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Original Research

Reduction of the Intermetatarsal Angle after First Metatarsal Phalangeal Joint Arthrodesis: A Systematic Review

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ABSTRACT

Arthrodesis of the first metatarsophalangeal joint (MTPJ) has commonly been used for the treatment of a variety of first MTPJ disorders, including hallux valgus. We undertook a systematic review of the electronic databases and other relevant sources to identify material relating to the reduction of the first intermetatarsal angle (IMA) after first MTPJ arthrodesis. Fifteen studies with a total of 701 first MTPJ arthrodesis procedures were identified that met the inclusion criteria. Our results showed the mean preoperative IMA was 13.74° and the mean postoperative IMA was 9.38°, for a mean change in the IMA of 4.36°. The data were analyzed further in 2 subsets. The first subset included 8 studies (434 procedures) that reported a mean preoperative IMA of less than 15°. The mean change in the IMA in this group was 3.70°. The second subset included 7 studies (267 procedures) that reported a mean preoperative IMA of greater than 15°. The mean change in the IMA in this group was 5.42°. The results of the present systematic review have confirmed that a significant reduction of the first IMA can be achieved by first MTPJ arthrodesis alone and that additional procedures to correct the IMA will not be necessary.

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First metatarsophalangeal joint (MTPJ) arthrodesis is widely accepted in the practice of foot and ankle surgery. Both angular and rotational deformities can be addressed at the first MTPJ with arthrodesis. First MTPJ arthrodesis has most commonly been used for pain relief due to hallux rigidus and as a salvage procedure for failed implant arthroplasty. Additionally, treatment of joint subluxation, dislocation, arrest of inflammatory or infectious processes, and hallux varus is possible with fusion. It has been noted by multiple investigators that correction of metatarsus primus adductus or the first intermetatarsal angle (IMA) can occur in conjunction with first MTPJ fusion. Although recognized by many surgeons, a reduction in the IMA has not been universally accepted. We undertook a systematic review of the published data on first MTPJ arthrodesis to understand further the consistency and magnitude of IMA reduction after first MTPJ fusion.

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Patients and Methods

We undertook a systematic review of the electronic databases, including PubMed (available at: http://www.ncbi.nlm.nih.gov/pubmed), OvidSP (available at: http://ovidsp.ovid.com/), Google Scholar (available at: http://scholar.google.com), and websites for the *Journal of Foot and Ankle Surgery* (available at: http://www.jfas.org/) and *Foot and Ankle International* (available at: http://www.aofas.org). We restricted the studies to reports published in English or translated into English and only included human studies. An inclusive search of "first MPJ arthrodesis," "first MPJ fusion," "first metatarsophalangeal joint arthrodesis," "first metatarsophalangeal joint fusion," with the Boolean operators "AND" and "OR" to add "intermetatarsal angle" or "hallux valgus." Only reports that included measurements of the preoperative and postoperative IMA were included. The criteria for study inclusion were case series of more than 20 subjects, measurements made from weightbearing radiographs, a clearly defined measurement protocol, and procedures performed for primary deformity correction. Studies with revision surgery were excluded. A manual reference search of the chosen reports was also performed to identify additional pertinent studies.

All reports were reviewed to evaluate for appropriateness according to the inclusion criteria by 4 of us (P.D., M.F., B.H., T.N.). Agreement by all was required for final inclusion, with the lead author (P.D.) acting as moderator. After a review of the included reports, the following variables were extracted: the number of cases in each study, mean preoperative IMA, mean postoperative IMA, mean change in the IMA, mean age of the patients, mean follow-up period, and gender characteristics. The reports were graded according to the American College of Foot and Ankle Surgeons Levels of Clinical Evidence Guidelines, as referenced in the *Journal of Foot and Ankle Surgery® Guide for*

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Authors. Those reports that were determined to be level 1, 2, 3, or 4 were included. Level 5 reports were excluded.

The present systematic review does not include a meta-analysis. A meta-analysis is typically reserved for randomized controlled trials, although observational studies, including case studies, can be used (1). A requirement for this statistical approach requires the original research report to have included individual level data or a measure of sample variance on the key outcome variables. None of the studies included in our systematic review include a measure of variance (e.g., standard deviation); therefore, meta-analytic techniques were not appropriate.

Using the mean preoperative IMA and mean postoperative IMA values reported in each study, we calculated a pooled mean IMA value using the formula ($\Sigma\ n_i\ m_i/\Sigma\ n_i$), where n_i was the sample size and m_i was the mean. The change in the mean IMA was then reported.

