Tricorrectional Osteotomy for the Correction of Late-Stage Hallux Limitus/Rigidus

The authors propose the use of the tricorrectional osteotomy for treatment of severe hallux limitus/rigidus as an alternative to joint-destructive procedures. A study of 19 patients with follow-up treatment ranges of 10 months to 6 years postoperatively was performed. Data were collected on preoperative and long-term postoperative x-rays, range of motion assessment, F-scan studies, and subjective patient questionnaires. High patient satisfaction along with increased range of motion, minimal complications, and an early return to activities make this an ideal procedure for grades II, III, and IV hallux limitus/rigidus.

Hallux limitus/rigidus is defined as a degenerative arthrosis of the first metatarsophalangeal joint characterized by a decrease in first metatarsophalangeal joint range of motion and eventual absence of motion. Cotterill and Davies-Colley first described this in the literature over a century ago, describing hallux limitus/rigidus as a progressive condition producing a severely painful and rigid big-toe joint. The goal of surgical intervention in hallux limitus/rigidus is to increase the range of motion within the first metatarsophalangeal joint and to decrease the pain and symptoms associated with the condition. The authors' hypothesis is that hallux limitus and hallux rigidus can be surgically corrected by utilizing a distal metatarsal head osteotomy. This is a preliminary study evaluating a modification of the tricorrectional bunionectomy with AO screw fixation for the surgical treatment of grades II, III, and IV hallux limitus/rigidus. The system used to classify the grade of deformity was that of the American College of Foot and Ankle Surgeons.

Classification of Hallux Limitus/Rigidus

Grade I

Joint dorsiflexion may be normal during normal weightbearing, but ground reactive forces may elevate an unstable first ray, producing first metatarsophalangeal joint limitation. There are no degenerative joint changes radiographically, but there may be hallux equinus/planus (plantar positioning of the proximal phalanx). Metatarsus primus elevatus and a pronatory foot type are also usually present.
Grade II

Radiographic changes seen are flattening of the first metatarsal head, small dorsal exostoses, subchondral eburnation, and periarticular lipping of the proximal phalanx and metatarsal head. There is limited passive range of motion with pain at ends of motion.

Grade III

Radiographic changes seen are severe flattening of the metatarsal head, dorsal osteophytes, nonuniform narrowing of the joint space, and subchondral cysts. Range of motion is severely decreased, with pain throughout the entire range of motion. There may also be acute inflammatory changes with deterioration of articular cartilage.

Grade IV

Range of motion is extremely limited, with possible total ankylosis. Changes seen radiographically are obliteration of the joint space with exuberant osteophysis and possible loose bodies within the joint space or capsule. Pain can decrease as the joint becomes fused and other joints must compensate for lack of dorsiflexion at the first metatarsophalangeal joint (Fig. 1).

Tricorrectional Osteotomy Procedure

The surgical procedure used for the correction of hallux limitus/rigidus is the tricorrectional osteotomy designed by Selner and described by Boggs et al in 1989. This article describes a modification of a bicondylar Austin procedure called the tricorrectional bunionectomy for the treatment of hallux abducto valgus deformity. A study on the repair of juvenile hallux valgus with the use of the tricorrectional bunionectomy showed the versatility of the tricorrectional procedure by reducing triplane deformities including intermetatarsal angle, hallux abductus angle, proximal articular set angle, and metatarsus primus elevatus. The tricorrectional bunionectomy has also been used for the correction of hallux abducto valgus in patients with intermetatarsal angles of 16° to 22°. This suggests that the procedure is an excellent alternative to proximal osteotomies, which have higher complication risks and a slower postoperative return to normal activities. Based on the efficacy of treating a variety of first metatarsophalangeal joint deformities, this procedure was applied to grades II, III, and IV hallux limitus/rigidus.

Methods

The criteria for selection of patients in this study were the following: 1) the presence of grades II, III, and IV hallux limitus/rigidus; 2) an intermetatarsal angle of less than 12°; 3) performance of the tricorrectional osteotomy procedure; and 4) a minimum of 6 months of postoperative follow-up care.

