Arthritis of the first metatarsophalangeal (MTP) joint, also known as hallux rigidus, is a progressive disorder causing pain, stiffness and enlargement of the joint.3,20 Several surgical procedures have been used to address the pain and stiffness associated with this disease at various stages. Although cheilectomy39 and a number of osteotomies38,48 may be suitable for stage I and II hallux rigidus, these procedures are not as effective for the treatment of more advanced stages.10 Resection arthroplasty,8,32 interpositional arthroplasty,2,34,37 hemiarthroplasty,7,22,23,29 total joint arthroplasty7,32 and arthrodesis16,36,45 have all been used for more advanced stages of the disease. Each of these procedures has their own benefits and deficits. Hemiarthroplasties which resurface the proximal phalangeal base have shown promise, but stiffness, continued joint pain and prosthetic loosening are still limitations to these techniques.22,49 Arthrodesis has been advocated by many authors for treating advanced hallux rigidus,16,36,45 and a recent study showed outcomes of arthrodesis after 30 months follow-up to be superior to metallic hemiarthroplasties that resurface the phalangeal base with 79.4 months follow-up.41 However, limitations in shoe wear, transfer metatarsalgia, permanent activity modifications, and complications from malrotation, malpositioning, malunion, or nonunion have made this procedure less attractive to the younger, active patient.3,9,15,20,24,28

The HemiCAP® platform technology (Arthrosurface Inc., Franklin, MA) was designed to resurface the damaged articular surface of the metatarsal head. The concept is based on intraoperative joint mapping and implantation of a matching, congruent resurfacing prosthesis allowing for joint preservation and restoration of the normal geometry. The earliest use was adopted in the shoulder, hip, and knee 478930

**Metatarsal Head Resurfacing for Advanced Hallux Rigidus**

Alex J. Kline, MD1 and Carl T. Hasselman, MD1

**Abstract**

**Background:** Advanced stages of first metatarsophalangeal (MTP) arthritis have traditionally been treated with various arthroplasties or arthrodesis. Studies suggest the outcomes of arthrodesis are superior to those of metallic joint replacement; however, complications and suboptimal outcomes in active patients still remain with arthrodesis of the first MTP joint. This study reports results of patients with advanced MTP arthritis who underwent metallic resurfacing of the metatarsal side of the MTP joint.

**Methods:** From 2005 to 2006, 26 patients (30 implants) with stage II or III hallux rigidus underwent resurfacing with the HemiCAP® implant and consented to participate in a study comparing pre- and postoperative radiographs, range of motion (ROM), American Orthopedic Foot and Ankle Society, and Short Form 36 Health Survey (SF-36) scores. Average age of these patients was 51 years. Patients were assessed at a mean of 27 months with outcome measures and contacted at 60 months to assess current symptoms and satisfaction.

**Results:** Assessment at 27 months demonstrated statistically significant improvements in ROM, AOFAS, and SF-36 scores ($P < .05$) when compared to baseline. Mean preoperative AOFAS scores improved from 51.5 to 94.1. Mean active ROM improved from 19.7 to 47.9 degrees. Mean passive ROM improved from 28.0 to 66.3 degrees. Mean RAND SF-36 physical component score improved significantly from 66.7 to 90.6. Average time for return to work was 7 days. At 60 months, all patients reported excellent satisfaction with their current state and would repeat the procedure. Implant survivorship was 87% at 5 years. Of the 30 implants, 4 were revised at 3 years.

**Conclusion:** The results at 5 years were very promising. Preservation of joint motion, alleviation of pain, and functional improvement data were very encouraging. Because minimal joint resection was performed, conversion to arthrodesis or other salvage procedures would be relatively simple if further intervention became necessary.

**Level of Evidence:** Level IV, prospective case series.

**Keywords:** hallux rigidus, first MTP joint, endoprosthesis, HemiCAP®, resurfacing

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with promising clinical outcomes. In 2004 this technology was also approved by the FDA and introduced for resurfacing of the metatarsal head in the treatment of advanced hallux rigidus (Figure 1). The technique and initial experiences with this implant have been presented and published in the past. This article focused on the midterm clinical results of metatarsal head resurfacing in the treatment of advanced stages of hallux rigidus.

