range of 3–42.1 months). All patients were reviewed at 2 weeks in a nurse lead clinic for wound inspection. Radiological and clinical assessment was performed at 6 weeks and 12 weeks. Subsequent follow up was only arranged if there was unsatisfactory evidence of union or a complication was evident. Postoperative wound complications, implant related failure or removal were all recorded in the patients' notes and clinic letters. Primary outcome measures were MoxFQ, EQ5D and union.

Clinical union was defined as a pain free joint with no motion. Radiographic union is achieved when bridging bony trabeculae is observed across three quarters of the MTPJ on postoperative radiographs in at least one projection. Statistical analysis was performed using the student T-test.

3. Operative technique

The operative technique with the steps outlined below was used in every case. Surgery was performed under a general anaesthetic followed by administration of a local anesthetic ankle block. A 20 mL mixture of 1% lidocaine and 0.5% bupivacaine was used. Patients were positioned supine on a standard operating table. A sandbag was placed underneath the ipsilateral buttock in order to achieve a neutral rotation of the foot. A high thigh tourniquet was applied.

A dorsal approach to the MTPJ from the midpoint of the proximal phalanx to the junction of the mid and distal third of the metatarsal (MT) shaft was utilised. The appropriate size cone and cup shaped reamers are then used to prepare the joint surface. A 2 millimetre (mm) drill bit is used to make drill holes in the prepared bony surfaces. The bone debris created by the drill flutes is used as local graft.

A 1.6 mm kirschner wire is used to hold the joint surfaces in the desired anatomical position under fluoroscopic control. The locking plate template is placed over the MTPJ with the landmark marker directly over the MTPJ. The position is checked with fluoroscopy and a 1.2 mm kirschner wire is advanced through the proximal kirschner wire hole. The cross plate (CP) reamer is placed over the kirschner wire and dorsal metatarsal surface is reamed creating a cavity for the plate lag screw counterbore.

The plate is placed flush to the metatarsal, with the counter bore for the lag screw fitting into the cavity prepared. Locking screws are sited proximally, then a non-locking 3.5 mm screw is placed through the counterbore of the plate to achieve compression. Care should be taken to ensure the trajectory of the nonlocking screw is in the correct obliquity to exit in the plantar cortex of the proximal phalanx (Figs. 1 and 2). Distal locking screws are placed in the proximal phalanx. The capsule is reflected back and closed over the plate to protect EHL and skin from the plate.

The skin is closed with a number 3-0 vicryl rapide. Dressing gauze, wool and crepe bandage is applied. All patients are given a flat postoperative rigid shoe for 6 weeks and are allowed full

Fig. 1. Anteroposterior plain radiography demonstrating implant.

Fig. 2. Lateral plain radiography demonstrating implant.

weight bearing. Low molecular weight heparin is given only if the risk of venous thromboembolism is present.

4. Results

Of the 40 procedures, clinical union was achieved at the first follow up between 6 to 8 weeks postoperatively. In 30 cases radiographic union was achieved at the first follow up (6–8 weeks). The remaining ten cases achieved radiographic fusion by their next postoperative follow up appointment at 12 weeks (range, 12–16 weeks). One patient developed pain at 4 months and underwent blood tests and a computed tomography scan, which excluded infection and demonstrated radiological union.

No wound related complications were observed. The hardware removal rate was 2.5% (1/40). This patient reported symptoms from the plate tip over the proximal phalanx and had the plate removed. No revision arthrodesis procedures were performed.

The mean preoperative and postoperative MOXFQ scores, in each of the 3 domains are illustrated in Fig. 3. The mean postoperative MOXFQ score in the Walking/Standing and Pain domains were significantly lower than preoperatively with a P value = 0.002 and P value = 0.004 respectively. Fig. 4 shows the proportion of patients reporting a problem in each of the 5 domains pre- and postoperatively. Preoperatively 92% (35/38) of cases reported a problem with mobility and 87% (33/38) had pain. Postoperatively 61% (23/38) resolved their problems with mobility and 55% (21/38) resolved their pain completely. The mean Visual Analogue Score (VAS) significantly improved from 62% preoperatively to 82% postoperatively, P value = 0.01.

