

# SALVAGE OF A FAILED KELLER RESECTION ARTHROPLASTY

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**Background:** A number of typical complications have been associated with Keller resection arthroplasty. Recurrent valgus deformity, cock-up deformity, and a flail toe may be difficult problems for the treating surgeon because options for salvage are limited. In this study, we evaluated arthrodesis of the first metatarsophalangeal joint as a salvage technique following a failed Keller procedure. In addition, the outcomes of motion-preserving procedures were reviewed in a separate series.

**Methods:** Arthrodesis of the first metatarsophalangeal joint was performed in twenty-eight patients (twenty-nine feet, group A), and either a repeat Keller procedure or an isolated soft-tissue release was performed in eighteen patients (twenty-one feet, group B). The patients were evaluated at least twenty-four months postoperatively, with a personal interview and a clinical examination with use of a modification of the hallux metatarsal-interphalangeal scale. Radiographs were also made for the group treated with the arthrodesis.

**Results:** In group A, the average duration of follow-up was thirty-six months and fusion was achieved in twenty-six of the twenty-nine feet. Satisfaction was excellent or good in twenty-three cases, and the postoperative score according to the modified hallux metatarsal-interphalangeal scale averaged 76 points (maximum, 90 points). A repeat arthrodesis was necessary in five feet because of malposition or pseudarthrosis. In group B, the average duration of follow-up was seventy-four months. Satisfaction was excellent or good in only six cases, and the patient was dissatisfied in eleven cases. The score according to the modified hallux metatarsal-interphalangeal scale averaged 48 points. Valgus deviation and cock-up deformity had recurred in the majority of the feet at the time of follow-up.

**Conclusions:** Although it is more technically demanding, we recommend arthrodesis for salvage following a failed Keller procedure since it may be associated with a higher rate of patient satisfaction and better clinical results.

**Level of Evidence:** Therapeutic study, Level III-2 (retrospective cohort study). See Instructions to Authors for a complete description of levels of evidence.

Resection arthroplasty of the first metatarsophalangeal joint, introduced by Keller in 1904<sup>1</sup>, has been utilized to treat both hallux valgus and hallux rigidus. This procedure offers a number of advantages, including technical simplicity, satisfactory pain relief, and easy postoperative care. However, the Keller procedure has been reported to be associated with several common complications<sup>2,3</sup>, including recurrent hallux valgus, transfer metatarsalgia, cock-up deformity, and a floppy toe when an excessive amount of bone has been resected. When these complications require salvage surgery, options are limited, and the literature contains few reports evaluating different salvage techniques.

Arthrodesis of the first metatarsophalangeal joint is an accepted treatment for severe hallux valgus and hallux rigidus. Its use as a salvage procedure following failed bunion surgery has been described in several studies<sup>4-8</sup>, but we are aware of only one report addressing arthrodesis for salvage after a failed Keller procedure<sup>9</sup>. In 1987, Coughlin and Mann<sup>9</sup> reported the results of sixteen arthrodeses of the first metatarsophalangeal joint that had been performed after a Keller procedure had

failed in eleven patients. Fusion was achieved in each patient, and all of the results were excellent or good. Lateral metatarsalgia was present in twelve feet preoperatively, and it resolved in all but one after the surgery.

Other procedures that can be potentially used for salvage following a failed Keller resection arthroplasty include implant arthroplasty and repeat resection arthroplasty with soft-tissue techniques (i.e., tendon lengthening), but their clinical effectiveness has not been reported, to our knowledge.

Treatment following a failed Keller procedure has been a controversial topic at our institution. In the past, joint-motion-preserving techniques were routinely used as salvage procedures. In the early 1990s, encouraged by the results of the study by Coughlin and Mann<sup>9</sup>, we extended the indication for arthrodesis of the metatarsophalangeal joint to include a failed resection arthroplasty, and increasing numbers of arthrodeses were performed in the following years.

