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Outcomes of Keller Gap Arthroplasty for Plantar Hallux Interphalangeal Joint Ulcers in Patients With Diabetes Mellitus

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Abstract

Background: Hallux ulcers are known for their recurrence and associated risk for future amputations. Traditional nonsurgical external offloading methods have poor compliance rates, and the data is sparse on surgical offloading of hallux ulcers. We performed this study to analyze the outcomes of Keller excision gap arthroplasty of the first metatarsophalangeal joint in patients with a neuropathic plantar hallux interphalangeal joint (IPJ) ulcer in patients with diabetes mellitus.

Research Design and Methods: A retrospective study of 105 diabetic patients with a plantar hallux IPJ ulcer who underwent a Keller excision gap arthroplasty between December 2014 and June 2020 was done. A total of 122 great toes had been operated upon for hallux IPJ ulcers. We studied the long-term wound healing rates from patient records and then did a prospective survey of the postreview period.

Results: All the hallux IPJ ulcers healed well in the immediate postoperative period. Six patients reported a recurrence of the ulcer at the original site during a mean follow-up period of 30 months. For these 6 patients, the mean time to recurrence of ulcer after operation was 2.5 years.

Conclusion: At an average of 30 months, we found the Keller gap arthroplasty for treatment of noninfected and nonischemic diabetic foot hallux IPJ ulcers was associated with an ulcer recurrence rate of 5%.

Level of Evidence: Level IV, cohort study.

Keywords: diabetic foot, hallux ulcer, interphalangeal joint, Keller gap arthroplasty, great toe ulcer

Introduction

The diabetic foot ulcer problem has attained immense proportions globally. In 2019, prevalence of diabetes mellitus was about 9.3% of the global population, and it is expected to increase to around 10.9% by 2045.[1] It is a consequence of the rising diabetic patient population combined with the increase in the average life span of patients with diabetes mellitus. Such a situation increases the prevalence of long-term complications of diabetes mellitus, particularly those associated with neuropathy. About 19% to 34% of the persons with diabetes mellitus are affected with a foot ulcer sometime during their life span.[2] Hallux ulcers are the most common type of trophic ulcers in diabetic feet, accounting for about 30% of all diabetic foot ulcers.[3] Conservative strategies to prevent ulcers, such as daily inspections and monitoring, are ineffective. A study by Lavery et al[15] reported that 97% of patients under surveillance of the foot had already developed an ulcer by the time they reported something abnormal. Active surgical intervention has been found to have high healing rates in noninfected, nonischemic ulcers and the lowest reulceration rates.[4] Even though the current International Working Group on the Diabetic Foot (IWGDF) guidelines to offload diabetic foot ulcers concentrates primarily on nonsurgical methods,[5] surgical offloading is increasingly recognized as an effective option for the healing of active diabetic foot ulcers.[5-8]

Hallux ulcers are well known for their predisposition to recurrence. Neglected hallux ulcers are associated with a partial foot or hallux amputation rate nearing 14% and a

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major limb amputation of about 6%.[9,10] Literature on surgical offloading of great toe ulcers is scarce. The Keller arthroplasty was first described in 1904[11] to treat hallux valgus deformity and subsequently has been used primarily to treat arthritis of the first metatarsophalangeal joint. It has been described for treating the surgical management of the interphalangeal joint (IPJ) ulcer of the hallux in diabetic feet.[12-14] Its safety and utility for treating foot problems in the diabetic population have been established.[15,16] The objective of this study was to find the long-term outcomes of Keller excision gap arthroplasty of the first metatarsophalangeal joint in diabetic patients with a plantar hallux IPJ ulcer in terms of ulcer healing, recurrence, and patient-reported outcomes.