Methods

Between 2005 and 2006, 38 patients with stage II and III hallux rigidus underwent metallic resurfacing of the first metatarsal head (several underwent bilateral procedures). After obtaining approval from our institutional review board, 26 patients (30 implants) consented to participate in the study and were followed prospectively. None of the consented patients were excluded from the study.

The diagnosis of advanced hallux rigidus was based on history, physical examination, and radiographic assessment. All patients had failed 1 or more nonoperative treatments including orthotics, modified shoe wear, anti-inflammatory medication, and steroid injections. The indications for surgery were based on patient history, severity of symptoms, physical and radiographic examination, and patient expectations. The mean age of the patients was 51 (range: 35 to 74) years. The demographics can be seen in Table 1.

Study selection criteria was based on a signed informed consent, grade 2 or 3 hallux rigidus, failed conservative management, absent sesamoid arthritis on preoperative examination and radiographs, and painful, limited range of motion on preoperative examination. Exclusion criteria were inflammatory or septic arthritis of the first MTP joint, history of allergic reaction to orthopedic implants or other significant metal allergies, and significant bone loss that would compromise implant fixation.

Surgical Technique

All patients were treated by the senior author using the same surgical technique and postoperative rehabilitation as described previously. The first MTP joint was exposed using a dorsal capsulotomy. An aggressive soft tissue release was performed, including the collateral ligaments, the sesamoid sleeve, and the fibrotic flexor brevis tendon insertion onto the proximal phalangeal base. These steps were critical in maximizing motion. The components were then placed per the manufacturer’s guidelines.

Soft tissue releases were performed until 75 to 90 degrees of dorsiflexion were obtained. At this point, if more than 50% of the cartilage on the phalangeal base showed significant degeneration, a sleeve of extensor digitorum brevis was interposed and fixed with mini suture anchors. The patients were placed into soft dressing, and were encouraged to walk as soon as possible postoperatively. In addition, they were instructed on doing aggressive passive range of motion exercises at home. At the first postoperative visit at 2 weeks, they were encouraged to walk in regular shoes, and were sent to formal physical therapy to aggressively work on joint mobility (Table 2).

Radiographic Evaluation

Preoperative disease severity was graded according to the classification of Hattrup and Johnson (Table 3). Standardized weightbearing AP, oblique, and lateral radiographs of the foot were obtained before surgery and as part of the clinical follow-up assessment. Preoperative radiographs were compared to 27-month follow-up radiographs. Analysis consisted of assessment of joint space, peri-prosthetic radiolucency (mm), implant disassembly, implant subsidence (mm), recurrence of the dorsal osteophyte, interphalangeal arthritis, elevation of the first ray, and first metatarsal declination angle (normal range: 19-25 degrees).

Physical Examination

Active and passive range of motion was assessed by the senior author prior to surgery and at every postoperative visit with a goniometer (Howmedica, Rutherford, NJ). Range of motion was determined as the angle made between the metatarsal shaft and the proximal phalanx with active and passive dorsiflexion.
Standing, we used the RAND-36 scoring system. All should be noted that the AOFAS scale is not validated. In an (max: 45 points), and alignment (max: 15 points). It is a self-administered, patient-based scoring system that has been found to be valid and reliable. For ease of understanding, we used the RAND-36 scoring system. All items are scored out of 100 with 0 being the worst and 100 the best.

The AOFAS clinical rating system for the hallux is a 100-point scale based on pain (max: 40 points), function (max: 45 points), and alignment (max: 15 points). It should be noted that the AOFAS scale is not validated. In an attempt to prevent bias, the 27-month follow-up surveys were mailed to the patients with the assurance that their surgeon would be blinded to their responses. At that point, patients were also asked if they were satisfied with their result and whether they would undergo the procedure again.

At an average of 60 months (range, 54 to 68 months) postoperative, the patients were again contacted to assess their symptoms and satisfaction. The pain and activity portion of the AOFAS was completed. They were asked if they were the same, better, or worse than reported at the 27-month time point and whether they would repeat the procedure if needed in the future.

