



Comparison of 4 different techniques in first metatarsophalangeal joint arthrodesis

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Abstract

Aims The aim of this study was to evaluate outcomes and fusion rates of 4 different methods of first metatarsophalangeal joint (MTPJ) arthrodesis.

Methods We performed a retrospective analysis of first MTPJ fusion using Bold® and Acutrak® compression screws, universal 1/3 tubular plate and Hallu®-S non-locking plate in 6 hospitals in Dublin over 4 years. A cohort of 300 patients (351 feet) was operated on by 3 feet and ankle fellowship trained orthopaedic surgeons (PK, MMS, JVmK) over 4 years. Mean age was 62.4 years. There were 261 females and 39 males. One hundred three patients had a fusion of first MTPJ using two Acutrak® screws and 90 with two Bold® screws. Sixty-five were fused with the Hallu-S® plate and 42 with the universal 1/3 tubular plate. Patients were evaluated clinically and radiographically at 6 weeks, 3 months and 12 months.

Results Functional outcome scores performed using Manchester-Oxford Foot Questionnaire (MOXFQ). Failure rate in those fused with the Hallu®-S plate was 0%, Acutrak® screws 2.4%, Bold® screws 9.5% and universal 1/3 tubular plate 12.5% ($p > 0.12$). All treatment groups demonstrated significantly reduced MOXFQ scores (p value < 0.05).

Conclusion In this retrospective study for first MTPJ fusion, a low profile, pre-contoured plate in combination with a screw mode had the best results with no failure rates and improved MOXFQ scores.

Level of clinical evidence: IV, retrospective study.

Keywords Fusion · Metatarsophalangeal joint · Osteoarthritis

Introduction

Hallux valgus was initially described by Hueter et al. [1], where the great toe is laterally subluxed at metatarsophalangeal joint and called it “hallux abducto valgus”. Clinically, patients with end-stage *hallux valgus* present with pain over the bunion, mainly as a result of pressure from foot wear [2]. With increasing severity, there are other pathologies, such as pronation of great toe, overriding second toe and, other lesser toe deformities.

Symptomatic end-stage *hallux valgus* and *hallux rigidus* with marked degenerative changes are treated with first metatarsophalangeal (MTP) joint arthrodesis. The first report of the first MTPJ fusion was made by Broca [3] in 1852, followed by Clutton [4] in 1894, and popularised by McKeever [5] in 1952. This procedure is performed primarily for the alleviation of pain, correction of deformity and restoration of activities of daily living.

End-stage *hallux rigidus* is a painful degenerative disease of the first MTPJ, where patients present with increasing pain during ambulation [6]. On clinical examination, patients complain of tenderness, crepitus and joint fullness with either reduced or no range of motion in dorsiflexion and the great toe can also be found in a plantar flexed position [7]. Radiographically, when the hallux shows grade 4 degenerative changes [8], the joint space is narrowed and flattened, have dorsal osteophytes, subchondral cysts and sclerosis.

Various techniques have been described for first MTP joint fusion to optimise the biomechanical properties and fusion rates. These include the use of; Kirshner-Wires (K-Wires) [9,

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10], memory staples [11, 12], 1/3 tubular plates [13], mini plate [14, 15], pre-contoured locking and non-locking plates [16–21], and single and crossed compression screws [22–25]. The Aim of this study was to compare the fusion rates between 4 different techniques by analysing clinical records and radiographs at 6 weeks and 3 months. Patients' functional outcomes also evaluated post operatively, using Manchester-Oxford Foot Questionnaire (MOXFQ).

Material & Methods

The operations were performed in 3 orthopaedic institutions in Ireland by three foot and ankle fellowship trained orthopaedic surgeons between September 2008 and December 2012. A total of 300 patients (351 feet) were included in the study. Mean age was 62.4 years (range 29–83 years). Two hundred sixty-one female patients and 39 male were included in the study. Table 1 illustrates the baseline characteristics of patients with various implants. This study was approved by the local institutional review boards.

Patients' clinical records from the six institutions were retrospectively analysed. Follow-up radiographs were obtained from the six hospitals picture archiving communication system (and evaluated by two senior assessors (FM and AJCG) who were not involved in the index and any revision procedures. Radiographic arthrodesis was confirmed by bridging trabeculae across three cortices on weight-bearing anterior-posterior (AP) and lateral radiographic views [26]. Patients diagnosed with either symptomatic end-stage *hallux valgus* (274 feet) or *hallux rigidus* (77 feet). One hundred three out of 300 patients (34.3%) had a fusion of first MTP joint using two crossed Acutrak® screws (Acumed™) and 90 patients (30%) with two crossed Bold® screws (Integra Life Sciences™). Sixty-five (21.7%) patients were fused with Hallu®-S non-locking plate system (Integra Life Sciences), and 42 patients (14%) had a universal 1/3 tubular plate.