Research Design and Methods

The retrospective study included all patients who underwent Keller excision gap arthroplasty of the first metatarsophalangeal joint at our institute between December 2014 and June 2020. We also collected simultaneous data on patients who had undergone a hallux amputation for a complicated ulcer in our center during the same period as a separate cohort. A total of 122 great toes underwent a Keller arthroplasty in 105 consecutive patients. We reviewed all inpatient and outpatient patient records. We collected retrospective data from case records about patient demographics, comorbidities, ulcer distribution, ulcer characteristics, surgery, wound healing, laboratory parameters, neuropathy, details of any previous treatments, perioperative complications, recurrence of ulcers, and incidence of secondary ulcers. We then interviewed 35 patients in person and 70 patients over the telephone when COVID restrictions were in place (Annexure 1). We collected data on ulcer recurrence, secondary ulcerations, footwear use, function after surgery, cosmesis, and patient satisfaction during the interview. We rated patient satisfaction on a scale of 1 to 10 points, 1 being very unsatisfied and 10 being highly satisfied.

Inclusion criteria included all diabetic patients with a noninfected, plantar hallux IPJ ulcer not probing to bone without other concomitant ulcers in the lower limbs who underwent surgery in the form of a Keller excision gap arthroplasty of the first metatarsophalangeal joint. All of the included patients had been on various modalities of conservative management offered by their primary care physician for the ulcer before they presented to our institute. None of the patients included in this study had concomitant issues relating to gastrocsoleus tightness such as metatarsal head ulcers. We excluded patients with hallux ulcers having nonpalpable pulses at ankle level (both anterior and posterior tibial artery pulses), any other associated plantar ulcer on the foot, infection or osteomyelitis, and peripheral neuropathy arising from other causes.

A single surgeon had operated on all patients. Patients presenting to the diabetic foot clinic with a hallux IPJ ulcer underwent a basic foot assessment and radiologic and pedobarographic evaluation. Those with a superficial, noninfected ulcer were offered surgery to heal the ulcer. A Keller excision gap arthroplasty of the first metatarsophalangeal joint was done to ablate the windlass mechanism and correct hallux rigidus/limitus. The procedure was done by excising the proximal third of the hallux's proximal phalanx through a dorsal incision over the first metatarsophalangeal joint (Figure 1). Correction of the problem was verified on the table by applying a dorsiflexion force to the first metatarsal with the great toe kept hyperextended at the end of the operation. Maintenance of hyperextension of the great toe indicated that the windlass mechanism had been disrupted. Postoperatively, the patients were put on alternate-day dressing changes and were not allowed to bear weight on the operated foot till suture removal at 2 weeks. Once sutures were removed and healing of the surgical site confirmed, patients were allowed a trial of partial weightbearing, followed by full weightbearing on the operated foot in the third week postsurgery.

Patients were then reviewed in the outpatient clinic once a month for 3 months and later once every 3 months. All patients had been followed for a minimum of 6 months postsurgery.

The postsurgery review questionnaire (Appendix 1) was presented to those who came in person for their follow-up by an independent surgeon who did not perform the surgeries. Those who could not review in the follow-up clinic because of COVID-19 travel constrictions were presented the questionnaire through WhatsApp, and their responses were relayed by telephone call.

We expressed continuous variables in mean (range and SD). We used Microsoft Excel 2019 for data collection and analysis.

Results

A total of 135 toes had undergone Keller gap arthroplasty for plantar hallux IPJ ulcers in 118 patients during the study period. After applying the exclusion criterion, those patients who were not contactable or those who passed away, the final cohort included 122 great toes in 105 patients (Figure 2) (Table 1). Nine patients had concurrent bilateral ulcers, and 8 cases had developed a subsequent ulcer of the opposite great toe during the study period. During the same period, 64 cases of hallux ulcers complicated with infective gangrene, osteomyelitis, abscess had been treated, of which 41 toes required amputation and 23 toes were salvaged by debridement with or without reconstruction.