**Statistical Analysis**

Statistical analysis was done using Excel data analysis tools (Microsoft, Redmond, WA) and SPSS for Windows (Chicago, IL). In addition to descriptive statistics, a 2-tailed Student t-test with the assumption of unequal variances was used to compare continuous variables. The level of significance was set at P < .05. For continuous variables that were normally distributed, a paired t-test was used to determine statistical significance. The Wilcoxon signed-rank test was used to compare ordinal variables.

**Results**

**Outcomes**

The average time for return to work was 7 (range, 3 to 20) days. The majority of patients had sedentary work, or went back initially with light duty precautions. At a mean follow-up of 27 (range, 17 to 38) months, assessment of range of motion and AOFAS scores demonstrated statistically significant improvement (P < .001) when compared to baseline (Figure 2). The mean preoperative AOFAS score improved from 51.5 (range, 35 to 74; SD: 12.61) to 94.1 (range, 82 to 100; SD: 6.2). The baseline pain Visual Analog Scale (VAS) improved from 6.8 to 1.4 at 27 months. The mean preoperative active range of motion improved from 19.7 (range, 5 to 50; SD: 9.82) degrees to 47.9 (range, 25 to 75; SD: 15.15) degrees. The mean preoperative passive range of motion improved from 28.0 (range, 10 to 60; SD: 12.57) degrees to 66.3 (range, 40 to 90; SD: 13.42) degrees.

The mean SF-36 Physical Health Component score improved significantly from 66.7 (range, 40 to 87) to 90.6 (range, 70 to 98; P < .001), and the Mental Health Component score also was significantly improved from 75.8 (range, 57 to 91) to 85.8 (range, 72.4 to 95.5; P < .001). Only 2 subscales of the Mental Health Component were not significant (Vitality, Mental Health; Table 4).

At an average of 60 months postoperative, the mean AOFAS pain score was 80% of the best possible score (32/40; range, 30 to 40) indicating only mild or occasional

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**Table 2. Summary of Technical and Clinical Considerations**

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Clinical Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Aggressive soft tissue release</td>
<td>• Exposure, range of motion</td>
</tr>
<tr>
<td>• Fluoroscopic control of guide wire placement</td>
<td>• Correct implant placement</td>
</tr>
<tr>
<td>• Joint decompression by altering the joint line: Advancing the fixation</td>
<td>• Range of motion, pain relief</td>
</tr>
<tr>
<td>component 1-3 mm</td>
<td></td>
</tr>
<tr>
<td>• Subperiosteal release of fibrotic flexor brevis tendon at its insertion</td>
<td>• Range of motion</td>
</tr>
<tr>
<td>• Release of sesamoid adhesions to include proximal plantar plate release at</td>
<td>• Range of motion</td>
</tr>
<tr>
<td>its insertion</td>
<td></td>
</tr>
<tr>
<td>• Metatarsal cheilectomy</td>
<td>• Range of motion</td>
</tr>
<tr>
<td>• Proximal phalanx resurfacing with capsular interpositional graft in bipolar</td>
<td>• Pain relief</td>
</tr>
<tr>
<td>degeneration of more than 50% of the phalangeal surface</td>
<td></td>
</tr>
<tr>
<td>• Nonmetal fixation for phalangeal concomitant procedures (correctional</td>
<td>• Avoid complications</td>
</tr>
<tr>
<td>osteotomies, interpositional graft fixation) to avoid metalosis</td>
<td></td>
</tr>
<tr>
<td>• Aggressive and early postoperative mobilization to maximize intraoperative</td>
<td>• Range of motion</td>
</tr>
<tr>
<td>gain in range of motion</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3. Hattrup and Johnson Radiographic Classification**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>Mild to moderate osteophyte formation but good joint space preservation</td>
<td>0</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Moderate osteophyte formation with joint-space narrowing and subchondral sclerosis</td>
<td>16 (53)</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Marked osteophyte formation and loss of visible joint space with or without subchondral cyst formation</td>
<td>14 (47)</td>
</tr>
</tbody>
</table>

**Clinical Scoring System**

All patients were assessed preoperatively and at 27 months postoperatively with the Short Form 36 Health Survey (SF-36) and the American Orthopedic Foot and Ankle Society (AOFAS) clinical rating system for the hallux. The SF-36 is a self-administered, patient-based scoring system that has been found to be valid and reliable. For ease of understanding, we used the RAND-36 scoring system. All items are scored out of 100 with 0 being the worst and 100 the best.
pain. The mean AOFAS activity score was also 80% (8/10; range, 7 to 10) indicating no limit to daily activities and only slight limitation in recreational activities.

