ORIGINAL RESEARCH

Arthrodesis of the Second and Third Tarsometatarsal Joints: Comparison of Radiological and Clinical Results Using Combined or Individual Plating Techniques

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Abstract

Background: Arthrodesis is an effective treatment of midfoot arthritis in reducing pain and improving function. However, there is a known risk of nonunion. Our aim was to compare the outcomes of individual plating vs combined plating for the fusion of both the second and third tarsometatarsal joints (TMTJs). Our primary outcome was bone healing, and secondary outcomes include patient-reported outcome measures.

Methods: All cases underwent primary arthrodesis of the second and third TMTJs. Arthrodesis was performed using either a single "H-shaped" plate (combined plating group) or using two separate plates (individual plating group). The outcome measures were bony union and the Manchester Oxford Foot Questionnaire score (MOX-FQ).

Results: A total of 45 procedures were undertaken with a mean follow-up of 527 days. The combined plating group had 28 cases, and the individual plating group had 17 cases. There were 10 cases (35.71%) of nonunion in the combined plating group and two cases (11.76%) in the individual plating group. Multivariate regression analysis showed a significant relationship of union with the use of the individual plating group [$p = 0.047$, odds ratio (OR) 5.822]. Patients who had also undergone the first TMTJ fusion had an increased chance of union ($p = 0.043$, OR 9.896). No other factors showed significance. MOX-FQ scores were superior in the individual group at 6 months postsurgery, although this statistical significance was lost when the nonunions were excluded.

Conclusion: This study is the first to report a difference in the union between combined plating and individual plating techniques in arthrodesis of the second and third TMTJs. We believe that individual plates permit a more anatomical reduction and greater compression at the site of arthrodesis as compared to a dual plate technique, achieving better union results and an early better functional outcome.

Keywords: Arthritis, Fusion, Outcome studies, Plating, Tarsometatarsal joint.

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Level of evidence: Level III–a retrospective cohort study.

Background

Osteoarthritis is a common chronic degenerative disease of joints. It affects approximately 10% of men and 18% of women over 60 years of age.[1] The prevalence of osteoarthritis affecting the foot is under-reported compared to joints such as the knee and the hand.[2] Recent estimates put the prevalence of symptomatic and radiographic midfoot osteoarthritis at 16.7%, with often more than one joint affected. The prevalence of osteoarthritis at the second tarsometatarsal joint (TMTJ) specifically is between 5.7 and 7.8%.[3] Osteoarthritis of the tarsometatarsal joints causes pain (P), aching, and stiffness of the feet. These symptoms result in reduced physical and social function for patients.[4,5] There are socioeconomic implications of foot osteoarthritis owing to increased primary care consultations and a reduction in employment.[3,6]

Nonsurgical management of TMTJ osteoarthritis includes analgesia, steroid injections, and orthotics. Surgical management usually involves arthrodesis of the affected joints. Surgery is effective at reducing pain and improving function for patients, with patient satisfaction rates of up to 90%.[7,8] Reported complications of arthrodesis include infection, wound breakdown, nonunion, malunion, metalwork irritation, complex regional pain syndrome, and metatarsalgia. The rate of nonunion following TMTJ arthrodesis is reported to be approximately 11%.[9]

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Several techniques for arthrodesis of tarsometatarsal joints have been described. These include percutaneous wires, staples, screws in isolation, plates in isolation, and so-called "hybrid" constructs with a separate lag screw and plate construct.[10] We are not aware of any publications of outcomes focussing specifically on the combined fusion of the second and TMTJ. At our center, two techniques have been used for arthrodesis of adjacent tarsometatarsal joints. Either a single "H-shaped" plate (Stryker Anchorage Lisfranc plate) where both second and third TMTJs are fused using a single plate covering both joints (combined plating) or dual plates are used (Stryker Utility or Orthosolutions general

fusion plates), where each TMTJ is plated separately with single plates (individual plating).

The aim of this paper was to record and compare the outcomes of these two techniques. Our primary outcome is bone healing, and secondary outcomes include patient-reported outcome measures (Manchester Oxford foot questionnaire). The null hypothesis was there would be no difference in bone healing or functional outcomes between the two surgical techniques.

