The Keller Resection Arthroplasty: A 13-year Experience

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ABSTRACT
The clinical results following Keller resection arthroplasty were reviewed in 54 feet with a 2- to 10-year follow-up. Patients were evaluated by radiographs, physical examination, and questionnaire. The primary indication for surgery was painful hallux valgus with associated degenerative changes of the first metatarsophalangeal joint. Additionally, rheumatoid arthritis was the underlying diagnosis in four feet. Seventy-five percent of all patients had complete relief of their symptoms. There was significant (P < .01) improvement in both the metatarsophalangeal and intermetatarsal angles, but a decreased range of motion in the first metatarsophalangeal joint, with a complete lack of plantarflexion in 67%. Application of the Bonney and MacNab grading system yielded a 72% rate of good and excellent results. The subjective patient satisfaction rate was 87.5%. Patient satisfaction was most strongly associated with the use of a K-wire for postoperative fixation (P = .03), and a limited resection of the proximal phalanx (P = .03). We conclude that the Keller resection arthroplasty is a reasonable alternative for the treatment of hallux valgus in the presence of degenerative changes in the first metatarsophalangeal joint.

INTRODUCTION
Painful hallux valgus is a common condition, which results from a combination of intrinsic and extrinsic factors. Over the years many procedures have been proposed for its treatment, none of which is universally applicable.10 Excisional arthroplasty of the first metatarsophalangeal joint by resection of the base of the proximal phalanx was first described in 1887 by Davies-Colley. The first two clinical studies were reported by W.L. Keller, in 1904 and 1912, allowing his name to be associated with the procedure.18 In the early half of the century, the Keller arthroplasty was one of the most common procedures performed for hallux valgus. In 1950, Cleveland and Winant4 reported a 96% patient satisfaction rate in their series of 163 Keller operations. Recently, there have been studies less favorable toward the use of the Keller resection arthroplasty for hallux valgus. Potential complications and the difficulties of salvaging a failed Keller procedure have been identified.5,6,12,28,29,31,38 Furthermore, the success of soft tissue realignment procedures and corrective osteotomies in the treatment of symptomatic hallux valgus have caused the Keller procedure to fall out of favor. This trend was reflected in our institution by a dramatic decline in the number of Keller operations performed, from a peak of 13 per year in 1980 to none since 1987 (Fig. 1).

The purpose of this study was to determine the long-term efficacy of the Keller operation in an effort to define its role in the treatment of painful hallux valgus. Specifically, is there a place for the Keller resection...
arthroplasty in the treatment of painful hallux valgus with associated degenerative changes at the first metatarsophalangeal joint?

MATERIAL AND METHODS

Seventy Keller resection arthroplasties were performed on 59 patients at Letterman Army Medical Center between 1976 and 1988. Forty-six patients were contacted, and 40 of those, accounting for 50 operations, were studied by questionnaire, physical examination, and radiographs. Additionally, one patient had only postoperative radiographs available, three patients were interviewed by phone, and two others refused follow-up. Of the remaining patients not included in this retrospective review of Keller resection arthroplasties, three were deceased and 10 others were lost to follow-up. Thus, follow-up information was available on 44 patients (54 feet). Of the patients included in this study, the mean age was 62.2 years (range 46-80 years), 75% of which were female (Fig. 2). The mean follow-up was 71.5 months, with a range of 24 to 112 months.

Twenty-three percent of the patients had bilateral procedures, which had been performed on separate occasions in all but one instance. Fifteen feet had additional procedures performed at the time of the Keller resection arthroplasty, most of which were lesser toe procedures (Table 1). A standard dorsal approach was used in all cases. In most cases, after resection of the base of the proximal phalanx, the capsule was imbricated into the joint space with suture. The exact number in which this was done could not be determined from the records, nor could we determine whether any attempt was made to reattach the flexor brevis mechanism to the remaining proximal phalanx. Temporary K-wire fixation was used in conjunction with the resection arthroplasty in 71% of the feet. The mean duration of fixation could not be determined because of inadequate documentation of the time of pin removal in many cases.

The indication for the Keller procedure in all the feet was painful hallux valgus with associated degenerative changes in the first metatarsophalangeal joint. In addition, hallux rigidus was present in five of the feet (9.3%). Rheumatoid arthritis was the underlying diagnosis in four of the feet (7.4%).