The aim of our study was to review the outcomes of two salvage techniques used for the treatment of patients with a failed Keller procedure. We present the results of a series of con-

TABLE I Preoperative Status

	Arthrodesis	Repeat Keller Procedure or Tendon Lengthening
No. of patients	32	26
No. lost to follow-up	4	8
No. of patients (feet) evaluated	28 (29)	18 (21)
Mean age (range) at op. (yr)	64 (49-78)	62 (49-74)
Mean time (range) since Keller procedure (yr)	13 (2-38)	8 (1-30)
Diagnosis		
Hallux valgus	10	7
Cock-up deformity	12	12
Hallux rigidus	6	2
Hallux varus	1	0
Concomitant transfer metatarsalgia	16	10

secutive arthrodeses of the first metatarsophalangeal joint and a series of two other, motion-preserving procedures: (1) z-shaped lengthening of the extensor hallucis longus tendon in patients with an isolated cock-up deformity and (2) a repeat Keller procedure with further proximal phalangeal resection in patients with recurrence of hallux rigidus or valgus deformity.

### Materials and Methods

A Keller procedure was considered to have failed when a patient had the typical painful sequelae of the resection arthroplasty, such as a valgus deformity or a cock-up toe. Surgery was indicated when conservative treatment, primarily with a custom-made shoe insert, did not relieve the pain sufficiently. Because of the retrospective nature of this study, the allocation of treatment between the two groups was not randomized; the type of procedure performed depended on the surgeon's preference and experience. The decision was not based on a selection criterion such as the severity of the deformity or any specific contraindication. Nevertheless, a selection bias cannot be ruled out, and therefore the two groups were not compared directly.

#### Arthrodesis (Group A)

Between 1993 and 1999, we performed thirty-three arthrodeses of the first metatarsophalangeal joint for salvage following a failed Keller operation in thirty-two patients (Table I). Twenty-eight patients (twenty-nine feet) were available for follow-up, and they formed the study group. All patients except two were female. The mean age at the time of the surgery was sixty-four years (range, forty-nine to seventy-eight years). The interval between the resection arthroplasty and the arthrodesis averaged thirteen years (range, two to thirty-eight years). Eight patients had undergone previous surgery: four had had another bunion procedure prior to the Keller procedure, and four had had revision surgery after the resection arthroplasty because of a cock-up toe deformity and recurrent valgus deformity (a tendon lengthening had been done in three patients and an implant arthroplasty, in one).

Preoperative diagnoses included painful cock-up toe deformity (twelve feet), recurrent hallux valgus (ten), persistent

hallux rigidus (six), and hallux varus (one). Transfer metatarsalgia in which callosities under the metatarsal heads were combined with symptoms was diagnosed in sixteen of the twenty-nine cases.

#### Operative Technique

We performed the salvage arthrodesis of the first metatarsophalangeal joint with use of regional anesthesia (peripheral nerve block), and a tourniquet was used in fourteen cases in this series. Through a dorsal approach, we performed a z-lengthening of the extensor hallucis longus tendon, released the contracted capsule, and débrided the joint. Residual articular cartilage was removed, and a ball-and-socket or flat-cut configuration was prepared for arthrodesis. (Between 1993 and 1999, our technique evolved from flat cuts to the ball-and-socket configuration.) It was our aim to position the fusion so that the residual proximal phalanx was in 15° of valgus and 20° of dorsiflexion in relation to the first metatarsal, but the position of the second toe and the inclination of the first metatarsal may have had an effect on the final position in some cases. In fourteen of the procedures, two crossed cannulated cancellous screws (3.0 mm in diameter; Synthes, Paoli, Pennsylvania) were used for fixation. In patients with insufficient bone in the residual phalanx, we inserted a single screw (three feet), one screw and a Kirschner wire (nine feet), or two crossed Kirschner wires (two feet). In one patient, we used a dorsal minifragment plate. Depending on the intraoperative stability of the fusion and the anticipated compliance by the patient, the patients either wore a stiff-soled shoe and were allowed weight-bearing to tolerance on the heel only for an average of seven weeks or had a below-the-knee walking cast for an average of six weeks, after which they wore a postoperative shoe for another four weeks.

*Additional procedures:* Associated subluxation of lesser metatarsophalangeal joints and hammer toes were treated simultaneously if they were symptomatic. Additional procedures were performed in eighteen of the twenty-nine feet. These procedures included a Weil shortening osteotomy of the lesser metatarsals (nine feet), a Helal osteotomy of the lesser metatarsals (one), a Hohmann partial phalangeal resection (five), and

**TABLE II AOFAS Hallux Metatarsophalangeal-Interphalangeal Scale**

	Points
Pain	40
Function	
Activity limitations	10
Footwear requirements	10
Metatarsophalangeal joint motion	10
Interphalangeal joint motion	5
Stability of metatarsophalangeal and interphalangeal joints	5
Callus related to metatarsophalangeal and interphalangeal joints of hallux	5
Alignment	15
Total	100

unionette procedures (a condylectomy of the fifth metatarsal head in two feet and a Hohmann metatarsal osteotomy in one).