The mean age of the study patients was 53.2 years (31-79 years). There were 61 female and 44 male patients. Diabetes mellitus was present in all 105 patients. The mean

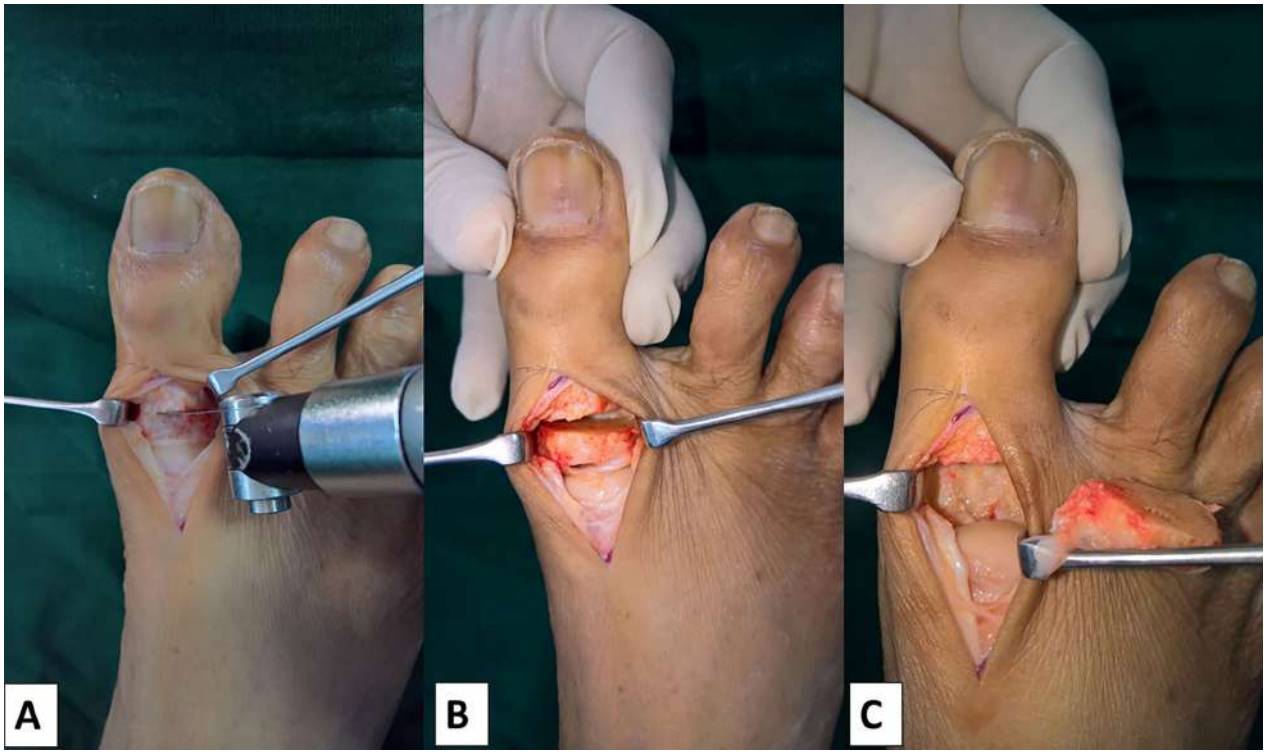

Figure 1. Intraoperative picture of Keller gap arthroplasty. (A) Dorsal approach to first metatarsophalangeal joint. (B) Excision of proximal one-third of the proximal phalanx of the hallux. (C) Gap produced after excising the proximal one-third of the proximal phalanx of the hallux.

duration of diabetes was 8.9 years (1 month to 27 years). The mean HbA1c at presentation was 6.4 (4.8-10.2). On looking into the comorbidities, 67 had systemic hypertension, 56 had coronary artery disease, 12 had hypothyroidism, and 9 had chronic renal failure (Table 1).

Of the 122 feet with ulcers, 106 feet had loss of protective sensation as indicated by the inability to perceive a 10g monofilament. In addition, 110 of 122 feet had a history of a preulcerative lesion in the form of callosity at the site of index ulcer on the great toe, which the patient had recognized but had not sought medical attention for.