The patients were questioned on their history of previous foot surgeries, their preoperative and postoperative symptoms and functional capacity, and their satisfaction with the result of their Keller resection arthroplasty. Fifty feet were examined by the first author, with particular emphasis on the range of motion of the great toe, the presence of metatarsal head tenderness or callosities, lesser toe deformities, and hallux valgus.

Fifty feet had new radiographs taken at followup, and 31 of those also had preoperative radiographs available for comparison. Radiographs were measured for metatarsophalangeal angle, intermetatarsal angle, amount of proximal phalanx remaining, subluxation of the hallux, lesser toe deformities, and relative lengths of the metatarsals. The results were analyzed for significance using the Wilcoxon signed rank test, the Chi-square, and student’s t-test.

The Bonney and MacNab 12-point grading system was applied to the results.* This system gives 4 points each for anatomic grade, subjective functional grade, and objective functional grade (Table 2). Bonney and MacNab2 never gave criteria for dividing their results into excellent, good, or poor. We arbitrarily called a total score of 12 an excellent result, 9–11 good, 7–8 fair, and 6 or less poor. Preoperative and postoperative anatomic grades were obtained from the radiographs, and subjective functional grades were obtained from

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![Fig. 2. Distribution of patient ages at the time of Keller resection arthroplasty (mean = 62.2).](image-url)
the questionnaire. The objective functional grades were based on the clinical examination. Because of inadequate or inconsistent clinic records in many cases, the preoperative grade was unobtainable for the objective analysis in order to allow for a more uniform study based on the clinical examination. Because of inadequacy of the data, the subjective functional grades were based on the patients’ satisfaction with the results of their procedures. For the purposes of this study, 50 feet in 40 patients were available for review.

RESULTS

When the Bonney and MacNab grading system was applied to the results, 72% of the patients were found to have good or excellent results. The average anatomic grade was 2.18 preoperatively and 3.38 at follow-up, for a 55% improvement. The average subjective functional grade was 2.29 preoperatively and 3.15 at follow-up, for a 37.4% improvement. The average objective functional grade was 2.8 at follow-up, with no preoperative grade available because of incomplete records (Tables 3 and 4) (Figs. 3 and 4). When asked whether they were satisfied with the result of their operation, 87.5% stated that they would be willing to undergo the same procedure again.

Radiographic Findings (Anatomic Grade)

Postoperative standing radiographs of 50 operated feet were obtained. Thirty-one feet had preoperative radiographs available for review. Radiographs were measured for first metatarsophalangeal angle, intermetatarsal angle, amount of proximal phalanx remaining, subluxation of the hallux, and lesser toe deformities.

Preoperatively, the average first metatarsophalangeal angle was 35.4° (range 18–53°). Postoperatively, the average metatarsophalangeal angle was 18.2° (range 0–43°), for an average correction of 48.6% (P < .01). A single patient was found to have asymptomatic varus of the hallux, measuring 6° at followup, but was also noted to have 6° of varus on the contralateral unoperated foot.

The average preoperative intermetatarsal angle was 14.4° (range 4–21°). Postoperatively, it was 10.3° (range 5–16°), for an average correction of 28.5% (P < .01) (Table 5).

The average amount of proximal phalanx removed was 31.0% overall in 41 feet. In five unsatisfied patients, 40.0% had been removed, while in 36 satisfied patients, 29.8% had been removed. Thus, there was a significant correlation (P = .03) between patient dissatisfaction and excessive proximal phalanx resection (Fig. 5). No correlation was found between the amount of proximal phalanx removed and the presence of lateral metatarsalgia (P = .17). At followup, 19 feet (41%) demonstrated dorsal or medial subluxation of the hallux, and 25 (57%) had lesser toe deformities.

Subjective Evaluation

Preoperatively, patients complained of pain in 96% of the feet, difficulty fitting shoes in 37%, and cosmetic deformity in 12% of the feet. In 81% of the feet, the preoperative symptoms were constant, causing complete limitation from normal activities in 9%, and intermittent limitation in 72% of the feet. The duration of preoperative symptoms was longer than 5 years in 79% of the feet.