Surgical Technique

A dorso-medial approach was used in patients who had Hallu®-S and universal 1/3 tubular plates and the medial

approach was utilised in patients with Acutrak® and Bold® screws. Conical reamers used for debriding first metatarsal and proximal phalanx articular surface in patients with Hallu®-S plate, Acutrak® and Bold® screw. However, a flat-cut osteotomy of the distal end of first metatarsal and base of the proximal phalanx was carried out in patients that had the 1/3 tubular plate.

Post-operative protocol

Patients who underwent Acutrak® and Bold® screw fusion were mobilised with a post-operative shoe. They were allowed heel weight bearing for the first 6 weeks and full weight bearing thereafter. Patients with a Hallu®-S plate fusion were non-weight bearing for the initial 2 weeks, followed by 2 more weeks of heel weight bearing, and a final 2 weeks of full weight bearing. Patients who had their first MTPJ fused using a 1/3 tubular plate, were placed in a forefoot gravity elimination “Barouk shoes” to weight bear fully immediately after the operation. Patients were assessed clinically and radiographically at 6 weeks, 3 months and 12 months. The patients in this study had an average follow-up of 12 months with a maximum of 48 months. Functional outcome measures performed using Manchester-Oxford Foot Questionnaire (MOXFQ) [27]. High scores reflect the severity of the patient symptoms and a reduction in the scores would signify an improvement. The highest scores in each category that can be attained are walking/standing: 28, pain: 20 and social: 16. The questionnaire was posted to all patients in a self-addressed envelope and those patients that did not respond were contacted by telephone.

Statistical analysis

Statistical analysis was performed using SPSS software version 21.0 (IBM Corp.). The statistical difference was set at *p* value of < 0.05 with the power of 0.90 to determine the number of patients required for this study. The difference in demographic information among the four procedure groups was analysed using one-way analysis variance. A chi-square test was used to analyse the patient reported outcome measure to detect any significance between the 4 fusion methods.

Table 1 Baseline characteristics of the study patients operated for first MTPJ fusion

	Hallu®-S plate	Universal 1/3 tubular plate	Acutrak® screw	Bold® screw
Age (mean)	62.4	63.4	61.2	64.6
Females (<i>n</i>)	50	36	96	79
Males (<i>n</i>)	15	6	7	11
<i>Hallux Valgus</i> (<i>n</i>)	49	40	102	83
<i>Hallux Rigidus</i> (<i>n</i>)	23	8	24	22
Left foot (<i>n</i>)	35	22	61	58
Right foot (<i>n</i>)	37	26	65	47

Results

A total of 300 patients (261 females and 39 male) took part in the study. Sixty-five patients underwent first MTPJ fusion using Hallu®-S non-locking plate, and 42 with universal 1/3 tubular plate. One hundred three patients fused with Acutrak® screws and the Bold® screw used in 90 patients. The mean age for Acutrak® screw group is 61.2 (range 29–77) years, Hallu®-S group was 62.4 (range 34–76) years, universal 1/3 tubular plate 63.4 (range 46–84) years, and 64.6 (range 26–83) years for Bold® screw group.

All 72 patients in the Hallu®-S group underwent successful first MTPJ fusion, and in the universal 1/3 tubular plate group, fusion was established in 36 out of 42 patients (86%). One hundred out of 103 patients in the Acutrak® screw group (97%) and 80 out of 90 patients in the Bold® screw group (89%) demonstrated complete fusion. Seven out of 65 patients in Hallu®-S plate group and 6 out of 42 patients in the 1/3 tubular plate group needed staged bilateral MTP joint fusion. Acutrak® screws were used in 126 feet and Bold® screws in 105 feet. A total of 23 patients needed staged bilateral first MTP joint fusion in Acutrak® group and 15 in the Bold® screw group. Detail data on the number of patients, implant types and failure rates demonstrated in the following flow sheet (Fig. 1). Figures 2 and 3 represent the percentage of implant used and their failure rate.