The mean duration of hallux ulcer was 16 months (2 months–11 years). All patients had undergone prior treatment with various dressings (topical antiseptic creams, foam dressings, silver-impregnated dressings) ranging from 1 to 9 months. Fifty-four feet had nonsurgical offloading in the form of footwear and removable-cast walkers earlier before presenting to our institute with a persistent nonhealing ulcer. On examination, all toes had either hallux rigidus or functional hallux limitus of the first metatarsophalangeal joint. All patients underwent surgery under regional block anesthesia for the involved limb.

Postoperatively, all hallux ulcers had healed (Figures 3-6) with a mean time of 3.5 (3-8) weeks to complete epithelial closure. Three patients had wound dehiscence of the surgical wound on mobilization (Figure 7). All 3 wounds healed by secondary intention. Two of them had superficial wound infection which was managed with dressings and topical antibiotic ointments. After ulcers healed, all patients had been advised preventive-offloading with therapeutic footwear.

The mean available long-term follow-up from the review of records was 30 months (6-62 mo). Five cases had a documented recurrence of hallux limitus and reduced range of motion at the first metatarsophalangeal joint. Two cases of recurrence had ankylosis on the radiograph (Figure 8). Three patients had a pronated foot with persistent weight-bearing on the first ray. In addition, 2 patients who had non-dependent edema of the operated foot were detected to have new-onset Charcot arthropathy and were managed conservatively with a protective below-knee nonremovable cast application.

In the postsurgery review questionnaire, a total of 6 patients reported recurrence of ulcers at the original site. The mean duration of time to recurrence was 2.5 years. Two

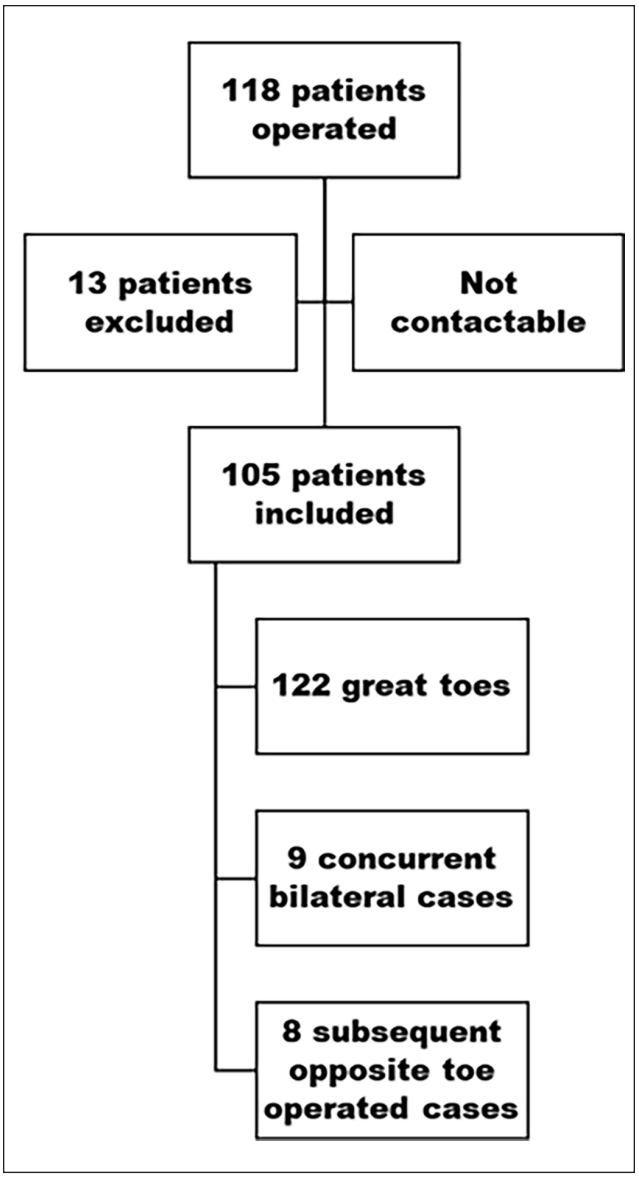

Figure 2. Flow of cases.

Table 1. Study Population Demographic Details.