#### Group B

The other group in our study comprised twenty-nine feet (twenty-six patients) in which we attempted to salvage the failed Keller operation without doing an arthrodesis of the first metatarsophalangeal joint (Table I). The procedures were performed between 1989 and 1997. Twenty-one feet (eighteen patients) were available for follow-up, four patients could not be located, and four patients had died. All patients were female; the mean age at the time of surgery was sixty-two years (range, forty-nine to seventy-four years). The preoperative diagnoses included hallux valgus (seven feet), hallux rigidus (two), and cock-up deformity (twelve). Symptomatic callosities under the lesser metatarsal heads were noted in ten feet before the revision surgery.

#### Operative Technique

The specific revision procedure in each patient in this group was dictated by the particular residual deformity. When a pa-

tient had an isolated cock-up toe deformity with contracture of the extensor hallucis longus tendon, we performed a z-lengthening of the tendon (twelve feet). In the presence of recurrent valgus deformity or painful limitation of joint motion, we performed a repeat Keller procedure with further resection of the base of the proximal phalanx and a medial capsulorrhaphy (nine feet). The extensor hallucis longus tendon was also lengthened in patients who had, in addition, a cock-up deformity, and medial sesamoidectomy was performed in one patient with sesamoiditis. The use of transient Kirschner wire fixation depended on the surgeon's preference, and it was used in five feet. Patients were permitted to bear weight as tolerated while wearing a stiff-soled postoperative shoe, for an average of four to six weeks, before resuming regular shoe wear.

Additional procedures were performed in six of the twenty-one feet. These procedures included a Helal osteotomy of the lesser metatarsals (two feet) and a resection of the lesser metatarsal heads (one) in three feet with lateral metatarsalgia as well as a Hohmann partial phalangeal resection in another three feet with symptomatic hammer toes.

#### Follow-up Evaluation

At the time of follow-up, we evaluated patients with use of the American Orthopaedic Foot and Ankle Society (AOFAS) hallux metatarsal-interphalangeal scale<sup>10</sup>. This 100-point scale was modified to a maximum score of 90 points for patients who had undergone arthrodesis, since 10 points of the original scale are assigned to the range of motion of the first metatarsophalangeal joint (Table II). Furthermore, because this outcome tool does not address transfer lesions of the lesser metatarsals, we noted the presence of transfer metatarsalgia independent of the AOFAS hallux metatarsal-interphalangeal score. The diagnosis of transfer metatarsalgia was based on the combination of the patient's report of symptoms and the presence of callosities under the metatarsal heads.

Special attention was paid to the presence of hallux valgus and cock-up deformities. Furthermore, patients were asked to rate their satisfaction with the result of the procedure. The result was considered excellent when the patient was very satis-

**TABLE III Results at Follow-up**

	Arthrodesis	Repeat Keller Procedure or Tendon Lengthening
No. of patients (feet) evaluated	28 (29)	18 (21)
Mean duration (range) of follow-up (mo)	36 (24-76)	74 (27-132)
Satisfaction (no. of feet)		
Excellent	13	0
Good	10	6
Fair	1	4
Poor	5	11
Mean score according to modified hallux metatarsophalangeal-interphalangeal scale* (points)	76 (50-90)	48 (15-75)

\*Maximum score, 90 points.



Fig. 1-A



Fig. 1-B

**Figs. 1-A, 1-B, and 1-C** Clinical photographs and a radiograph showing the results two years after arthrodesis of the first metatarsophalangeal joint in a fifty-four-year-old woman. The patient was free of symptoms and had no limitations with regard to shoe wear or walking distance.

fied, had no problems related to the foot, and would have the procedure again without reservation. The result was considered good when the patient was satisfied despite minor problems and would definitely undergo the surgery again. The result was defined as fair when the patient had major problems, only some improvement, and reservations about the success of the surgery, whereas the result was graded poor when the patient was dissatisfied and regretted having had the surgery.