Results

A total of 89 studies were identified in the systematic search of the databases noted in the "Patients and Methods" section. After the abstract review, 60 studies were excluded because of non-applicability. A complete review of the remaining 29 studies with application of the inclusion criteria resulted in a final selection of 15 studies (Table 1). The included studies reported on 701 first MTPJ arthrodesis procedures. The level of evidence was level 3 in 1 study and level 4 in 14 using the *Journal of Foot and Ankle Surgery Guides for Authors*. The demographic information, such as age and gender distribution, was not consistently reported among the included studies and therefore could not be analyzed. The raw data are reported in Table 1. In the 11 studies that reported the follow-up period, the mean follow-up duration was 50.9 months. The preoperative pooled mean IMA for the 701 cases was 13.74°. The postoperative pooled mean IMA was 9.38°, for an overall change in the IMA of 4.36°.

Seven studies reported an average preoperative IMA greater than 15° (Table 2). These studies included 267 procedures, and the pooled mean IMA reduction for this subset was 5.42°. The remaining 8 studies reported a pooled mean IMA of less than 15° (Table 3). This subset included 434 procedures, and the pooled mean IMA reduction was 3.70°.

Discussion

Numerous studies in the past have compared the preoperative and postoperative radiographic angles after arthrodesis of the first MTPJ. A summary of the results from the radiographic studies found by our search that met the inclusion criteria is presented in Table 1. The present systematic review was undertaken to specifically evaluate the reduction in the IMA after first MTPJ arthrodesis procedures. We did not set out to define any other outcome characteristic, such as patient satisfaction or the long-term success of the procedure. Our inclusion criteria allowed for studies to be included that did not have detailed demographic or length of follow-up data. Therefore, we were not able to analyze these characteristics of the study population. We do not believe that the lack of an analysis of these and other demographic characteristics harmed our conclusions regarding IMA reduction after first MTPJ arthrodesis. Throughout the entire study population, a consistent reduction in the IMA was noted. The reduction was quite consistent despite a variety of procedures used in the various studies reviewed. This finding strengthens the recommendation of first MTPJ arthrodesis for correction of hallux abducto valgus and argues against the need for additional procedures to correct the IMA. The results from the present systematic review have further clarified the reduction in IMA that can be expected after first MTPJ arthrodesis.

The following summarizes the studies in which IMA reduction was reported after first MTPJ arthrodesis. Although the vast majority of studies considering IMA correction after first MTPJ arthrodesis have maintained that additional procedures such as proximal osteotomy to correct the IMA are not needed, some investigators have advocated the need for additional procedures (2). A review of the studies

Table 1
Data extracted from 15 studies included in the present systematic review

Investigator	LOE	Cases (n)	Preoperative IMA (°)	Postoperative IMA (°)	Change in IMA (°)	Age (y)	Follow-up (mo)	Gender
Feilmeier et al, 2013 (5)	4	94	15.32	9.88	5.44	NR	NR	NR
Sung et al, 2010 (3)	3	58	14	9.7	4.3	57.7	17.7	45 Females 11 Males
Besse et al, 2010 (11)	4	36	16.1	10.4	5.7	61	38.6	46 Females 8 Males
Pydah et al, 2009 (4)	4	69	13.1	8.6	4.5	59.4	NR	40 Females 16 Males
Goucher et al, 2006 (7)	4	54	13	10	3	62	16	43 Females 6 Males
Cronin et al, 2006 (8)	4	20	16.7	8.7	8	54.2	13.7	20 Females 0 Males
Nicholas et al, 2005 (12)	4	76	10.9	8	2.9	57.7	16.7	50 Females 19 Males
Coughlin et al, 2005 (9)	4	21	17.3	11.2	6.4	71	98.4	11 Females 5 Males
Dayton et al, 2002 (6)	4	22	17.3	10.9	6.1	62.5	NR	20 Females 1 Male
Lombardi et al, 2001 (10)	4	21	10.6	8.5	2.1	53.2	28.1	10 Females 7 Males
Agoropoulos et al, 2001 (13)	4	62	12.9	8.5	4.4	63	258	30 Females 12 Males
Coughlin, 2000 (14)	4	47	11	8	3	55	72	24 Females 8 Males
Tourne et al, 1997 (15)	4	42	15	11	4	67	NR	30 Females 3 Males
Gregory et al, 1990 (16)	4	32	16.2	12	4.2	61	8	1 Female 24 Males
Mann et al, 1989 (17)	4	47	12.7	8.3	4.4	54.8	31.9	NR

Abbreviations: IMA, intermetatarsal angle; LOE, level of evidence; NR, not reported.
Total cases, 701; mean preoperative IMA, 14.14°; mean postoperative IMA, 9.58°; mean IMA change, 4.56°; mean age, 60.1 years; mean follow-up period, 57.9 months; total stratified by gender, 370 females and 120 males.