Radiographs

Preoperative radiographs demonstrated advanced stages of hallux rigidus (stage 2 or 3) in all patients and no evidence of sesamoid involvement was found in any patient (Figures 3, 4). At 27 months postoperative, radiographs demonstrated no signs of implant loosening, subsidence or disengagement and there was no evidence of peri-prosthetic radiolucency consistent with implant wear. The 1-2 intermetatarsal angle remained unchanged in the postoperative radiographs. No new osteophyte formation was evident at the metatarsal head on postoperative x-rays even at 5 years after surgery (Figure 5). The proximal phalangeal base did undergo dysplastic changes consistent with wear due to the metatarsal metal resurfacing. There was no radiographic evidence of first interphalangeal joint changes and no first ray elevation postoperatively.

Satisfaction

At 27 months, all patients (100%) were satisfied with their current condition and would be willing to have the procedure performed again. At the 60-month follow-up all patients continued to report excellent satisfaction (very satisfied 11.5%, satisfied 88.5%) describing their current state as the same (84.5%) or better (15.4%) when compared to the 27-month follow-up. All (100%) said they would repeat the procedure.

Complications

Immediately postoperative, there was 1 postoperative infection that resolved with oral antibiotics and local
wound care. No other complications were noted in the perioperative period.

The implant survivorship was 87% at 5 years. Of the 30 implants, 3 were revised using a silastic implant, and 1 was converted to a primary arthrodesis without the use of interpositional bone graft. The 3 conversions to silastic implants were elderly patients with a low activity threshold. All 3 patients were warned of the risk with silicone implants, but all 3 chose implant arthroplasty over fusion. All 4 conversions were necessary due to phalangeal pathology and were performed at the 3-year mark. All metatarsal head implants were well incorporated without any signs of loosening. Interestingly, all conversion patients indicated they would repeat resurfacing again as a primary procedure.

**Figure 3.** Preoperative weightbearing radiograph with grade 3 hallux rigidus of the left foot.

**Figure 4.** Postoperative AP weightbearing radiograph at 3 years follow-up after first MTP resurfacing in grade 3 hallux rigidus.

**Figure 5.** Postoperative lateral weightbearing radiograph with 5 years follow-up after first MTP resurfacing in grade 3 hallux rigidus.
Discussion

The HemiCAP® prosthesis is a novel approach to the treatment of arthritis of the first metatarsophalangeal joint because it is the first metallic implant to resurface the metatarsal head (Figure 6). In this study patients had a better range of motion and pain reduction compared to the other implant hemiarthroplasties.22,49 One possible explanation is that the metatarsal head is usually the more involved side of the MTP joint degeneration in hallux rigidus. Resurfacing the metatarsal side would therefore address the more advanced cartilage destruction and provide better pain relief. Furthermore, impaction of the proximal phalanx on the metatarsal head is thought to be a major etiologic factor for the progression of hallux rigidus.

Hemiarthroplasty techniques that resurface the proximal phalanx will still leave a damaged metatarsal head surface. The impaction of the implant onto the remaining damaged metatarsal head could be a major cause for persistent pain with those implants. Technically the implant can be advanced further into the metatarsal head by several millimeters allowing for decompression of the joint and reduction of impact forces. This technique of decompressing the joint has been previously described by others as a means of relieving joint stresses.6,20,38

The arthroplasty technique of Berlet et al2 is similar to that of the HemiCAP® in that both attempt to resurface the metatarsal head. In both cases, the range of motion gained, decrease in pain and patient satisfaction was similar. It is possible that because the metatarsal head is resurfaced in both techniques that further decreases in pain and improvements in range of motion are seen compared to metallic hemiarthroplasties that resurface the phalangeal base.