Anteroposterior and lateral weight-bearing radiographs were made for the patients treated with the arthrodesis, to determine whether there was evidence of metatarsophalangeal joint fusion and to assess proximal phalanx-to-first metatarsal alignment. Joint fusion was considered to be present when there was trabecular bone crossing the fusion site, and the angle formed by the intersection of the diaphyseal axes was measured. In group B, preoperative weight-bearing radiographs were not available for a number of patients, especially those who had had an isolated soft-tissue procedure. Therefore, a radiographic evaluation of this group was not performed.

### Results (Table III)

#### Group A (Arthrodesis)

Twenty-nine feet (twenty-eight patients) treated with an arthrodesis were evaluated at the time of follow-up, at a mean of thirty-six months (range, twenty-four to seventy-six months). The average AOFAS hallux metatarsal-interpha-



Fig. 1-C

langeal score was 76 points (range, 50 to 90 points). Since 1995, this score has been assessed routinely at our institution, and the preoperative score was available for fourteen feet. In this subset of patients, the average AOFAS hallux metatarsal-interphalangeal score improved from 42 points (range, 15 to 65 points) preoperatively to 80 points (range, 70 to 90 points) at the time of follow-up. We did not try to determine preoperative scores retrospectively, as such scores are a poor indicator of the patient's preoperative condition<sup>11</sup>.

The average hallux valgus angle decreased 12.8°, from 27.3° (range, 5.5° to 53.5°) preoperatively to 14.5° (range, 6° to 32.5°) at the time of follow-up. Two cases of preoperative varus deformity (-2.5° and -37°) were changed to postoperative values of 10.5° and -9.5°, respectively. The one case of postoperative hallux varus was the result of a nonunion. The average preoperative and postoperative intermetatarsal angles were 9.9° (range, 2° to 17.5°) and 9.8° (range, 4.5° to 15°), respectively.

Radiographically, dorsal angulation of the hallux (the angle formed by the longitudinal axes of the first metatarsal and the proximal phalanx) averaged 21° (range, 5° to 42°). The mean first metatarsal inclination was 21° (range, 11° to 31°). Clinically, this translated into an average proximal pha-

langeal position that was neutral relative to the ground.

Assessment of radiographic evidence of preoperative arthrosis of the interphalangeal joint was limited in feet with severe cock-up toe deformity. Postoperative radiographs suggested only one case of degenerative changes of the interphalangeal joint, in an asymptomatic patient.

The outcome of the salvage arthrodesis was considered by the patient to be excellent for thirteen feet, good for ten, fair for one, and poor for five. All five feet with a poor result were subsequently treated with a revision arthrodesis. Fusion of the metatarsophalangeal joint was achieved in twenty-six of the twenty-nine feet (Figs. 1-A, 1-B, and 1-C). One asymptomatic fibrous nonunion was observed; the AOFAS score was 85 points, and no additional surgical management was performed. There were two other, symptomatic nonunions, and they were treated with a revision arthrodesis. Malunion was the indication for the other three revision arthrodeses. In these cases, inadequate abduction and/or dorsiflexion of the proximal phalanx created pain, abnormal hallux load-bearing, and limitations with regard to shoe wear.

We observed sixteen cases of transfer metatarsalgia preoperatively; at the time of follow-up, nine cases had resolved,



Fig. 2-A



Fig. 2-B

Preoperative (Fig. 2-A) and postoperative (Fig. 2-B) radiographs of a woman treated with arthrodesis of the first metatarsophalangeal joint and Weil osteotomies of the second, third, and fourth metatarsals when she was sixty-seven years old.

five had improved, and two had remained unchanged. In ten of the sixteen feet, simultaneous shortening osteotomies of the lesser metatarsals were performed (Figs. 2-A and 2-B), and, at the time of follow-up of these ten feet, the transfer metatarsalgia had resolved in seven, decreased in two, and remained unchanged in one. There was a single case of new-onset transfer metatarsalgia following the arthrodesis.

In addition to the three malunions and three nonunions, other complications included two superficial wound infections, one deep infection, one complex regional pain syndrome, and four cases of painful hardware. The superficial wound infections resolved with local wound care and oral antibiotics. The deep infection was eradicated with intravenous antibiotics. The complex regional pain syndrome resolved after one year, and removal of prominent screws alleviated the symptoms that they had been causing in the four patients.