Category	Mean/Range/ Number (n)
Mean age of patients, y	53.2 (31-79)
Male, Female, n	61, 44
Mean duration of diabetes, y	8.9 y (1 mo–27 y)
Mean HbA_{1c}	6.4 (4.8-10.2)
Comorbidities	
Systemic hypertension	67
Coronary artery disease	56
Hypothyroidism	12
Renal failure	9
Nonsurgical offloading prior to surgery	54
Healed with recurrence	
Complete	34
Near complete	20
Mean duration to heal with nonsurgical offloading, mo	5 (1-9)
Mean time for ulcer to recur with nonsurgical offloading, mo	5 (2-18)
Mean time to healing of the ulcers, post–Keller gap arthroplasty, wk	3.5 (3-8)
Mean follow-up, mo	30
Recurrence of hallux limitus after Keller gap arthroplasty	5 cases
Cocked up toe deformity	7
Ulcer recurrence, post–Keller gap arthroplasty	6
Mean time for ulcer to recur, post–Keller gap arthroplasty, mo	30 (6-40)
Great toe amputation, post–Keller gap arthroplasty (unrelated to primary surgery)	4
Relative shortening of the operated great toe, observed by the patient	34
Customized footwear compliance	25
Indoor footwear usage	10
Difficulty in wearing footwear following surgery	11

Abbreviations: y, Years; mo, Months; wk, Weeks; n, Number.

patients reported persistent ulceration, whereas 3 reported resolution of the ulcers following rest and increased compliance with therapeutic footwear. One patient underwent a first-metatarsophalangeal joint arthrolysis with subsequent healing of the ulcer. Four patients complained about the stiffness of the operated great toe, which did not affect their routine activities. Seven patients reported a cocked-up toe deformity.

A total of 11 patients reported the development of secondary transfer ulcers. Six patients reported secondary ulcers over the first metatarsal head. Five of them underwent surgery for the transfer ulcers. Three underwent a Modified Jones tenosuspension combined with Peroneus longus to brevis transfer, one dorsiflexion osteotomy of first metatarsal with peroneus longus to brevis transfer and one shaving of first metatarsal head with peroneus longus to brevis transfer. One patient refused surgery. Five reported ulcers over the lesser metatarsal heads. Four of them underwent floating distal metatarsal osteotomy and 1 underwent a Weil osteotomy. Four patients had a subsequent amputation of the operated great toe (2 had gangrene due to peripheral vascular disease and 1 due to nail infection, and 1 more due to neglected trauma). Eight patients had a subsequent below-knee amputation (2 due to peripheral vascular disease; 3 due to necrotizing fasciitis secondary to heel ulcer, dorsum of foot ulcer, and webspace ulcer respectively; 2 due to infected Charcot arthropathy with

Figure 3. (A) Hallux interphalangeal joint ulcer. (B) Healed hallux interphalangeal joint ulcer 4 months after Keller gap arthroplasty. (C) Healed scar over the dorsum of resultant mobile and short great toe.

midfoot ulcer; 1 due to high-velocity trauma). None of the major amputations were directly connected to the hallux surgery. Thirty-four patients noticed a relative shortening of the operated great toe, but none of them worried about it. The average shortening of toe following the surgery was 6.3 ± 3.1 mm as measured on digital radiographs taken preoperatively and in the immediate postoperative period. Though all patients were prescribed therapeutic footwear for indoor and outdoor use, only 25 patients used them and only 10 among those 25 reported the use of footwear indoors. Twelve patients reported persistent pain in the great toe for a mean period of 8 months postsurgery, which settled spontaneously. The overall mean satisfaction score was 6.3 ± 2.7. Seventy-eight patients self-reported satisfaction of 8 or more in the satisfaction scale with surgery in respect to great toe ulcers.