There have been no reports of implant loosening or osteolysis around the HemiCAP® implant to date. We also found no evidence of radiolucency, implant loosening, subsidence or disengagement. In contrast, loosening of the implant is a significant problem even with short term follow-up of hemiarthroplasty implants that resurface the proximal phalanx.22,34 It is possible that the shear stresses seen in the proximal phalanx with repetitive dorsiflexion cause the implant to loosen or prevent proper bony ingrowth early on. Even newer generation phalangeal implants have shown failure by cut-out of the dorsal cortex.41 The metatarsal side may not see the same stresses as the phalangeal side since it does not move with gait. Furthermore, shear stresses typically experienced by onlay implants are reduced for the HemiCAP® implant which is placed as an inlay onto a supporting bone bed and connected to a tapered screw fixation component. We did find that the phalangeal side does appear to undergo dysplastic changes similar to what has been reported for the acetabulum with hemiarthroplasty of the hip joint. Although the phalangeal side showed changes in most people, few were symptomatic. The 4 patients in this study who had symptoms underwent successful revision of the phalangeal side, fusion without bone block grafting, or revision to a silastic joint.

A recent study suggests that arthrodesis is superior to metallic hemiarthroplasty of the phalangeal base.41 This conclusion was based on a follow-up for arthrodesis of 30 months and hemiarthroplasties of 79.4 months. Different endpoints may have influenced the results: pain, function, satisfaction and complications may have demonstrated significant differences for hemiarthroplasties at 30 months and arthrodesis at 80 months, respectively. When compared to this investigation, AOFAS scores of our patients were similar to the arthrodesis group and superior to the hemiarthroplasty patients. When compared to previous reports of hemiarthroplasty and joint fusion16,22,45,49 current 2- to 5-year results of metatarsal head resurfacing demonstrated equivalent or better results for range of motion, pain reduction, and patient satisfaction (Table 5).

It remains important to stress the risks and pitfalls associated with MTP arthrodesis when comparing treatment options...
### Table 5. Literature Comparison at Last Follow-Up