### Group B

Twenty-one feet (eighteen patients) treated with a salvage procedure other than an arthrodesis were available for follow-up at an average of seventy-four months (range, twenty-seven to 132 months). The AOFAS hallux metatarsal-interphalangeal score averaged 51 points (range, 15 to 80 points), and when the values for metatarsophalangeal joint motion were subtracted (as they were in group A) the scores averaged 48 points (range, 15 to 75 points). None of the outcomes were rated by the patient as excellent; six were rated as good; four, as fair; and eleven, as poor. Problems leading to less favorable outcomes included cock-up toe deformity (eight feet, Fig. 3-A) and recurrent valgus deformity (five feet). Cock-up toe deformity resulted in subjective loss of push-off strength, transfer metatarsalgia, and shoe-wear limitations. Not all patients with recurrent hallux valgus were symptomatic; one patient with a 42° hallux valgus angle was asymptomatic when wearing custom shoes. The other four feet with recurrent hallux

valgus subsequently underwent a salvage arthrodesis.

Transfer metatarsalgia was diagnosed in ten feet preoperatively. At the time of follow-up, symptomatic callosities were noted in nine feet (Fig. 3-B), and in five of them the callosities had developed postoperatively.

There was also one deep infection in this group, which resolved with intravenous antibiotics.

### Discussion

Failed Keller resection arthroplasty is a difficult problem, both for the patient and the treating surgeon. Persistent pain, shoe-wear limitations, instability or stiffness, and transfer metatarsalgia are often recalcitrant to nonoperative management and more disabling than the original problem that led to the Keller procedure. Several studies have demonstrated that the extent of the proximal phalangeal resection dictates functional outcome, and most authors have recommended removing between one-third and one-half of the proximal phalanx<sup>2,3,12</sup>. Resection of less than one-third increases the risk of insufficient decompression of the metatarsophalangeal joint, leading to recurrent hallux rigidus and reduced joint mobility<sup>2</sup>. Conversely, excessive resection often results in an unstable toe. Detachment of the flexor hallucis brevis tendon may lead to the development of a cock-up toe deformity. Decreased stability of the first metatarsophalangeal joint is a common complication after the Keller procedure. As a consequence, weight-bearing on the first ray is impaired<sup>12-14</sup>, often resulting in transfer metatarsalgia as excessive loads are placed on the lesser metatarsal heads. Although modifications of the original method have been described<sup>15,16</sup>, instability and its consequences still occur.

Salvage procedures consist of either (1) arthrodesis of the first metatarsophalangeal joint or (2) joint-motion-retaining surgery, which is confined to correcting the existing deformity. The second approach does not typically solve the problem of instability, which is the underlying cause for most of the compli-



Fig. 3-A

Commonly encountered complications after joint-preserving procedures are the recurrence of hallux valgus deformity with a cock-up deformity (Fig. 3-A) and plantar callus with lateral metatarsalgia (Fig. 3-B).



Fig. 3-B

cations occurring after resection arthroplasty. This shortcoming was noted with an alarming frequency in our patients in group B. Moreover, joint-motion-preserving surgery failed to consistently treat preexisting transfer metatarsalgia.

In contrast, successful arthrodesis of the metatarsophalangeal joint addresses instability, alignment, and transfer metatarsalgia relatively effectively, although at the expense of mobility. To our knowledge, the only study addressing metatarsophalangeal arthrodesis as a salvage procedure following a failed Keller procedure was the study of eleven patients by Coughlin and Mann<sup>9</sup>. Five of their patients underwent a bilateral procedure, for a total of sixteen procedures. Fixation was achieved with multiple intramedullary threaded Steinmann pins, and interposition of an iliac crest graft was performed in four feet. The results in this small series, after an average duration of follow-up of twenty-nine months, were exceptional. Satisfaction was excellent in twelve cases and good in four. We observed good-to-excellent results after twenty-three of twenty-nine salvage arthrodeses of the first metatarsophalangeal joint.