5. Discussion

First MTPJ fusion has been reported to improve pain [17], provide a normal or near normal gait [24], improve balance and

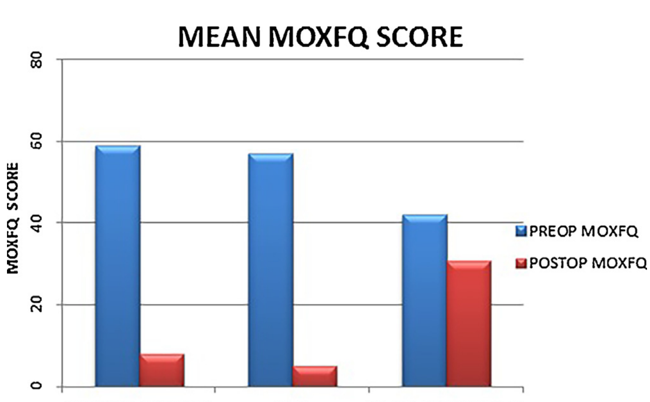

Fig. 3. Bar chart showing the mean MOXFQ scores in the 3 domains.

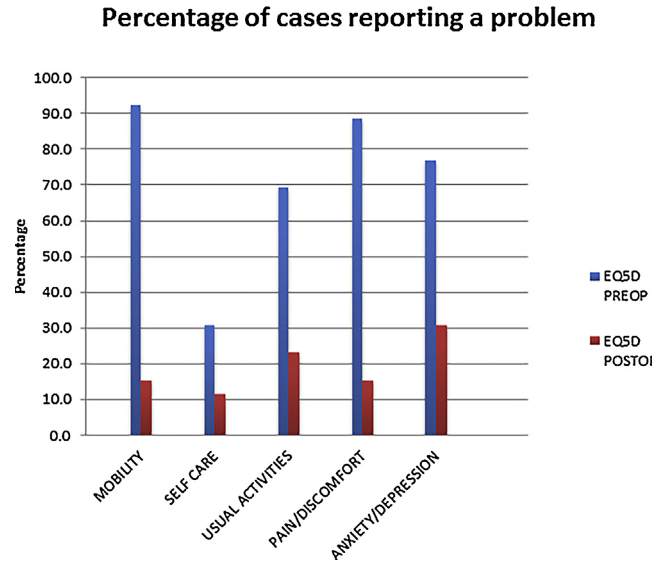

Fig. 4. Percentage of cases reporting a problem pre- and postoperatively.

enable fitting into normal shoes [25]. In order to achieve good clinical results, it is important to achieve an anatomical position of the hallux [26], adequate flexion of the distal interphalangeal joint (DIPJ) at toe off, correcting the intermetatarsal angle associated with a hallux valgus deformity [27] and ultimately obtaining a successful arthrodesis.

Successful fusion after 1st MTPJ arthrodesis is dependent on technical and biological factors. The technical factors include satisfactory joint surface preparation, correct position of the fusion and the fixation technique employed (Figs. 1 and 2). Biological factors include co-morbidities (such as inflammatory arthropathy and vascular disease), regular medications (such as corticosteroids and non-steroidal anti-inflammatory drugs) that can hinder healing and smoking. Preparing joint surfaces in a cup and cone configuration has the advantage of being versatile in positioning of the fusion site and increases the stiffness at the fusion site [12]. The use of flat cuts to the joint surfaces may increase surface area for fusion, with Politi et al. [20] also suggesting that this preparation provided more stability than conical reaming when oblique compression screws are used for fixation. Planar joint excision pre-determines the alignment of the arthrodesis. Curtis et al. [12] reported that a conical construct required significantly higher loads to failure, whether crossed wires, interfragmentory screws or plates were used for fixation.

The fixation construct should be mechanically strong, biocompatible, bone conserving, implanted with a precise and reproducible technique and should not routinely require hardware removal. Fixation with k-wires [7,28], cerclage wire loop [29,30], screws [6,31], a dorsal plate [19,32,33] and low profile titanium plate [5,8,10] have been described. Politi et al. [20] studied the strength of five different fixation constructs and found the strongest was with conical reaming fixed with a mini-fragment plate and lag screw. They suggested that the low resistance of a dorsal plate alone technique to micromotion can be explained by the fact that the plate is applied on the dorsal side which is the compression side of the joint and is therefore at a biomechanical disadvantage.