The patients in this study were from the Medstar Foot and Ankle Center in Studio City, CA, where the tricorrectional osteotomy was performed by Allen Selner and Marc Selner. Patients were informed of the possible need for additional surgery. Charts were reviewed for preoperative measurements of first metatarsophalangeal joint ranges of motion and radiographic evidence of hallux limitus/rigidus. Patients had preoperative F-scan assessments of dynamic foot pressures. The patients were brought back for follow-up care 10 to 72 months after surgery.

A modification of the tricorrectional bunionectomy was used in the treatment of 21 feet in 19 patients with hallux limitus/rigidus. Ten patients were female and nine patients were male. The patients’ ages at the time of surgery ranged from 16 to 63 years, with an average age of 49.95. In one patient, both feet were treated with tricorrectional osteotomy but at separate times (1 month apart), and one patient had both feet treated at the same time. There were six cases with grade II hallux limitus, 12 cases with grade III
hallux limitus, and three cases with grade IV hallux limitus/rigidus. Four right feet and two left feet had grade II hallux limitus, five right feet and seven left feet had grade III hallux limitus, and one right foot and two left feet had hallux limitus/rigidus. Overall, the surgery was performed on 10 right feet and 11 left feet.

The tricorrectional osteotomy procedure includes an "L-shaped" metaphyseal osteotomy with a long plantar arm and a short dorsal arm (Fig. 2). The osteotomy can be angled in a plantar lateral direction to additionally plantarflex the capital fragment (Fig. 3). The dorsal cut can be angled in a proximal manner to shorten the bone or in a distal manner as the head is transposed to lengthen the bone (Fig. 4). The dorsal cut includes a rectangular-shaped resection of bone for decompression when no proximal articular set angle correction is needed (Fig. 5). Approximately 4 to 8 mm of rectangular-shaped bone can be removed when hallux limitus is present. By shortening the bone, the cubic content of the joint, or joint space, is increased. When hallux abducto valgus is present, a triangular-shaped resection is taken from the dorsal cut to correct the proximal articular set angle, and when a combination of hallux abducto valgus and hallux limitus is present, a trapezoid-shaped resection of bone is taken. Remodeling of dorsal ridging is done to remove any bony block and preserve gliding motion. Care must be taken not to remove excess bone in order to prevent a rocking motion at the osteotomy site. A single cannulated bone screw is placed proximal dorsal to distal plantar to fixate the

![Chevron cut](image)

**Figure 2.** Side view of chevron bone cut in relation to tricorrectional procedure.

![Medial Lateral](image)

**Figure 3.** Plantarflexing cut of tricorrectional procedure.

![A B C](image)

**Figure 4.** Dorsal view of first metatarsal possible bone cuts. A, Shortening the bone. B, Maintaining the length. C, Lengthening the bone.
osteotomy (Fig. 6). The single AO screw allows greater stability and compression than Kirschner wires. There is minimal disability for the patients and immediate weightbearing and range of motion are allowed. Capsular closures are performed medially for correct alignment of the extensor hallucis longus tendon and sesamoid apparatus. The capsular closure can be biased to derotate a valgus hallux (Fig. 7). An intracapsular dissection with an emphasis on complete sesamoidal release is performed, taking care to preserve the vascular supply to the metatarsal head within the plantar fascial slip. The lateral capsule and adductor hallucis tendon are left intact.

Passive range of motion exercises at the first metatarsophalangeal joint are started on the first postoperative day because of the importance of early range of motion. Physical therapy begins 12 to 17 days postoperatively and consists of approximately 12 visits over 4 to 6 weeks. Physical therapy sessions consist of active and passive range of motion exercises, deep massage, heat, and electrical stimulation.

The protocol for returning to normal activities is based on radiographic assessment of x-rays, patient compliance, and discomfort levels. Patients return to athletic shoes as early as 10 days, with an average of 2 weeks, after surgery. At that time they are able to resume most daily activities, including walking, driving, and swimming, as well as work schedule not involving excessive standing. At 4 weeks, most patients are able to resume athletic activities such as exercise walking and bicycling. Finally, at 6 to 8 weeks, the majority of patients are able to resume more active sports including tennis, jogging, and skiing.