Methods

A retrospective study of prospectively collected data was undertaken. Patients who had completed 1-year postsurgical follow-up with the initial diagnosis of primary or secondary (posttraumatic) arthritis of the second and TMTJ were included. All patients had failed nonoperative measures prior to surgery. Exclusion criteria included, acute trauma, revision cases, and fusion for Charcot arthropathy. The surgical procedures were carried out by three fellowship-trained foot and ankle surgeons at a tertiary teaching hospital. The selection of surgical technique was the surgeon's preference.

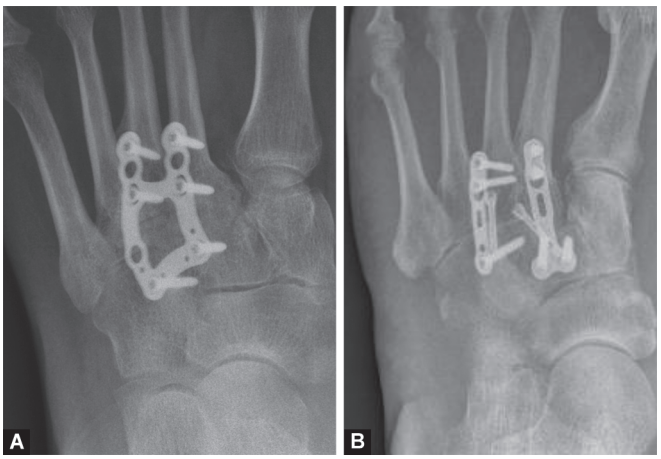
Operative Technique

The combined plating technique involved the use of a single "H-shaped" plate (Stryker Anchorage Lisfranc plate) placed dorsally in compression mode. This plate is designed to span the second and third TMTJs. The second technique, the individual plating group, involved using two separate plates (Stryker Anchorage Utility or OrthoSolutions UltOS). Arthrodesis was performed as per the technique described by Filippi et al.[10] A single incision was made dorsally, centered over the interspace between the second and third metatarsals. Subcutaneous tissues were separated, and branches of the superficial peroneal were identified and preserved. The tendon of the extensor hallucis brevis and the neurovascular bundle under the extensor hallucis brevis muscle belly was retracted medially. All articular cartilage was removed with flexible chisels, and subchondral bone was perforated multiple times with a 2.0 mm drill to encourage bleeding. With the combined plating technique, the second and third TMT joints were reduced anatomically, and then the single plate was applied. It was secured on the proximal aspect of the arthrodesis, and then compression was generated by placing two eccentric nonlocking screws on the distal aspect of the arthrodesis. With the individual plate technique, the adjacent TMTJs were reduced separately. Individual compression plates were then placed dorsally (Fig. 1).

Where necessary, lag screws were used to generate additional compression at the arthrodesis site. When they were used, lag screws were applied from the distal to the proximal direction prior to the application of the plate. Bone graft was used if there was a residual gap at the arthrodesis site following reduction, for example, if a large subchondral cyst was encountered. The graft used was an autologous cancellous or corticocancellous graft in all cases.

Data Analysis

Our primary outcome of bone healing was measured by the persistence of pain postoperatively and radiological evidence of the failure of bone union. Bone union was defined radiologically as trabecular crossing the fusion site on at least two of three radiological views (anteroposterior, Lateral weight-bearing and oblique radiograph). In cases where nonunion was suspected, a computerized tomography (CT) scan was undertaken. On CT, nonunion was diagnosed if there was <25% osseous union (Fig. 2).[11] All CT scans were reported by musculoskeletal radiologists.



Figs 1A and B: Anteroposterior radiograph of the (A) Combined; and (B) Individual plating techniques

Secondary outcome measures included the validated patient-reported outcome measure, the Manchester Oxford Foot Questionnaire (MOX-FQ).[12] The MOX-FQ is measured over three domains: walking/standing (WS), pain and social interaction (SI). Each is scored from 0 to 100, with lower scores being clinically superior. The three scores may be combined to give a summary index score (SIS). Dawson et al. described a minimally important clinical change of 13 for each of the MOX-FQ domains.[12] Scores were collected prospectively at a preoperative clinic at both 6 and 12 months postoperatively.

Statistics

Continuous parametric data are presented as the mean and 95% confidence intervals, and dichotomous data as a cross-tabulation of frequencies and percentages. Statistical analysis was performed using the student *t*-test if continuous data were tested to be normally distributed and Mann–Whitney or Fisher's exact test if tested to be nonnormally distributed. Binary data were tested using Chi-square. Uni and multivariate analyses were performed using univariate and multivariate logistic regression analysis to identify factors significant contributing factors to nonunion. The univariant analysis was performed using union as a dichotomous dependent variable. Any factor which achieved a *p*-value of <0.1 on univariate analysis underwent further multivariant regression analysis. Significance was given to variables that reached $p < 0.05$. Statistical analysis was undertaken using Statistical Package for the Social Sciences statistics version 27 (IBM, New York, United States of America).