Postoperatively, only 15% of the feet had constant symptoms with intermittent limitation from normal activities. Fifty-one percent had occasional mild symptoms

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**TABLE 2**

<table>
<thead>
<tr>
<th>Anatomical grades</th>
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<tbody>
<tr>
<td>1. Hallus valgus less than 20°, no bunion</td>
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<tr>
<td>2. Hallux valgus 20–30°, bunion</td>
</tr>
<tr>
<td>3. Hallux valgus 30–50°, bunion, bursitis</td>
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<tr>
<td>4. Hallux valgus more than 50°, bunion, bursitis</td>
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**TABLE 3**

<table>
<thead>
<tr>
<th>Bonney and MacNab Grades Before and After Keller Resection Arthroplasty</th>
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<tbody>
<tr>
<td>Anatom grade</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>Preoperative</td>
</tr>
<tr>
<td>Postoperative</td>
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**TABLE 4**

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<tr>
<th>The Final Result Based on the Total Bonney and MacNab² Grade for Each Patient (N = 50)</th>
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<tbody>
<tr>
<td>Rating</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Excellent</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Fair</td>
</tr>
<tr>
<td>Poor</td>
</tr>
</tbody>
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Fig. 3. A, The preoperative and postoperative anatomical grade of Keller resection arthroplasty, according to the grading system of Bonney and MacNab.² B, The preoperative and postoperative subjective functional grade in 48 patients. C, The objective functional result in 47 patients at followup.

Fig. 4. Comparison of the mean preoperative grades with the mean grades following Keller resection arthroplasty.

TABLE 5
Preoperative and Postoperative Pain and Radiographic Measurements

<table>
<thead>
<tr>
<th></th>
<th>Pain (%)</th>
<th>MTP angle (°)</th>
<th>IM angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>96.0</td>
<td>35.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Postoperative</td>
<td>28.6</td>
<td>18.2</td>
<td>10.3</td>
</tr>
</tbody>
</table>

with no limitations, and 34% had completely absent symptoms postoperatively. All patients demonstrated some postoperative improvement in function and pain relief (Table 6). Comparison of the patients younger than 60 years at the time of surgery (12 feet) with those older than 60 (37 feet) yielded the following trend: 100% of the younger patients were satisfied with their result, at an average followup of 84 months. Eighty-four percent of the older patients were satisfied, even though their average followup was only 67 months. The differ-
ence between the satisfaction rates, though interesting, was not statistically significant \( (P = .11) \). There was no significant difference in the amount of proximal phalanx excised between the two groups (27% in the younger group versus 34% in the older group, \( P = .22 \)), nor was the difference in the length of followup significant \( (P = .10) \).

Lateral metatarsalgia was a complaint preoperatively in 14 of 34 feet (41%). In seven of those feet, the pain had resolved by the time of follow-up, while three more developed the pain postoperatively. The remainder of the patients were unable to remember whether lateral metatarsalgia had been present preoperatively. Overall, lateral metatarsalgia was present at final followup in 26.7% of the feet. There was a significant difference in the lateral metatarsalgia if a K-wire was used for postoperative fixation following resection arthroplasty. The incidence of lateral metatarsalgia in the K-wire group was 19%, while it was 46% if no K-wire was used \( (P = .03) \). Absence of lateral metatarsalgia, however, was not found to correlate with patient satisfaction \( (P = .17) \).

Objective Evaluation

Patients were assessed for postoperative change in walking distance and medication use, lateral metatarsal pain and callosities, first metatarsophalangeal range of motion, and the presence of lesser toe deformities. Fifty-six percent of the patients felt that their preoperative walking distance was decreased when compared with their walking distance prior to the onset of symptoms. Only 19% complained of decreased walking distance at followup.

Nonsteroidal anti-inflammatory medication was used for pain control in 28% of the cases preoperatively, and was supplemented by narcotic analgesics in two instances (in the same patient). Postoperatively, only 10% of the feet required any nonsteroidal medication, and none required narcotic analgesics (Fig. 6).

At follow-up examination, 20 feet had callosities under the lateral metatarsal heads, 35% of which were located at the second metatarsal head, and 40% at both the second and third metatarsal heads. In 10 of the feet (50%) the callosities were painless. Thirty-eight percent of the feet treated with a K-wire fixation had callosities, and 50% of the feet treated without K-wire fixation had callosities \( (P = .20) \). In most cases the preoperative examination of this feature had not been adequately detailed for comparison.