Several methods were used to evaluate the tricorrectional osteotomy for the treatment of grades II, III, and IV hallux limitus/rigidus. These methods are an extensive history and physical examination, goniometer dynamic measurements, manual measurements of first metatarsophalangeal joint range of motion, postoperative F-scan, x-rays, and a patient questionnaire.

The F-scan is an in-shoe pressure-measurement system. The transducer is an ultra-thin, flexible device with 960 sensors distributed evenly across the entire plantar surface. Like a sheet of paper, the transducer is virtually undetectable in a shoe and does not interfere with gait. The transducer plugs into a 6-ounce cuff about the size of a deck of cards, which is attached to one or both of the patient’s legs. A thin wire connects the cuff unit to the computer. Each sensor is continuously sampling 100 times per second as the patient walks. Summary screens show peak forces, graphs of force versus time, and the path of the center of force. Each patient was exam-
ined with the F-scan postoperatively without orthoses and in a tennis-type shoe.

Standard anteroposterior and lateral view x-rays were taken and examined for increased joint spacing, decreased osteophytes, and decreased metatarsus primus elevatus. Assessment of first metatarsal joint range of motion was performed on a stress lateral x-ray. The stress lateral x-ray is taken with the patient bearing weight on the desired foot and then raising the heel from the ground until maximal dorsiflexion is achieved at the first metatarsophalangeal joint with the first metatarsal head bearing weight.

A questionnaire was completed by each of the study participants to assess pre- and postoperative pain, activities patients could now perform, and whether patients would recommend the surgery.

**Results**

**First Metatarsophalangeal Joint Range of Motion**

Follow-up care ranges were from 10 to 72 months, with an average of 31.67 months postoperatively (Table 1). Preoperative measurements of patients with grade II hallux limitus were between 0° and 20° with an average of 10.83°, and postoperative measurements were between 30° and 72° with an average of 51° of dorsiflexion. Preoperative measurements of patients with grade III hallux limitus were between 5° and 20° with an average of 9.58°, and postoperative measurements were between 29° and 71° with an average of 44.75° of dorsiflexion. Preoperative measurements of patients with grade IV hallux limitus/rigidus were between 5° and 15° with an average of 8.33°, and postoperative measurements were between 25° and 52° with an average of 42.33° of dorsiflexion. Overall, the average first metatarsophalangeal joint range of motion was 9.8° preoperatively and 46.2° postoperatively, an increase of 36.4°.

The dynamic range of motion with the goniometer resulted in an average of 30.33° of dynamic dorsiflexion, with a range of 11° to 45°. The average dorsiflexion measured from a stress lateral x-ray was 40.90°, with a range of 32° to 57° (Table 2). Three patients did not want any additional x-rays taken and were not included in the stress lateral x-ray measurements.
Joint-Space Assessment

Joint spaces at the first metatarsophalangeal joint were measured at the minimum and maximum spacing between the joint in millimeters (Tables 1 and 2). The average minimum joint space preoperatively was 0.25 mm and the average maximum was 1.33 mm, with a range of 0 to 4 mm. Average postoperative measurements were 1.42 mm at the most minimal point and 2.58 mm at the most maximal point, with a range of 0 to 5 mm. The average joint-space increase at the most minimal point was 1.08 mm. The average joint-space increase at the most maximal point was 1.16 mm.

F-scan Assessment

F-scan results show that every patient who was evaluated preoperatively displayed a gait pattern that avoided the first metatarsophalangeal joint. In the grade II hallux limitus foot, avoidance of the first metatarsal on F-scan can be attributed to lack of motion, pain, or metatarsus primus elevatus. Postoperatively, in the foot with the grade II hallux limitus, there is increased forefoot loading medially, which is caused by dynamic plantarflexion of the metatarsal head and an increase in joint dorsiflexion. Patients had either no increase or only a mild increase in pressures under the first metatarsal head. Most of these patients had a more propulsive gait postoperatively.