Results

A total of 45 procedures were performed on 40 patients between March 2011 and January 2020 that met the inclusion criteria. The combined plating group included 28 cases, with the remaining 17 cases being the individual plating group. Patient demographics are summarized in Table 1. There were two nonunions (11.76%) in the individual plating group and 10 nonunions (35.71%) in the combined plating group. This difference was not statistically significant on Fisher's exact test ($p = 0.076$) when assessed without taking other factors into account.

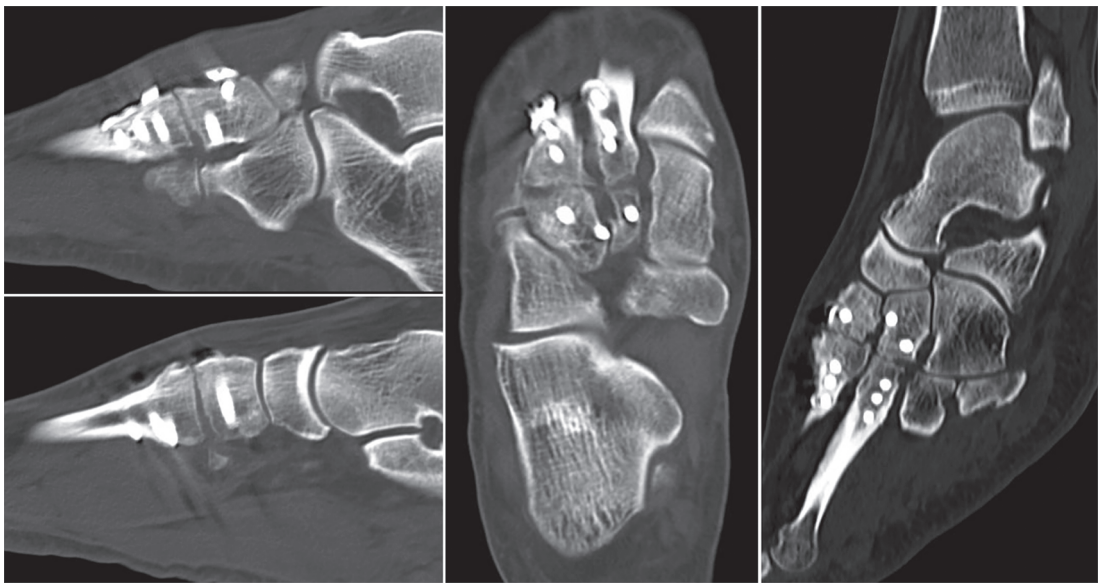


Fig. 2: Axial and sagittal CT slices through a foot 12 months postsurgery where a combined plating technique has been used; this shows the nonunion of the second TMT joint and partial union of the third TMT joint

Table 1: Cross-tabulation of patient demographics of the combined and individual plating groups (ASA, American Society of Anesthesiologists)

	Combined plating (n = 28)	*Individual plating (n = 17)*
Mean age (years)	60.00	63.20
Gender		
Male	2	6
Female	26	11
Laterality	15	5
Right	13	12
Left		
Comorbidity		
Diabetes	2	0
Asthma	8	1
Depression	8	3
Hypertension	10	6
Cerebrovascular event	2	1
Ischemic heart disease	1	1
Atrial fibrillation	1	0
Venous thromboembolism	0	1
Epilepsy	0	1
Chronic kidney disease (3 or 4)	0	1
Mean body mass index	30.72	31.18
Smoker	3	0
ASA grade		
1	6	2
2	19	13
3	3	2

One or more compression screws, that is, screws in lag mode across the arthrodesis site, were used in 20 cases. In 25 cases, no compression screw was used. Compression screws were used more frequently in the individual plating group. Bone graft was used in 20 cases: 13 cases in the combined plating group and seven cases in the individual plating group. Of the 13 cases in the combined plating group where the bone graft was used, the graft was taken from the iliac crest in three cases, the proximal tibia in three cases, the calcaneum in six cases and from an exostosis in the remaining case. For the individual plating group, in five cases, the graft was taken from the iliac crest and, in two cases, from the proximal tibia.