Fusion rates as high as 90% has been reported in a large series using a number of fixation methods [33]. Arthrodesis with a titanium plate and a compression lag screw reported 98% fusion [10] and 98.7% fusion without a screw [4]. In our series all patients achieved clinical fusion at or following their 6–8 weeks review. Our results produced 100% union and are comparable to other reported studies [10,13,16,18,34].

In addition to rigid fixation and reproducibility of the surgical procedure, one of the goals is to prevent the need for further surgery, specifically, hardware removal. Mann and Oates [24] reported fusion rates of 94%, however they planned removal of all hardware, which occurred at an average of 111 days postoperatively. Subsequent procedures to remove hardware come with associated risk and can indeed add to the cost of the procedure. Reports on removal of hardware vary between 6% [32] to 34% [19].

In our study, only one patient had symptoms related to metal work. The distal part of the plate was prominent, which we feel was related to technical error (Fig. 5). The low-profile plate shall only position appropriately if the cross-screw countersink is prepared satisfactorily. In this case, the countersink was not deep enough to seat the plate and thus it became prominent distally. This was acknowledged as a technical error and avoided subsequently. There were no cases of metal work failure and no hardware related pressure symptoms were reported. Infection rates of 3–6% [35,36] have been reported with 1st MTPJ arthrodesis. There were no documented infections in our case series.

The postoperative treatment regimen may also be a contributing factor to non-union. Ellington et al. [8] reported a 12% non-union rate with stainless steel plates, in patients commencing weight bearing in a boot at two weeks postoperatively. Hunt et al. [37] described a non-union rate with a locking plate of 23% with the same postoperative protocol. Our protocol allowed weight bearing from the day of surgery in a rigid shoe for the six weeks. This permits earlier mobilization, facilitates patient discharge on the day of the operation, allows earlier return to work and appears not to have an adverse affect on union. We believe this is due to the rigidity of the construct.

Malunion is poorly tolerated by patients [38]. Dorsiflexion of less than 10 degrees can result in increased pressure at the tip of the hallux [14], while excessive dorsiflexion results in increased pressure beneath the metatarsal head [25]. Excessive pronation or medial rotation of the hallux can lead to pressure along the medial border, and rotational mal-alignment should be avoided [39].

The authors believe that the reported system addresses many of the concerns above, with the use of a low contoured prefabricated angulated dorsal locking plate that incorporates an interfragmentary screw. The shape of the plate dictates the position of arthrodesis to ensure reproducibility and reduce human error. In our experience, in no case was plate contouring required and optimal alignment was achieved with no cases of mal-union reported. The interfragmentary screw was positioned in a satisfactory position across the fusion site in all cases. However, the system does not address the concern voiced by Politi et al. [20] regarding the plate being applied on the compression side of the fusion. Biomechanically, the plate should be applied on the tension side of the fusion site, however our results suggest that compression was achieved and subsequent union in all cases with the use of the combined interfragmentary screw and dorsal plate technique.

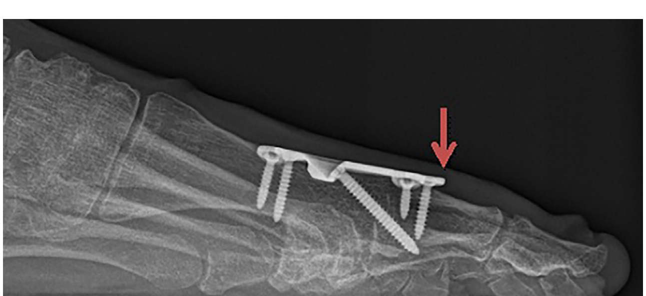

Fig. 5. Showing elevation of the distal tip of the plate (arrow).

In our institution, a first MTPJ fusion utilising the anchorage cross plate achieved consistently satisfactory results with a reliable and reproducible MTPJ position and a 100% union rate. The complication rates were close to zero with only 2.5% (1/40) rate of hardware removal.

This study was limited by the low number of cases, which reduces the strength of the findings. Also, there was no control cohort to compare the results with. Further work would require a randomised controlled study assessing the various operative techniques to determine the most consistent method with lowest complication profile.

Conflict of interest

There are no sources of funding to declare, nor any conflict of interest.

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