Preoperatively, grade III hallux limitus patients displayed an increase in hallux pressures due to functional hallux flexus and dorsiflexion demand at the interphalangeal joint. This abnormal increase in force under the hallucus compensates for decreases in metatarsophalangeal joint dorsiflexion. There is also avoidance of the first metatarsophalangeal joint preoperatively secondary to pain or metatarsus primus elevatus. Postoperatively, most patients show increases in propulsion, symmetrical pressures under both feet, minimal avoidance of the first metatarsal, and decreased pressures under the hallucus. The symmetrical pressures demonstrate no favoring of one foot due to pain or foot deformity.

One patient with a preoperative F-scan assessment of grade IV hallux rigidus presented with avoidance of the first metatarsal with mild pressure under the hallucus. She had decreased propulsion during gait, with no peak propulsion noted. Postoperatively, all three patients with grade IV hallux rigidus showed an increase in propulsion, no avoidance of the first metatarsal or hallucus, and no high pressures under the second metatarsal or hallucus.

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<th>Table 2. Comparison of Grades II, III, and IV Hallux Limitus</th>
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<td><strong>Age</strong></td>
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**GRADE III**

| Mean    | 51.25 | 9.58  | 44.75 | 29.42 | 0.25 | 1.33 | 1.42 | 2.58 | 30.33 | 40.90 |
| Median  | 52.00 | 10.00 | 42.00 | 27.50 | 0.00 | 1.50 | 1.00 | 3.00 | 29.00 | 39.00 |
| SD      | 5.99  | 5.42  | 13.23 | 15.67 | 0.45 | 0.78 | 0.51 | 0.31 | 7.29  | 7.88  |
| Mode    | 53.00 | 5.00  | 35.00 | 2.00 | 2.00 | 1.00 | 3.00 | 39.00 |
| High    | 63.00 | 20.00 | 71.00 | 54.00 | 1.00 | 2.00 | 2.00 | 3.00 | 45.00 | 57.00 |
| Low     | 40.00 | 5.00  | 29.00 | 10.00 | 0.00 | 0.00 | 1.00 | 2.00 | 20.00 | 32.00 |

**GRADE IV**

| Mean    | 59.00 | 8.33  | 42.33 | 21.33 | 0.00 | 0.33 | 0.67 | 1.67 | 32.67 | 38.33 |
| Median  | 59.00 | 5.00  | 50.00 | 18.00 | 0.00 | 0.00 | 1.00 | 1.00 | 35.00 | 39.00 |
| SD      | 4.00  | 5.77  | 15.04 | 9.45  | 0.00 | 1.00 | 1.00 | 1.00 | 4.93  | 6.03  |
| Mode    | 5.00  | 5.00  | 5.00  | 5.00  | 0.00 | 0.00 | 1.00 | 1.00 | 5.00  | 5.00  |
| High    | 63.00 | 15.00 | 52.00 | 32.00 | 0.00 | 1.00 | 1.00 | 3.00 | 36.00 | 44.00 |
| Low     | 55.00 | 5.00  | 25.00 | 14.00 | 0.00 | 0.00 | 0.00 | 1.00 | 27.00 | 32.00 |

Abbreviations: DF, dorsiflexion; SD, standard deviation.
Eight feet out of 21 were back into athletic shoes an average of 13.87 days after surgery, with a range of 10 to 21 days. The remainder of the patients were all back into athletic shoes within 2 to 3 weeks, but an exact date of the return to shoes was not documented for these patients.

**Postoperative Questionnaire**

Eighteen of the 19 patients returned the postoperative questionnaire. Patients responded that they had an 89.5% (range of 50% to 100%) improvement in their first metatarsophalangeal joint range of motion after the tricorrectional osteotomy procedure. Preoperatively, 18 patients felt that they had moderate to severe pain. The patients gave their pain an average rank of 75, with a range of 30 to 100, on a scale of 0 to 100, with 100 indicating severe pain. Of 17 patient responses, nine had no pain, seven had mild pain, and one had moderate pain. Preoperatively, three patients had ankle pain, two patients had knee pain, and one had back pain. Postoperatively, two patients with ankle pain and two with knee pain reported resolution of the pain and felt that their pain was related to their hallux limitus/rigidus deformity. Thirteen out of 18 patients reported having no pain upon first metatarsophalangeal joint range of motion. Four patients reported having mild pain at the joint to date and one patient reported still having moderate pain at the joint during motion.