Both univariate and multivariate analyses are illustrated in Table 2, where the dichotomous variable used was bone union. There were only two procedure-related factors that showed a significant association with arthrodesis union, both use of individual plates to perform the procedure and the central column fusion procedure being combined with a Lapidus fusion (fusion of the first TMT joint).

Results of patient-reported outcome measures are summarized in Tables 3 and 4. The 6-month MOX-FQ scores were available for 32 cases. Mean scores were lower, and thus improved, in the individual plating group as compared to the combined plating group in all three domains of the MOX-FQ and for the SIS. In the WS and SI domains, this difference had statistical significance and exceeded the minimally important clinical difference. For the SIS, this difference was statistically significant. With the nonunions excluded, 6-month scores were available for 23 cases. Once again, mean scores were lower in all domains in the individual plating group; however, the statistically significant difference between groups was lost. 12-month MOX-FQ scores were available for 31 cases. Scores were lower in all three domains and for the SIS in the individual plating group; however, the difference was not statistically significant. With nonunions excluded, 12-month MOX-FQ scores were similar in the two groups.

Discussion

The aim of this paper was to record and compare the outcomes of two different surgical techniques for the combined fusion of the second and third TMT joints. In the primary outcome of bone healing, there was a significant association with the union in the individual plating group, with the additional procedure of a Lapidus fusion also showing a positive effect. In secondary outcomes of functional patient-related outcome measures, there were significant improvements in the individual plating group, although this statistical significance was lost when nonunion was excluded.

Several studies have investigated plate fixation for TMTJ arthrodesis. Nemec et al. reported the outcome of 104 cases of

Table 2: Univariate and multivariate regression analysis (*p*-value of <0.005 classed as significant; OR, odds ratio) where the bone union was used as the dichotomous variable

	Univariate-regression Analysis		*Multivariate-regression analysis*	
	p-value	*OR*	*p-value*	*OR*
Patient factors				
Diabetes	0.464			
Depression	0.311			
Asthma	0.261			
Hypertension	0.851			
Stroke	0.999			
Ischemic heart disease	0.467			
Atrial fibrillation	0.267			
Venous thromboembolism	0.733			
Epilepsy	0.733			
Chronic kidney disease	0.267			
ASA	0.157			
Smoker	0.999			
Surgeon factors				
Group	**0.093**	**4.167**	**0.047**	**5.822**
Compression screw	0.529			
Bone graft				
Iliac crest	0.999			
Proximal tibia	0.109			
Calcaneum	0.136			
Exostosis	0.267			
Other procedure				
Lapidus	**0.075**	**7.15**	0.043	9.896
4/5 TMTJ fusion	0.733			
First metatarsal osteotomy	0.550			
Lesser toe fusion	0.486			
Lesser ray osteotomy	0.533			
Other midfoot fusion	0.404			
Gastrocnemius recession	0.733			

Bold values indicate statistical significance

arthrodesis for arthritis of tarsometatarsal joints. They used either screws alone or a combination of screws and plates with high rates of union (92%). The screw and plate combination was favored in osteopenic bone. However, no relationship was made between the fixation technique and nonunion.[8] Gougoulias and Lampridis present a case series of 30 patients undergoing arthrodesis for symptomatic midfoot arthritis. Fixation was performed with either screw in isolation or with a combination of screws and a locking plate. Again, they did not claim the superiority of one technique over the other, although they reasoned that the addition of a plate might provide better initial stability and allow earlier mobilization.[13]

Buda et al. conducted a retrospective cohort study to investigate the effect of fixation type and use of bone graft on tarsometatarsal joint fusion. Three techniques for arthrodesis were considered; cross-screw fixation, bridge plate fixation with all screws traversing the plate, and the so-called hybrid fixation, with at least one compression screw across the arthrodesis site in addition to a bridge plate. Joints stabilized with plates alone had a significantly higher rate of nonunion. The authors reason that the ability of a lag screw to generate compression across the TMT joint may supersede that of plate constructs.[9]

Elliot et al. suggested that for a union to be achieved, the correct biological and mechanical conditions must be met.[14] Surgical technique concerns the latter. The aim of TMT joint fusion surgery is to achieve primary bone healing at the arthrodesis site. For this to occur, anatomical reduction and absolute stability are usually required. Theoretically, anatomical reduction and absolute stability are more likely achieved with the individual plating technique than with the combined plating technique, as it is easier to control the joints separately than in combination. Achieving anatomical alignment of