Postoperative passive range of motion of the great toe averaged an arc of 50.8°. The average dorsiflexion was 47.8° (range 0–80°). Seven feet had extension contractures, averaging 13° (range 10–20°). Twenty-nine feet (67%) were unable to actively plantarflex past neutral, while the average plantarflexion in the remaining 21 feet was 18° (range 10–40°). The satisfaction rate was nearly identical when comparing patients with or without plantarflexion of the first metatarsophalangeal range of motion.
geal joint. The satisfaction rate in the group who could plantarflex the hallux was 85.7%, while in the group of those who could not plantarflex, it was 86.2%, indicating that the ability to plantarflex was not in itself associated with an improved satisfaction rate ($P = .08$). Interestingly, all seven of the patients whose feet had extension "cock-up" deformities were satisfied at followup.

A K-wire was used for postoperative fixation in 34 feet. In two feet we were unable to ascertain whether or not a pin had been used. The arc of motion of the great toe at follow-up in these feet was 50.8° (SD 22.4°, range 10–110°), with an average plantarflexion of 4.8° and a satisfactory result in 94%. In 14 feet, no K-wire was used, the final arc of motion averaged 48.2° (SD 22.7°, range 10–80°) with an average plantarflexion of −1.0° and a satisfactory result in 69%. The difference in satisfaction rates between the two groups was statistically significant ($P = .03$).

Lesser toe deformities were found on examination in 25 of 44 feet (57%) at followup. Forty percent of those had one or more hammer toes, 36% had one or more claw toes. Preoperative lesser toe deformities had not been adequately recorded to allow for meaningful comparison (Table 7). In contrast to Holden,12 who found only a 10% rate of good results in patients with lesser toe deformities, we found that lesser toe procedures performed at the time of the Keller resection arthroplasty had no effect on the end result ($P = .89$).

Complications

There were no major wound complications among the patients in the study, but there was one pin tract infection that resolved with pin removal, local wound care, and antibiotics. Seven of the feet that had undergone Keller resection arthroplasty required eight subsequent operations, six of which were lesser toe procedures. There were two feet that required subsequent surgery for persistent first metatarsophalangeal joint pain, for a reoperation rate of 4%. One patient underwent arthrodesis of the first metatarsophalangeal joint, with a satisfactory result. The other patient underwent a repeat Keller procedure at another institution, and also obtained a satisfactory result.

<table>
<thead>
<tr>
<th>TABLE 7</th>
<th>Lesser Toe Deformities at Followup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deformity</td>
<td>Number</td>
</tr>
<tr>
<td>Hammer toes</td>
<td>10</td>
</tr>
<tr>
<td>Claw toes</td>
<td>9</td>
</tr>
<tr>
<td>Mallet toes</td>
<td>1</td>
</tr>
<tr>
<td>Bunionette</td>
<td>1</td>
</tr>
</tbody>
</table>

Rheumatoid Arthritis

There were four Keller resection arthroplasties performed on patients with rheumatoid arthritis. In all cases the primary indication was painful hallux valgus with erosive changes in the first metatarsophalangeal joint. All four feet also underwent additional procedures, including proximal phalangeal osteotomies of all the lesser toes in two cases, proximal first metatarsal osteotomy in one case, and PIP arthroplasties of the second and third toes in one case. Two of these patients were dissatisfied with their result because of persistent first metatarsophalangeal joint pain. All four feet demonstrated lesser toe deformities typical of rheumatoid arthritis at followup. These feet were grouped with the remainder of the cases for overall analysis.

DISCUSSION

The goal of treatment of hallux valgus is to relieve pain by attempting to restore the normal biomechanical relationships of the first ray.6,20,23,33 To this end, there have been more than 100 reported surgical procedures for treating hallux valgus.10,15 Surgical options include distally based first metatarsal osteotomies, soft tissue realignments, resection arthroplasties, and arthrodeses. Success of these procedures is associated with the use of correct surgical indications. Despite differing indications, the results of differing procedures have been similar in the treatment of hallux valgus. Metatarsal osteotomies and soft tissue realignment procedures of the first metatarsophalangeal joint have yielded reported satisfaction rates of 80% to 90%.3,11–17,20–26,30,32,39

If degenerative disease of the first metatarsophalangeal joint accompanies the hallux valgus, the options include resection arthroplasty, silicone implant arthroplasty, and arthrodesis. The silicone implant has not been shown to give better results than the simple resection arthroplasty, but it does decrease the degree of toe shortening.15 Arthrodesis gives long-lasting pain relief, can correct a large deformity, and is indicated for all ages. It is frequently used as a salvage procedure, chosen more frequently by men than women because it can cause limitation of heel heights. Reported satisfaction rates are 85% to 95%.3,5,7,19,27