The main complication was symptomatic non-union and hardware failure, requiring revision arthrodesis. Failure of first MTPJ fusion included 9 patients (10 feet) in Bold® screw group (see Fig. 4a), 6 patients (6 feet) in universal 1/3 tubular group (see Fig. 4b), and 3 patients (3 feet) in Acutrak® group (see Fig. 4c). However, there was no failure, recorded in

Hallu®-S group, this was not statistically significant (p value > 0.12).

The fusion rate between the 2 pathological entities was analysed. All the 77 feet with *hallux rigidus* went on to complete fusion clinically and radiologically at the three-month follow-up. However, 17 out of 274 feet in patients with *hallux valgus* went into non-union in this cohort study. This included 8 feet using crossed Bold® screws, 6 feet with AO 1/3 tubular plate and 3 with crossed Acutrak® screws.

The Manchester-Oxford Foot Questionnaire (MOXFQ) [27] was used to measure the functional outcomes of all patients. All mean functional scores (with standard deviations) are represented in Table 2. At the mean follow-up of 12 months (range 6–48 months), a significant reduction was noted in MOXFQ scores for all 4 groups. The highest scores for the mean pain, walking/standing and social parameters were recorded in the universal 1/3 tubular plate group, and the lowest scores were seen in the Acutrak® screw group. The p value for pain parameter was significant ($p < 0.007$ with 95% confidence interval of 1.68–2.17) among all 4 groups. This was also true with respect to the walking/standing parameter with $p < 0.008$ (with 95% confidence interval of 1.68–2.58). However, the social score p value fell short of any significance between all groups ($p = 0.55$ with 95% confidence interval of 0.99–1.79) (Table 2).

Discussion

Various methods have been described for first MTP joint arthrodesis, using a host of different implants [3–5, 10–25]. To our knowledge this is the largest retrospective study,

Fig. 1 Flow chart representation of 4 procedures

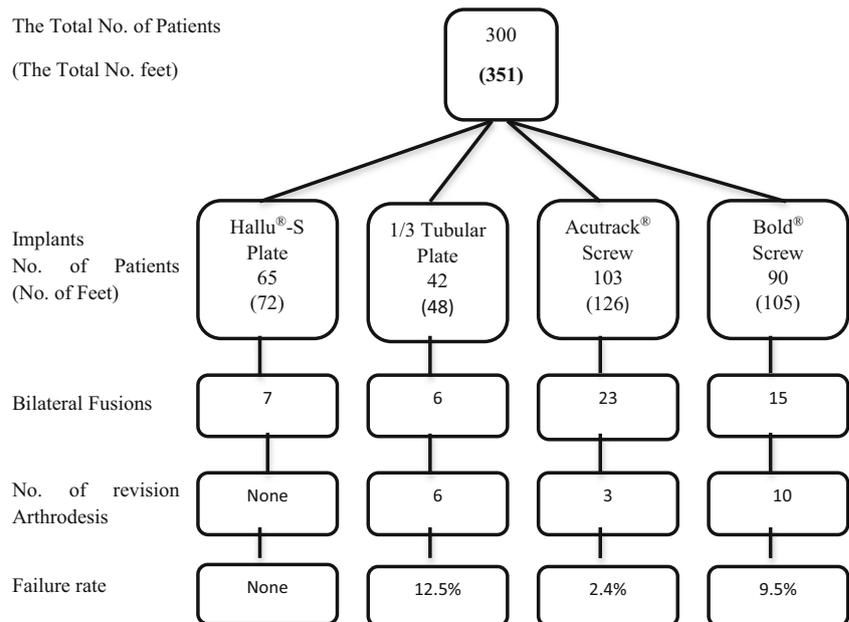
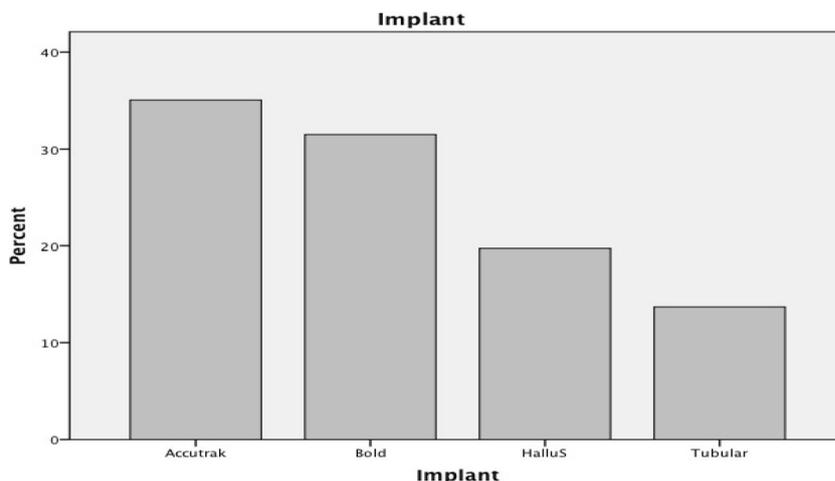