Improvement in weight-bearing and gait depends on achieving a solid fusion in acceptable alignment. In the face of a relatively short first ray, the potential for persistent transfer lesions exists despite arthrodesis. In such cases, the surgeon may wish to consider rebalancing the lengths of the first ray and lesser metatarsals. This can be achieved by means of bone-block distraction arthrodesis of the first metatarsophalangeal joint or shortening osteotomies of the lesser metatarsals, as were done in several of our patients (Figs. 2-A and 2-B). We do not wish to imply that such forefoot rebalancing procedures are a necessity. Of primary importance is achieving a successful fusion of the first metatarsophalangeal joint. Any additional procedures introduce the potential for new complications, but if they are performed successfully, they may further reduce the potential for persistent transfer metatarsalgia. In certain cases, bone-block distraction arthrodesis of the first ray may also be a useful way to realign the forefoot. Although reports of this technique have been encouraging, it is technically more difficult than in situ arthrodesis and is associated with increased nonunion rates, wound complications, and skin necrosis<sup>3,7</sup>. In our series, we were able to successfully perform a revision in situ arthrodesis in all five feet in which the arthrodesis following the Keller procedure had failed.

In revision surgery, the amount of residual bone often dictates the method of fixation. Two crossed cancellous screws were used in fourteen of the feet in our series. While fusion was achieved in all of those feet, nonunion was observed in two feet in which fixation had been limited to a single screw. Nonunion also occurred in one of two feet in which two crossed Kirschner wires had been used. We therefore emphasize that stabilization should include more than a single screw.

McKeever stressed that "it is the arthrodesis and its position that is important and not the method by which it is produced."<sup>17</sup> The recommended hallux valgus angle for arthrodesis<sup>7,11,18-23</sup> has ranged from 0° to 30°; however, in a practical sense, the amount of abduction of the hallux is limited by

the position of the second toe<sup>17,24,25</sup>. In our series, the average hallux valgus angle measured 13.2° at the time of follow-up, with the vast majority ranging from 5° to 20°. Subjective results were rated as excellent even by patients with hallux valgus angles measuring -1° and 32°. In our opinion, the correct amount of hallux abduction should be determined for the individual patient, with the position of the second toe and the intermetatarsal angle taken into account.

The dorsiflexion angle of the hallux can be determined by the angle between the metatarsal and the phalanx<sup>17-19,21,22</sup> or by the angle of the hallux relative to the floor<sup>20,26,27</sup>. Although setting dorsiflexion of the phalanx relative to the first metatarsal may be practical in the operating room, we recommend that the degree of metatarsal inclination as seen on preoperative lateral weight-bearing radiographs be taken into account. In our series, we revised one salvage arthrodesis because of intractable pain under the proximal phalanx. In this patient, the metatarsophalangeal joint was fused in only 12° relative to the metatarsal, but, when we reviewed preoperative lateral weight-bearing radiographs, we noted a first metatarsal inclination angle of 31°. Finally, the position of the fusion site may be influenced by the preferred type of shoe and height of heel<sup>26</sup>.

Salvage of a failed Keller procedure should create a stable, well-aligned first ray to improve gait and weight-bearing. In our experience, a repeat Keller procedure and tendon lengthening failed to correct instability and deformity in most patients. However, it must be stressed again that these poor results cannot be compared directly with the results of the arthrodeses. The allocation of treatment to the two groups was not randomized, and a selection bias cannot be ruled out. We also wish to point out that salvage arthrodesis following a failed Keller resection arthroplasty is technically demanding, and failures can be anticipated when stabilization is inadequate or the fusion is in a poor position. Nevertheless, successful arthrodesis of the first metatarsophalangeal joint in an anatomic position consistently improved function and provided acceptable patient satisfaction in our series. ■