Discussion

Hallux IPJ ulcers are closely related to the dysfunction of the first metatarsophalangeal joint. They result from a reduction in the range of motion in the joint. The first metatarsophalangeal joint movement restriction results in an increase in pressure on the hallux during gait. The windlass mechanism causes the first metatarsal ray to plantarflex when the hallux is hyperextended and conversely the hallux to plantarflex when the first metatarsal ray dorsiflexes during loadbearing. The excision of the base of the proximal phalanx (PPX) of the first metatarsophalangeal joint disrupts the windlass mechanism.[10] The resultant offloading of the hallux leads to rapid healing of the ulcer.

Various reports of first metatarsophalangeal joint arthroplasty for managing the hallux IPJ diabetic foot ulcer have shown success rates ranging from 78% to 95.2%.[14,15] In our study, Keller gap arthroplasty's long-term success rate (ulcer healing without recurrence) was 95%. The immediate postoperative complications directly resulting from surgery accounted to 4.1%. There was a development of transfer ulcers in about 9% of cases. The overall complication rate was about 18%. Frykberg and Banks[17] in their study reported 21% complication, predominantly infection and wound dehiscence. The recurrence rate in our study was 5% at a mean of 30 months. The compliance with the footwear was very low, with only about 25% of patients using them

Figure 4. (A) Hallux interphalangeal joint ulcer. (B) Postoperative photograph showing complete healing of the hallux interphalangeal joint ulcer 2 months after Keller gap arthroplasty. (C) Well-settled scar over the dorsum of mobile and short great toe.

Figure 5. (A) Preoperative hallux interphalangeal joint callous ulcer and (B) healing 3 months post Keller gap arthroplasty.

Figure 6. (A) Preoperative and (B) Postoperative radiographs showing the extent of bone resection of the proximal third of the proximal phalanx of the hallux.

Figure 7. Immediate postoperative picture of patient with wound dehiscence that was allowed to heal by secondary intention.

Figure 8. Radiograph showing ankylosis at the arthroplasty site in great toe.

at all and only 9.5% using them indoors. Low compliance with footwear may contribute to the high incidence of secondary transfer ulcers.

The cocked-up toe deformity reported by 7 patients resulted from the loss of the flexor hallucis longus function most probably because of a prior episode of deep infection, resulting in the unopposed action of the extensor mechanism. The occurrence of new-onset Charcot arthropathy after surgery in 2 patients was probably triggered by the surgery. Similar cases have been reported in literature.[18] Patient satisfaction with the procedure was high, and patients were not very concerned about the shortening of the toe.

The study's limitations include its retrospective nature and the absence of a control group. In addition, possible sources of bias include the exclusion of patients with ischemia and active infection. These patients would have had deeper ulcers and possibly higher postoperative complications and recurrence rates. Considering the retrospective nature of the study and the absence of statistical analytical data, this study cannot be used to ascertain superiority of surgery over traditional conservative methods. However, these data can be used as a basis for future comparisons.

To our knowledge, this study presents the largest cohort of patients who have undergone a Keller gap arthroplasty for a plantar hallux IPJ ulcer in persons with diabetes mellitus.

Literature shows Keller's first metatarsophalangeal joint arthroplasty to be better than conservative measures such as total contact casting in healing hallux ulcers.[13] Surgery for hallux ulcers has been shown to be more effective than conservative measures in preventing reulceration and in healing ulcers that have failed cast trials.[13,14]

The results strengthen the existing literature that the Keller gap arthroplasty is an effective form of therapy that can provide predictable healing in a large majority of patients. This study supports Bus and colleagues'[19] arguments that there needs to be a paradigm shift in how diabetic foot ulcers are treated by prioritizing preventive procedures before the ulcers become infected. In the face of low compliance rates for external offloading methods, and the recommendations to avoid using conventional or standard therapeutic footwear to treat active plantar neuropathic ulcers,[20] surgical procedures with high recurrence-free cure rates can be adopted earlier in the course of the disease. This procedure also addresses the most common diabetic foot ulcers, the hallux ulcer, which suggests that surgical treatment for plantar hallux ulcers early in the disease would heal these ulcers and prevent their complications.

Conclusion

At an average of 30 months, in this cohort, the Keller gap arthroplasty was associated with an ulcer recurrence rate of 5%.

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Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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