Table 2
Subset of studies reporting mean IMA greater than 15°

Investigator	Cases (n)	Preoperative IMA (°)	Postoperative IMA (°)	Change in IMA (°)
Feilmeier et al, 2013 (5)	94	15.32	9.88	5.44
Besse et al, 2010 (11)	36	16.1	10.4	5.7
Cronin et al, 2006 (8)	20	16.7	8.7	8
Coughlin et al, 2005 (9)	21	17.3	11.2	6.4
Dayton et al, 2002 (6)	22	17.3	10.9	6.1
Tourne et al, 1997 (15)	42	15	11	4
Gregory et al, 1990 (16)	32	16.2	12	4.2

Abbreviation: IMA, intermetatarsal angle.
Total cases, 267; pooled mean preoperative IMA, 15.90°; pooled mean postoperative IMA, 10.48°; mean change in IMA, 5.42°.

included in our report consistently showed a reliable IMA reduction after isolated first MTPJ arthrodesis.

Sung et al (3) in 2010 conducted a retrospective case study involving 58 cases of hallux valgus and/or hallux rigidus surgically corrected using first MTPJ arthrodesis. They rated the deformities as mild, moderate, or severe, depending on the preoperative radiographic findings, and the cases were grouped accordingly. The mean follow-up period was 12 months, and the fusion rate was 95%. The mean IMA decreased from 14° preoperatively to 9.7° postoperatively, and the mean HAA decreased from 31.9° preoperatively to 13.4° postoperatively. On analysis, the amount of reduction in each deformity group varied according to the size of the preoperative IMA. Thus, the more severe the hallux valgus deformity preoperatively, the greater the correction that was achieved postoperatively.

In 2009, Pydah et al (4) completed a retrospective case series of 69 first MTPJ fusions for hallux valgus. Their results showed the mean IMA decreased from 13.1° preoperatively to 8.6° postoperatively and the mean hallux abductus angle (HAA) decreased from 23° to 16°. They also noted that the mean tibial sesamoid position was improved by an average of 1 grade. That study obtained results similar to those from the study by Sung et al (3) in that a more severe preoperative IMA correlated with a larger IMA reduction. They suggested that the amount of mean angular correction achieved in their study after first MTPJ arthrodesis was satisfactory and that an additional osteotomy would not be needed.

In 2013, Feilmeier et al (5) performed a radiographic review of 94 cases involving first MTPJ arthrodesis. That series represents the largest series reported to date. The study compared the preoperative and postoperative IMAs and calculated a mean IMA reduction. The inclusion criteria were patients with an IMA greater than 11°. The results showed a mean preoperative IMA of 15.32°, a mean postoperative IMA of 9.88°, and a mean reduction in the IMA of 5.44°. When the patients were separated into subsets of a low preoperative IMA (11° to 15°) and a high preoperative IMA (16° to 24°), the respective mean IMA reduction was 4.21° and 6.83°, respectively. The investigators concluded that arthrodesis of the first MTPJ for correction of hallux valgus deformity results in a consistent reduction in the IMA and a proportionately larger reduction can be expected from a larger preoperative IMA.

Table 3
Subset of studies reporting mean IMA less than 15°

Investigator	Cases (n)	Preoperative IMA (°)	Postoperative IMA (°)	Change in IMA (°)
Sung et al, 2010 (3)	58	14	9.7	4.3
Pydah et al, 2009 (4)	69	13.1	8.6	4.5
Goucher et al, 2006 (7)	54	13	10	3
Nicholas et al, 2005 (12)	76	10.9	8	2.9
Lombardi et al, 2001 (10)	21	10.6	8.5	2.1
Agoropoulos et al, 2001 (13)	62	12.9	8.5	4.4
Coughlin, 2000 (14)	47	11	8	3
Mann et al, 1989 (17)	47	12.7	8.3	4.4

Abbreviation: IMA, intermetatarsal angle.
Total cases, 434; pooled mean preoperative IMA, 12.40°; pooled mean postoperative IMA, 8.70°; mean change in IMA, 3.70°.