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## References

1. **Keller WL.** The surgical treatment of bunions and hallux valgus. *New York Med J.* 1904;80:741-2.
2. **Anderl W, Knahr K, Steinbock G.** [Long term results of the Keller-Brandes method of hallux rigidus surgery]. *Z Orthop Ihre Grenzgeb.* 1991;129:42-7. German.
3. **Axt M, Wildner M, Reichelt A.** Late results of the Keller-Brandes operation for hallux valgus. *Arch Orthop Trauma Surg.* 1993;112:266-9.
4. **Kitaoka HB, Patzer GL.** Arthrodesis versus resection arthroplasty for failed hallux valgus operations. *Clin Orthop.* 1998;347:208-14.
5. **Brodsky JW, Ptaszek AJ, Morris SG.** Salvage first MTP arthrodesis utilizing ICBG: clinical evaluation and outcome. *Foot Ankle Int.* 2000;21:290-6.
6. **Myerson MS, Miller SD, Henderson MR, Saxby T.** Staged arthrodesis for salvage of the septic hallux metatarsophalangeal joint. *Clin Orthop.* 1994; 307:174-81.
7. **Myerson MS, Schon LC, McGuigan FX, Ozgur A.** Result of arthrodesis of the hallux metatarsophalangeal joint using bone graft for restoration of length. *Foot Ankle Int.* 2000;21:297-306.
8. **Wu KK.** First metatarsophalangeal fusion in the salvage of failed hallux abducto valgus operations. *J Foot Ankle Surg.* 1994;33:383-95.
9. **Coughlin MJ, Mann RA.** Arthrodesis of the first metatarsophalangeal joint as salvage for the failed Keller procedure. *J Bone Joint Surg Am.* 1987;69:68-75.
10. **Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M.** Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int.* 1994;15:349-53.
11. **Toolan BC, Wright Quinones VJ, Cunningham BJ, Brage ME.** An evaluation of the use of retrospectively acquired preoperative AOFAS clinical rating scores to assess surgical outcome after elective foot and ankle surgery. *Foot Ankle Int.* 2001;22:775-8.
12. **Henry AP, Waugh W, Wood H.** The use of footprints in assessing the results of operations for hallux valgus. A comparison of Keller's operation and arthrodesis. *J Bone Joint Surg Br.* 1975;57:478-81.
13. **Samnegard E, Turan I, Lanshammar H.** Postoperative evaluation of Keller's arthroplasty and arthrodesis of the first metatarsophalangeal joint using the EMED gait analysis system. *J Foot Surg.* 1991;30:373-4.
14. **Stokes IA, Hutton WC, Stott JR, Lowe LW.** Forces under the hallux valgus foot before and after surgery. *Clin Orthop.* 1979;142:64-72.
15. **Viladot R, Rochera R, Alvarez F, Pasarin A.** [Resection arthroplasty in the treatment of hallux valgus]. *Orthopade.* 1996;25:324-31. German.
16. **Capasso G, Testa V, Maffulli N, Barletta L.** Molded arthroplasty and transfer of the extensor hallucis brevis tendon. A modification of the Keller-Lelievre operation. *Clin Orthop.* 1994;308:43-9.
17. **McKeever DC.** Arthrodesis of the first metatarsophalangeal joint for hallux valgus, hallux rigidus and metatarsus varus primus. *J Bone Joint Surg Am.* 1952;34:129-34.
18. **Coughlin MJ.** Arthrodesis of the first metatarsophalangeal joint with mini-fragment plate fixation. *Orthopedics.* 1990;13:1037-44.
19. **Fitzgerald JA.** A review of long-term results of arthrodesis of the first metatarso-phalangeal joint. *J Bone Joint Surg Br.* 1969;51:488-93.
20. **Harrison MHM, Harvey FJ.** Arthrodesis of the first metatarsophalangeal joint for hallux valgus and rigidus. *J Bone Joint Surg Am.* 1963;45:471-80.
21. **Lipscomb PR.** Arthrodesis of the first metatarsophalangeal joint for severe bunions and hallux rigidus. *Clin Orthop.* 1979;142:48-54.
22. **Mann RA, Oates JC.** Arthrodesis of the first metatarsophalangeal joint. *Foot Ankle.* 1980;1:159-66.
23. **Turan I, Lindgren U.** Compression-screw arthrodesis of the first metatarsophalangeal joint of the foot. *Clin Orthop.* 1987;221:292-5.
24. **Moynihan FJ.** Arthrodesis of the metatarso-phalangeal joint of the great toe. *J Bone Joint Surg Br.* 1967;49:544-51.
25. **Shereff MJ, Baumhauer JF.** Hallux rigidus and osteoarthritis of the first metatarsophalangeal joint. *J Bone Joint Surg Am.* 1998;80:898-908.
26. **Thompson FR, McElvenny RT.** Arthrodesis of the first metatarsophalangeal joint. *J Bone Joint Surg Am.* 1940;22:555-8.
27. **Mann RA, Thompson FM.** Arthrodesis of the first metatarsophalangeal joint for hallux valgus in rheumatoid arthritis. *J Bone Joint Surg Am.* 1984;66: 687-92.