<table>
<thead>
<tr>
<th>Author</th>
<th>Procedure</th>
<th>Procedures</th>
<th>Mean Follow-Up (mos)</th>
<th>Mean Age (yrs)</th>
<th>Mean AOFAS</th>
<th>Mean Range of Motion</th>
<th>Mean Pain VAS: Score</th>
<th>AOFAS: Score</th>
<th>Satisfaction (%)</th>
<th>Complications (%/n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DelaCruz et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Meniscus allograft interposition</td>
<td>13</td>
<td>16.5</td>
<td>48.6</td>
<td>90.0</td>
<td></td>
<td>47.8</td>
<td>VAS: n/a</td>
<td>AOFAS: n/a</td>
<td>No complications reported or failures reported</td>
</tr>
<tr>
<td>Fuhrmann&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Total MTP arthroplasty</td>
<td>43</td>
<td>25-28</td>
<td>n/a</td>
<td>74.0</td>
<td></td>
<td>45.0</td>
<td>VAS: n/a</td>
<td>AOFAS: 32.8/40</td>
<td>9% / n = 4</td>
</tr>
<tr>
<td>Gibson et al&lt;sup&gt;21&lt;/sup&gt;</td>
<td>Total MTP arthroplasty</td>
<td>39</td>
<td>24.0</td>
<td>55.5</td>
<td>n/a</td>
<td>14.0 (active)</td>
<td>VAS: 2.7</td>
<td>AOFAS: n/a</td>
<td>94-70&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Outcome: 4 conversions to fusion 15% / n = 6 Outcome: -6 phalangeal component loosening and revisions 7% / n = 3 Outcome: -2 revised to arthrodesis -1 larger implant inserted 18% / n = 7</td>
</tr>
<tr>
<td>Chee et al&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Total MTP arthroplasty (ceramic)</td>
<td>41</td>
<td>33</td>
<td>62</td>
<td>83.7</td>
<td></td>
<td>34</td>
<td>VAS: n/a</td>
<td>AOFAS: 30.5/40</td>
<td>87.3</td>
</tr>
<tr>
<td>Gibson et al&lt;sup&gt;21&lt;/sup&gt;</td>
<td>Arthrodesis</td>
<td>38</td>
<td>24.0</td>
<td>54.2</td>
<td>n/a</td>
<td></td>
<td>VAS: 1.1</td>
<td>AOFAS: n/a</td>
<td>94-97&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Outcome: -7 local infections, 2/7 surgical removal of Kirschner wire, 5/7 oral antibiotics</td>
</tr>
<tr>
<td>Raikin et al&lt;sup&gt;41&lt;/sup&gt;</td>
<td>Arthrodesis</td>
<td>27</td>
<td>30.0</td>
<td>54.1</td>
<td>83.8</td>
<td></td>
<td>n/a</td>
<td>VAS: 0.7</td>
<td>AOFAS: n/a</td>
<td>85% / n = 2 Outcome: -2 removals of prominent screw under local anesthesia 6% / n = 1 Outcome: -1 manipulation under anesthesia</td>
</tr>
<tr>
<td>Kennedy et al&lt;sup&gt;44&lt;/sup&gt;</td>
<td>Interposition arthroplasty</td>
<td>21</td>
<td>38.0</td>
<td>56.0</td>
<td>78.4</td>
<td></td>
<td>VAS: n/a</td>
<td>AOFAS: n/a</td>
<td>94%</td>
<td>No failures reported One patient with bilateral metatarsalgia Four with residual stiffness</td>
</tr>
<tr>
<td>Sanhudo et al&lt;sup&gt;42&lt;/sup&gt;</td>
<td>Interpositional arthroplasty</td>
<td>25</td>
<td>45.8</td>
<td>60.8</td>
<td>93.6</td>
<td></td>
<td>n/a</td>
<td>VAS: n/a</td>
<td>AOFAS: 36.4/40</td>
<td>75</td>
</tr>
<tr>
<td>Mackey et al&lt;sup&gt;35&lt;/sup&gt;</td>
<td>Interpositional arthroplasty</td>
<td>10</td>
<td>63</td>
<td>64</td>
<td>89.6</td>
<td></td>
<td>VAS: n/a</td>
<td>AOFAS: n/a</td>
<td>n/a</td>
<td>No complications reported or failures reported</td>
</tr>
<tr>
<td>Carpenter et al&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Metatarsal head resurfacing</td>
<td>30</td>
<td>27.3</td>
<td>62.8</td>
<td>89.3</td>
<td></td>
<td>n/a</td>
<td>VAS: n/a</td>
<td>AOFAS: 36.25/40</td>
<td>100</td>
</tr>
<tr>
<td>Current study: Kline and Hasselman&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Metatarsal head resurfacing</td>
<td>30</td>
<td>60.0</td>
<td>51.0</td>
<td>94.1 (27 mo)</td>
<td>66.3 (27 mo)</td>
<td>VAS: n/a</td>
<td>AOFAS: 32/40</td>
<td>100</td>
<td>-3 silastic implants at 3 years -1 arthrodesis without bone graft</td>
</tr>
</tbody>
</table>

Studies were chosen (authors bolded) to be comparative based on recent publication date (2005-2011), mean age (± 5 yrs) of each study cohort, mean length of follow-up (± 12 mos), and preoperative disease severity (advanced hallux rigidus rating); in comparative publications, both treatment arms are listed. MTP = metatarsophalangeal; n/a = not applicable/not available.

<sup>a</sup>Degrees of passive dorsiflexion.

<sup>b</sup>Pain was reported either as Visual Analog Scale (VAS) pain score (0 = no pain, 10 = worst pain) or American Orthopedic Foot and Ankle Society (AOFAS) pain subscore (0 = severe/almost always present, 40 = no pain).

<sup>c</sup>Patients asked if satisfied and would undergo the procedure again.

<sup>d</sup>Complications used in this summary included secondary surgical interventions, manipulation under anesthesia, hardware removal, and postoperative infections (symptomatic calluses, transfer metatarsalgia, and other complications reported by several comparison studies were not included).

<sup>e</sup>Kennedy et al pain score: 89% of patients with "little or no pain."

<sup>f</sup>Fuhrmann patients were satisfied with the relief of pain and the increasing amount of dorsiflexion—patients were not asked if they would undergo the procedure again.