Fig. 2 Represents the percentage of implant used



comparing 4 different techniques used in first MTP joint fusion. These include Hallu®-S non-locking titanium plate in combination with a lag screw and Universal 1/3 tubular plate with a lag screw, 2 cross Acutrak® and 2 cross Bold® compression crossed screws.

In this study, Hallu-S® non-locking titanium plate showed the highest fusion rate at 3 months follow-up, in both the clinical and radiographic assessment. Several clinical and biomechanical studies have also observed similar results [14, 19, 20, 23]. Kumar et al. [20] demonstrated 98% fusion rate by using a low-profile contoured dorsal plate with compression screw in 46 patients. In a similar study [18], using a low-profile dorsal plate with a lag screw involving 50 patients (54 feet), the fusion rate was 92%. Coughlin et al. [18] demonstrated 98% fusion rate on a series of 47 patients (58 feet) and Aslam et al. [19] displayed 97% fusion rate (on 32 feet), using Vitallium plate and an oblique lag screw.

In two different clinical works by Denning et al. and Flavin et al., using Hallu®-S with a crossed compression screw for first MTPJ fusion demonstrated 93% and 100% fusion rate

respectively [19, 24]. Moreover, biomechanical work by Politi et al. were they compared 5 different techniques of first MTP joint fusion, concluded that the most stable construct is a dorsal plate with a compression screw [10].

In this study, the universal 1/3 tubular plate had the highest failure rate (12.5%). Various studies have also shown high failure rate [13, 15]. Ellington et al., using a stainless-steel dorsal plate for first MTP joint fusion in 98 patients (155 feet), demonstrated an 18.7% revision rate. However, the method of joint preparation may have a direct impact on the stability of the fusion. In the universal 1/3 tubular plate group, the articular surfaces were prepared with a flat-cut osteotomy, and we are not certain whether this might have had a deleterious effect on union rates as compared to ball and socket joint preparation [15]. Our results differ in comparison to those of Rothenwerger et al. [28], were they documented 22% non-union with a spherical reamer and 3% with flat-cut osteotomy in 110 first MTP joint fusions. Moreover, in a recent biomechanical study, the mean stiffness of 1/3 tubular plate, X-type locked plate and crossed screws were compared [13]. Foote

Fig. 3 The failure rate of the 4 fusion techniques

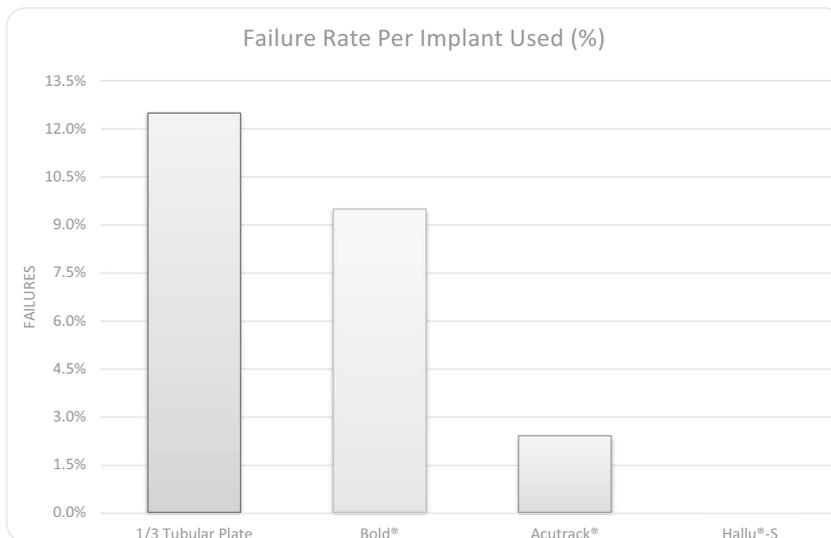


Fig. 4 **a** Post-operative AP X-ray of a failure of first MTP joint fusion with cutout cross Bold® screws. **b** Post-operative AP radiograph of the first MTP joint fusion non-union with a universal 1/3 tubular plate. **c** First MTPJ arthrodesis failure with crossed Acutrak® screws, showing lysis at 3 months



et al. showed that the mean stiffness of a 1/3 tubular plate was 25% and 49% greater than the X-type locked plate and crossed screws respectively [13].