Seventeen patients reported being able to wear “normal” shoes (leather dress shoes, high-heel shoes). One patient reported having to always wear a tennis-type shoe with her orthoses and not yet being able to initiate her regular exercise regimen. All 18 patients stated that they were satisfied with the results of the tricorrectional osteotomy procedure and would recommend the procedure.

**Complications**

Patient S5 had sufficient bone bridging and stability of his osteotomy 2 weeks after the operation (September 22, 1994) to allow for safe ambulation in athletic shoes and initiation of rehabilitation. On January 17, 1995, he returned for a 4-month follow-up visit and an incidental finding of osteotomy gapping was observed on lateral radiograph. He did not report pain or discomfort at that time. It was felt that overly aggressive rehabilitation performed by the patient (especially manual plantarflexion of the metatarsophalangeal joint) was the cause of this problem. A bone stimulator was applied 10 days later (January 27) and was used for 6 to 8 weeks to assist in bone bridging. Radiographs taken on March 9, 1995, showed closing and bridging of the plantar wing of the osteotomy. It was also noted that the dorsal wing showed evidence of early bone callous bridging. At this time it was believed that the osteotomy gapping was a delayed union caused by mechanical trauma. Because of the bridging that had taken place, the 6 to 8 weeks of bone stimulation was very beneficial in closing the osteotomy. At this time the patient was allowed to return to “normal daily activities.” Later radiographs showed complete bone healing with no loss of correction. Three patients had complaints of pain under the second and third metatarsal heads postoperatively. Two patients had relief with the use of orthoses and one with the use of accommodative inserts. One patient is suffering from chronic tibial sesamoiditis that has not been relieved by conservative treatment.

**Case Presentations**

**Case 1**

A 63-year-old male presented to the clinic complaining of pain within the bunion joints of both feet for approximately 15 years. The patient is a salesman who is on his feet constantly. The patient has a history of gout controlled by diet. X-rays showed osteophytic lipping medially, laterally, and dorsally, diminished joint spaces, and mild dorsal elevation of the first metatarsal in relation to the second metatarsal (Figs. 8 and 9). Postoperative x-rays showed an increased visible joint space, removal of the joint osteophytes, and a mild reduction of hallux valgus deformity (Figs. 10 and 11). Preoperative F-scans showed a pronated center of gait with higher pressures under the hallux of the left foot (Fig. 12). Physical therapy and orthotic devices after surgery allowed the patient to return to normal walking in regular shoes and to go back to work in 30 days. The postoperative F-scans showed a dramatic decrease of pressures on the hallux bilaterally and decreased pronation as indicated by the change in the center of pressure line during gait (Fig. 13).

**Case 2**

A 53-year-old male presented for surgical consultation for hallux limitus in the left foot following 5 years of conservative therapy without relief of pain. The patient denied any medical history. The preoperative x-rays showed osteophytic lipping surrounding the joint and mild dorsal elevation of the first metatarsal in relation to the second metatarsal (Figs. 14 and 15).
The patient was back in athletic shoes on the tenth day after surgery. The patient returned to normal daily activities by 6 weeks with the aid of orthotic devices. Postoperative x-rays showed an increase in plantarflexion of the first metatarsal head and an increase in joint space (Figs. 16 and 17). The postoperative F-scans showed decreased pressure on the left hallux and improved pressure distribution under all of the metatarsal heads compared to the preoperative F-scan (Figs. 18 and 19).

**Discussion**

The purpose of this study is to propose a joint-salvage procedure for the repair of severely damaged first metatarsophalangeal joints as an alternative to a joint-destructive or cheilectomy procedure.\(^5\) The authors propose a twofold theory of the formation of hallux limitus/ rigidus. First, pronation induces osseous column elongation of the foot and causes the tissues to tighten, which leads to jamming of the joint. Second, structural or functional elevatus may also induce jamming of the joint through a sagittal plane misalignment of the joint surfaces. In most cases of end-stage symptomatic hallux limitus/ rigidus, conservative treatments will not result in a significant reduction of pain or improved function. However, the use of the tricorrectional osteotomy is a more viable option for preserving the joint before a joint-destructive procedure is indicated.