<sup>g</sup>Gibson et al 69% of arthroplasty and 97% of arthrodesis patients who would undergo procedure again; arthrodesis: 94% satisfied; arthroplasty: 70% satisfied.
for advanced hallux rigidus. A number of complications have been reported with this procedure; they include nonunion, transfer metatarsalgia,11,12,13 progressive interphalangeal irritation and degeneration,11,12,13,33,46 difficulty with kneading and other activities,46 and marked changes in gait pattern and foot function.13,18,46 Fusion rates average 90%, and many of these patient go on to require a revision arthrodesis. In addition, some patients have symptomatic prominent hardware that must be removed.

Malalignment is also a major pitfall after arthrodesis.12 It is critical to achieve neutral rotation, adequate dorsiflexion, and adequate valgus while keeping in mind that too little valgus places the interphalangeal joint at risk of degenerative arthritis while excessive valgus may cause difficulty in shoe wear. Excessive dorsiflexion may cause pressure on the dorsal aspect of the toe, whereas inadequate dorsiflexion may create pressure on the tip of the toe.12 In addition, inadequate joint preparation could lead to a nonunion or fibrous union. In the presence of sclerotic bone, meticulous joint preparation requires reaming and debridement to cancellous bone surfaces to enable a successful arthrodesis.12

Given these risks and pitfalls, it is ill-fated to endorse fusion as a universally accepted treatment option for patients with grade 2 or 3 hallux rigidus, particularly when motion sparing procedures have shown similar clinical efficacy.

Several recent articles have looked at the clinical outcomes following variants of a Keller interpositional arthroplasty for the treatment of hallux rigidus. Both techniques utilize a metatarsal chilectomy, with minimal resection of the proximal phalanx to preserve the flexor hallucis brevis insertion, along with capsular interposition. Mackey et al reported on 10 patients who underwent this technique versus twelve patients undergoing fusion.35 They showed improved AOFAS scores for the hallux (89.6 vs 64.5) and decreased peak plantar pressures under the hallux in the interpositional arthroplasty group. Sanhudo et al looked at 25 patients who underwent a similar technique, and showed AOFAS scores of 93.6 and an overall complete satisfaction rate of 75% at a mean 45.8 month follow-up.42

Reported measurements of motion during normal gait vary with values for dorsiflexion ranging from 50 to 90 degrees.5,29,43 Nawoczenski et al40 found that measurements of range of motion exceeded the motion that is required during normal walking. They concluded that only 42 ± 2.3 degrees of dorsiflexion was necessary for normal walking gait. In our study, patients achieved an AROM of 47.9 degrees thereby also exceeding the requirement for normal gait patterns.

When compared to previous reports of hemiarthroplasty and joint fusion, current 2- and 5-year results of metatarsal head resurfacing demonstrated equivalent or better results for range of motion, pain reduction, and patient satisfaction (Table 5). The results were similar to those seen in recent interpositional arthroplasty groups (Table 5).

Several weaknesses of our article should be mentioned. First, we did not have a control group for comparison. Second, this was a nonrandomized trial. Everyone who participated specifically wanted a motion preserving treatment for hallux rigidus, which brings in a selection bias. In addition, a nonvalidated outcomes instrument (the AOFAS score) was utilized. It should also be mentioned that some of the potential pitfalls with hallux metatarsophalangeal arthrodesis are also concerns with implant arthroplasty. Malalignment can potentially lead to uneven loading of the joint, as well as transfer metatarsalgia.

Conclusion

This is the first longer term report on a fourth generation, screw fixation, MTP resurfacing implant that demonstrated durability of the procedure with excellent pain relief and functional improvement at an average follow-up of 5 years. The technique allowed for joint preservation keeping healthy cartilage and subchondral bone functional. At the same time, future conversion to arthrodesis remains a viable option if the condition requires further treatment. The goal of contemporary joint preserving surgery is to relieve pain and improve and maintain joint function. MTP resurfacing provided a viable alternative to joint fusion for appropriately selected patients with grade 2 or 3 hallux rigidus.

Declaration of Conflicting Interests

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