With regard to crossed compression screws, Bold® screws showed the second highest failure rate (9.5%) in this study. Similar retrospective work by Mohammed et al. using crossed compression Bold® screws on a series of 21 patient (23 feet), demonstrated comparable results of 8.6% failure rate [25]. Work carried out by Dening et al. using crossed Bold® screws, in 21 feet, showed a 90% fusion rate. However, Acutrak® crossed compression screws in our study proved a failure rate of 2.4%, and to date we are unaware of any study, using this technique for fusion of the first MTP joint [24]. Curtis et al. compared 4 different techniques for first MTP joint arthrodesis and concluded that the most stable construct was the crossed interfragmentary screws [22]. In an in vitro study by Faraj et al., comparing crossed screws with circumferential wires on the synthetic bones, they showed that crossed screws fail by permanent deformation at a load six times higher than the wire construct [23]. Clinically, the results have shown that Acutrak® screws had a higher fusion rate than Bold® screws. We are unaware of any biomechanical study available in the literature comparing these 2 different screws designs. A biomechanical study comparing these 2-screw construct may be warranted.

This study included more than three times the number of feet with *hallux valgus* than the *hallux rigidus* when compared to the literature available. All the feet with *hallux rigidus* went on to unite without any complication; whereas, 6.2% of *hallux valgus* feet went to non-union, requiring revision fusion. MOXFQ was used for assessing clinical outcome and patient satisfaction in this study. This is a validated 16-item questionnaire that can be presented as either a profile form or as a summarised MOXFQ-index form [27]. We used the profile form to estimate the impact of treatment on the 3 specific domains of pain, walking/standing and social interaction. One potential shortfall of this study is that the MOXFQ was carried out retrospectively. However, there was a significant reduction in the mean scores of pain, walk/standing and social domains in all 4 groups. The patients in the AO 1/3 tubular group showed a considerable decrease in the three mean scores; nevertheless, they showed a relatively higher score than other techniques. This was closely followed by Bold® screw and Hallu®-S plate groups respectively. The lowest scores were recorded in the Acutrak® group. In this study, reduction in pain and walking/standing scores were quite significant. This indicates that all the four techniques used in first MTP joint arthrodesis had substantially reduced the patient pain and ambulatory difficulties. However, the patient social scores demonstrated a decrease in all four groups, but it did

Table 2 Mean Manchester-Oxford Foot scores for all 4 fusion groups

Implant type	MOXFQ mean		
	Pain score (Max = 20)	Walking/standing score (Max = 28)	Social score (Max = 16)
AO 1/3 tubular plate	2.57 (STD = 3.99)	3.64 (STD = 5.86)	2.20 (STD = 3.54)
Bold® screw	2.29 (STD = 3.99)	2.65 (STD = 4.06)	2.05 (STD = 3.81)
Hallu®-S plate	1.96 (STD = 3.49)	1.87 (STD = 3.71)	0.98 (STD = 2.11)
Acutrak® screw	0.86 (STD = 2.68)	1.07 (STD = 3.6)	0.72 (STD = 3.72)

STD Standard deviation

not contribute significantly to patient overall social interaction.

Weight bearing protocols after first MTPJ fusion vary from immediate weight bearing to non-weight bearing until 6 weeks after the fusion [29, 30]. According to current literature immediate or early weight bearing does not have any impact on the non-union rate if the construct is protected [29, 30].

The main limitation is the retrospective nature of the study; therefore, a baseline functional score could not be obtained. Furthermore, patients' co-morbidities were not collected and these may have effected the outcome of the fusion technique. Follow-up for this study is relatively short.

Conclusion

In this study, we compared failure rate and functional outcomes of 4 different implants, used in first MTP joint fusion for two end-stage pathological entities of the hallux. The results of this study would suggest that the use of a low profile, a pre-contoured non-locking plate with a lag screw for first MTP joint fusion results in no failure rate at the 12 months follow-up and it has also revealed a significantly lower Manchester-Oxford Foot Questionnaire scores. The second-best technique for first metatarsophalangeal joint fusion is 2 crossed Acutrak® screws, which demonstrate a low failure rate and low MOXFQ scores when compared with the other two techniques.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional review board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This is a retrospective study formal consent is not required.

Conflict of interest The authors declare that they have no conflict of interest.

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