Table 3: Cross-tabulation of the compression screw and bone graft with union across groups

	Combined plating (n = 28)		*Individual plating (n = 17)*	
	Number	*Nonunion (n/%)*	*Number*	*Nonunion (n/%))*
Compression screw				
2 compression screws	7	3 (42.86%)	11	1 (9.09%)
1 compression screw	0	0	2	0
0 compression screws	21	7 (33.33%)	4	1 (4.76%)
Bone graft				
Iliac crest	3	0	5	0
Proximal tibia	3	3 (100%)	2	0
Calcaneum	6	0	0	0
Exostosis	1	1 (100%)	0	0
No bone graft	15	6 (40.00%)	10	2 (20.00%)

Table 4: Cross-tabulation 6- and 12-month MOX-FQ scores in the combined and individual plating groups (WS, walking/standing; P, pain; SI, social interaction; SIS, summary index score)

	6-month scores (mean) n = 32				*6-month scores (mean) nonunions excluded n = 22*			
	WS	*P*	*SI*	*SIS*	*WS*	*P*	*SI*	*SIS*
Combined plating	77.15	64.25	62.50	203.90	67.87	49.17	58.33	175.37
Individual plating	60.41	51.67	35.33	147.41	56.43	44.50	32.40	133.33
p-value	**0.039**	0.13	**0.0089**	**0.024**	0.16	0.34	**0.039**	0.10
	12-month scores (mean) n = 31				*12-month scores (mean) nonunions excluded n = 21*			
	WS	*P*	*SI*	*SIS*	*WS*	*P*	*SI*	*SIS*
Combined plating	67.86	61.18	57.72	186.75	48.81	41.11	43.06	132.98
Individual plating	64.81	51.79	43.30	159.90	61.33	45.42	39.06	145.80
p-value	0.39	0.20	0.13	0.20	0.18	0.27	0.40	0.37

Bold values indicate statistical significance

two tarsometatarsal joints simultaneously is technically demanding, with compression at one joint not necessarily enabling compression at the other. Alignment of adjacent joints individually using separate plates reduces the risk of mal-reduction, achieves better compression, and therefore, theoretically increases the likelihood of union. We believe that separate plates also allow appropriate compression at each joint, unlike the single "H" plate, where only one of the joints may be adequately compressed.

Our results have shown a statistically significant higher rate of union in the individual plating group. Patient-reported outcomes at 6 months were superior, with the individual plating group meeting statistical and clinical significance in two of the three MOX-FQ domains. When the cases of nonunion are excluded, this superiority is lost, implying that it is the failure of fusion that is responsible for the poorer patient-reported outcomes. At 12 months, the MOX-FQ scores in the individual plating group remained lower (superior). However, the difference between the two groups had reduced, and both statistical and clinical significance were lost. This suggests that whilst those in the dual plate group recovered quicker, the cases treated with the single "H" plate did appear to catch up.

The results of the multivariate regression analysis demonstrated a positive relationship between the first TMT joint arthrodesis and the union of the second and third TMT joint arthrodesis. This is possibly due to the middle column joints not being held distracted by an undisturbed length of the medial column and the distraction forces of intact distal intermetatarsal ligaments. The use of bone graft had no significant effect on the union in our series, unlike in the series by Buda et al.[9] However, in our series, the numbers were low, and multiple bone graft sites were utilized.

The study shares the limitations of any cohort study, including a lack of randomization and, therefore, the risk of selection bias. Additional procedures of bone grafting and additional compression screws, in some cases, have added additional compounding variables, although regression analysis was used to try and mitigate this where possible. There were three smokers included in the study, all of whom were in the combined plating technique group. Smoking is known to have a negative effect on the bony union.[15] In our study, they were not equal across the groups; however, there was no correlation noted.

Conclusion

The outcomes have been described for two methods of arthrodesis of the second and TMTJ. Our study showed a higher nonunion rate in the combined plating technique group. It has also shown that 6-month patient-reported outcomes are superior when an individual plating technique is used, although this may be explained by an improved clinical outcome due to a lower rate of nonunion. We believe that separate plates permit a more anatomical reduction and greater compression at the site of arthrodesis, and we have fully integrated the use of individual plating techniques into our practice.

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