Previous studies have reported that an osteotomy
Figure 12. F-scan, preoperative grade II hallux limitus for Case 1.

Figure 13. F-scan, postoperative grade II hallux limitus for Case 1.

Figure 14. Anteroposterior view x-ray of preoperative grade III hallux limitus.

Figure 15. Lateral view x-ray of preoperative grade III hallux limitus.

Figure 16. Anteroposterior view x-ray of postoperative grade III hallux limitus.

Figure 17. Lateral view x-ray of postoperative grade III hallux limitus.
can decompress the first metatarsophalangeal joint while preserving the joint in young patients.\textsuperscript{11, 12} The ideal corrective procedure for hallux limitus/rigidus would decompress the joint-reducing jamming of the first metatarsophalangeal joint, maintain the radius arc of dorsiflexion of the first metatarsophalangeal joint throughout propulsion, and reduce the elevatus position of the first metatarsal. According to Durrant and Siepert,\textsuperscript{13} planterflexing and shortening the first metatarsal essentially lengthen the plantar intrinsic musculature and allow the sesamoids to move more distally during propulsion. The tricorrectional osteotomy accomplishes the criteria above while being performed in metaphyseal bone of the head and neck of the first metatarsal, which allows for fast bone healing and a quick return to activity.

The design of the osteotomy allows the surgeon to correct hallux abducto valgus as well as all grades of hallux limitus/rigidus at the first metatarsophalangeal joint. The authors speculate that because the first metatarsophalangeal joint is a horizontally loaded joint and not a vertically loaded joint, such as the knee or hip, decompression allows even severely damaged joints to function. The flexor hallucis brevis and longus, sesamoid apparatus, and joint capsule are structures that can restrict dorsiflexion of the hallux.\textsuperscript{13} The preoperative ranges of motion indicate a destructive pathology at the first metatarsophalangeal joint. Postoperative measurements show encouraging results with significant increases in dorsiflexion.

The F-scan demonstrated two methods of compensation for hallux limitus/rigidus. The center of pressure of the forefoot moves in a lateral direction instead of a medial direction. This indicates that during propulsion there is a complete avoidance of the first metatarsophalangeal joint (Fig. 12). Second, when the center of pressure distribution is normal, and there is a lack of dorsiflexion of the first metatarsophalangeal joint, the pressures under the first metatarsal head are abnormally low or nonexistent. There is, however, an increase in the pressure under the hallux interphalangeal joint region of the great toe (Fig. 13). These patterns were seen in all of the F-scans preoperatively for patients with grades II through IV hallux limitus. Postoperatively, the patients functioned with an appropriate range of motion of the first metatarsophalangeal joint and the center of pressure was closer to a normal distribution of pressure load through the forefoot and the first metatarsophalangeal joint (Fig. 14).

The results of the study show that the tricorrectional osteotomy procedure for grades II, III, and IV hallux limitus achieved the result of a pain-free and functional foot. The tricorrectional osteotomy can be an effective alternative to joint-destructive procedures. Complications associated with hallux limitus/rigidus surgery may include lack of hallux purchase, lesser metatarsal fractures, capsulitis, avascular
necrosis, malunion, delayed union, nonunion, progressive pain, and limitation of motion.

Conclusion

The patient with hallux limitus/rigidus presents a challenge to the foot and ankle surgeon. Various etiologies for hallux limitus/rigidus have been described in the literature, and many treatments exist for this debilitating condition. Surgical intervention is almost always indicated in the late stages of the disorder. For late-stage hallux limitus/rigidus, joint-destructive procedures are typically indicated. The authors believe that the tricorrectional osteotomy is a good alternative to joint-destructive procedures and an excellent option for use in grades II, III, and IV hallux limitus/rigidus. Although the research used a small study group, the results indicate a new way to approach hallux limitus surgery. However, further studies are warranted.

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References