Dayton et al (6), in 2002, performed a retrospective radiographic review of 22 patients that evaluated the reduction in the IMA after first MTPJ arthrodesis in those patients with a preoperative IMA greater than 15°. The results revealed a reduction from a mean preoperative IMA of 17.27° to a mean postoperative IMA of 10.86°, for a mean change of 6.41°. The mean HAA was reduced from a mean of 41.7° to 20.4° after the procedure. The study found reliable and predictable reductions in the IMA and HAA after first MTPJ arthrodesis without the need for additional first metatarsal osteotomy in their study population with a large IMA.

In 2006, Goucher and Coughlin (7) performed a prospective study of 54 cases of either hallux rigidus or hallux valgus corrected with first MTPJ arthrodesis. The mean IMA decreased from 13° preoperatively to 10° postoperatively and the mean HAA decreased from 20° to 13°. These results indicate a satisfactory reduction in the deformity after the procedure.

Cronin et al (8), in 2006, performed a retrospective review of 20 cases of first MTPJ arthrodesis. Their goal was to measure the reduction in the IMA and HAA postoperatively to assess the need for an additional basilar osteotomy. Varying degrees of hallux valgus deformity were present in all patients. Radiographs were taken preoperatively, 6 weeks postoperatively, and at an average of 13.72 months postoperatively. The mean preoperative and postoperative IMA was 16.65° and 8.67°, respectively. The mean preoperative and postoperative HAA was 46.55° and 12.35°, respectively. Similar to the previously cited studies, the amount of IMA correction achieved had a direct correlation with the severity of the deformity preoperatively. In most patients, most of the IMA correction had been obtained by 6 weeks. In 4 patients, 4° or more of correction was achieved between 6 weeks and the final follow-up visit, indicating that the correction improved even after the 6-week follow-up point. That study showed a statistical significance for the mean IMA reduction. Their study has shown that first MTPJ arthrodesis can reduce a wide range of IMA deformities, without the need for an additional basilar osteotomy, with reliable and reproducible results.

Another retrospective study by Coughlin et al (9) performed in 2005 evaluated patient satisfaction, the subjective reduction of symptoms, physical examination findings, and radiographic reduction of the IMA, HAA, and dorsiflexion angle after first MTPJ arthrodesis. A total of 21 cases in 16 patients with moderate to severe hallux valgus were included in their study, and all included patients had a preoperative HAA greater than 21°. The average follow-up period was 8.2 years. On radiographic examination, the mean preoperative IMA of 17.3° had decreased to 11.2° postoperatively, and the mean HAA of 41.7° had decreased to 20.4°, showing a significant reduction in the deformity. No long-term complications developed in any of the patients. Overall, that study provided a good demonstration of the use of first MTPJ arthrodesis for a significant reduction of the IMA and HAA in a group of patients with moderate to severe hallux valgus with a high success rate and lengthy average follow-up time. Including a study group of only patients with moderate to severe deformity allowed the investigators to eliminate the speculation that patients with mild preoperative hallux valgus could skew the results toward a more favorable outcome.

Lombardi et al (10) conducted a retrospective review in 2001 of 21 cases of hallux rigidus treated with first MTPJ arthrodesis. The mean follow-up period was 28.1 months after surgery. The mean IMA decreased from 10.6° preoperatively to 8.5° postoperatively. The

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mean HAA decreased from 13.1° preoperatively to 11.0° postoperatively. Overall, a notable reduction in the IMA occurred; however, the results were not as significant as those from other similar studies, likely because only patients with hallux rigidus had been included and patients with hallux valgus had been excluded.

All these studies with radiographic preoperative IMA, postoperative IMA, and IMA reduction after surgery data are listed in Table 1. A few additional studies (11–17) have also been included in Table 1. These studies recorded a similar reduction in the IMA after first MTPJ arthrodesis. We also realize that our systematic review does not offer a quantitative synthesis of pooled data from prior reports that have been determined to be homogenous (we did not conduct a meta-analytic test of heterogeneity); therefore, biases between the different studies that we compiled could threaten the validity of our conclusions. Nonetheless, we believe that uniformity related to the radiographic measurement of the first IMA permeates the realm of foot and ankle surgeons, and for this reason, we believe that it is likely that our observation of a clinically relevant reduction in the angle is associated with correction of hallux valgus. The results of the present systematic review strongly suggest that a clinically significant reduction in the first IMA can be achieved with first MTPJ fusion alone. Our results also clearly support the notion that an increased magnitude of IMA reduction can be expected in the case of a larger preoperative IMA. This is an important point when considering the need for additional procedures to correct the IMA when using first MTPJ fusion for hallux valgus correction. The present review has clearly shown that additional procedures of the first metatarsal should not be necessary, even in the case of severe hallux valgus.

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