The Keller resection arthroplasty has traditionally been indicated for painful hallux valgus in older patients with degenerative disease of the first metatarsophalangeal joint, or with hallux rigidus.11,12,15,17 The results of the Keller procedure have been reported in several series, with satisfaction rates ranging from 79% to 98%.1,4,9,17,37 Our 87.5% overall satisfaction rate compares favorably with most of these published results.
Specific points of comparison between Keller resection arthroplasties and other procedures have been addressed in several reports. Turnbull and Grange reported nearly identical rates of pain relief and satisfaction in a comparison of Keller procedures with distal first metatarsal osteotomies. They noted that the osteotomies with the best results were those in which the distal fragment was fixed in some plantarflexion, thus allowing some preservation of the weight-bearing function of the first ray. Similarly, the Keller resection arthroplasties with the best results were those in which shortening of the first ray was minimized, and some active plantarflexion of the first metatarsophalangeal joint was maintained, thereby allowing weightbearing on the great toe and decreasing the risk of developing lateral metatarsalgia.

Moynihan compared Keller resection arthroplasties to arthrodesis of the first metatarsophalangeal joint, and found similar satisfaction rates. Henry and Waugh compared 85 Keller procedures with 85 fusions using Harris-Beath footprinting pads. They found that the development of lateral metatarsalgia was inversely related to the weightbearing function of the great toe. Patients with the hallux fused in more dorsiflexion bore less weight on it, and had a higher rate of lateral metatarsalgia. It follows that the loss of plantarflexion of the great toe leads to a greater likelihood of abnormal weightbearing on the lesser metatarsal heads, and subsequent lateral metatarsalgia. In addition, Henry and Waugh found that a similar propensity for the development of lateral metatarsalgia occurred in feet in which more than a third of the proximal phalanx was removed during Keller resection arthroplasty. The shared feature in the two groups of failures was the loss of weightbearing function of the great toe, which was shown qualitatively on the Harris-Beath footprinting pads.

Wrighton reported that the amount of proximal phalanx excised has a direct relationship to the weight-bearing function of the great toe. A higher rate of poor results was associated with larger amounts of proximal phalanx excised, because of an increased incidence of lateral metatarsalgia. Johnson has stated that extension deformity of the great toe and subsequent lateral metatarsalgia are "not infrequent" following the Keller procedure, and could be attributed to failure to preserve the flexor hallucis brevis soft tissue attachments to the residual portion of the proximal phalanx. This effect would be accentuated by the removal of a large amount of proximal phalanx. In our series, there was a significant inverse relationship between the amount of proximal phalanx removed and the subjective satisfaction of the patient at follow-up (P = .03). In addition, the amount of proximal phalanx removed seemed to influence the presence of lateral metatarsalgia at followup, though this was not a significant relationship (P = .17).

The use of a K-wire for postoperative fixation following Keller resection arthroplasty has been reported by Thomas to improve the eventual range of motion of the great toe. Patients with preservation of some ability to plantarflex tended to have better results, with decreased likelihood of lateral metatarsalgia. In contrast, Sherman et al. found that the use of a K-wire gave no significant improvement in the final results. In our series, the passive arc of motion at follow-up (50.8°) was about half of normal, with much of the decrease accounted for by a complete loss of plantarflexion in 67% of the feet. Our results suggested that the use of a K-wire for postoperative fixation resulted in improved plantarflexion with greater patient satisfaction. Although the difference in satisfaction rates could not be accounted for solely by the ability to plantarflex, there was a definite association between the use of a K-wire and a decreased incidence of lateral metatarsalgia at followup.

CONCLUSIONS

This long-term follow-up study has shown that the Keller resection arthroplasty can give predictable patient satisfaction within reasonable indications. The Keller resection arthroplasty is a successful procedure for the treatment of hallux valgus in the presence of degenerative changes of the first metatarsophalangeal joint. There were two factors that seemed to contribute to a successful result by their positive influence on weightbearing function of the great toe: preservation of proximal phalanx length, and the preservation of great toe plantarflexion. The use of K-wire fixation after resection arthroplasty tended to enhance the ability to plantarflex the first metatarsophalangeal joint and was associated with improved patient satisfaction by virtue of decreased lateral forefoot symptoms.

REFERENCES

8. deleted in press.