

# Nonoperative and Operative Intervention for Hallux Rigidus

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CASE STUDY

**Study Design:** Case study of the management of an individual with hallux rigidus deformity. **Objective:** To describe the outcome of nonoperative and operative treatment, including kinematic and kinetic changes following cheilectomy surgery, for an individual with hallux rigidus deformity.

**Background:** Hallux rigidus is a common disorder of the first metatarsophalangeal joint characterized by progressive limitation of hallux dorsiflexion, prominent dorsal osteophyte formation, and pain. Surgery may be considered when nonoperative management strategies have proven unsuccessful. Kinematic and plantar pressure changes during dynamic activities have not been previously described following cheilectomy surgery for hallux rigidus deformity.

**Methods and Measures:** The patient was a 54-year-old man who sustained a traumatic injury to the great toe. Conservative treatment included nonsteroidal anti-inflammatory drugs, custom insole fabrication, and footwear outsole modification. Because of continued pain, loss of motion, and restrictions in daily activities, the patient elected to have surgery, and a cheilectomy procedure was done. Presurgical and postsurgical kinematic data of first metatarsophalangeal joint motion were collected using an electromagnetic tracking device during clinical motion tests and walking. Peak plantar pressures were assessed during gait. The patient was evaluated preoperatively, at 6 months, and again at 18 months following surgery.

**Results:** The outcome of surgery proved favorable, both subjectively and objectively. Peak dorsiflexion increased significantly (a minimum of 20°) for all clinical tests and walking trials at the first metatarsophalangeal joint when compared with preoperative measurements. Peak plantar pressures also increased over the medial forefoot (68%) and hallux (247%) between preoperative testing and follow-up, indicating increased loading to this region of the foot.

**Conclusions:** Restrictions in motion and daily activities and persistent pain may warrant surgical intervention for individuals with hallux rigidus deformity. A successful outcome, as measured by the patient's self-reported pain, return to recreational activities, and kinematic and plantar pressure changes at the follow-up examination, was demonstrated in this case study. *J Orthop Sports Phys Ther* 1999;29:727-735.

**Key Words:** cheilectomy, electromagnetic device, first metatarsophalangeal joint

Adequate motion of the first metatarsophalangeal (MTP) joint, specifically in the direction of dorsiflexion, is essential for the propulsive phase of normal ambulation. The motion required during gait has been reported to range between 42 and 90°. Limitations of motion of this joint due to trauma, abnormal foot mechanics, or osteoarthritis can result in significant functional disability. Hallux rigidus is a common disorder of the first MTP joint, reportedly affecting 1 in 45 individuals who are 50 years and older.<sup>11</sup> It is characterized by a progressive limitation of dorsiflexion, prominent dorsal osteophyte formation at the first metatarsal head and base of the proximal phalanx, and pain.<sup>10,22</sup>

One of the most common causes of hallux rigidus is related to trauma of the first MTP joint.<sup>7,9,22</sup> Intra-articular fracture, direct compression, crush injuries, or forceful and extreme dorsiflexion (hyperextension) to the great toe may result in chondral or osteochondral injuries and the ensuing degenerative characteristics of hallux rigidus.<sup>22</sup> The natural course of this disorder is typical of degenerative processes, including loss of articular cartilage, narrowing of the joint space, and formation of periarticular osteophytes.<sup>20,22,27</sup> Radiographically, hallux rigidus has

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been classified into 3 grades.<sup>12</sup> Grade I is characterized by mild-to-moderate formation of osteophytes with preservation of the joint space; grade II, by moderate formation of osteophytes, narrowing of the joint space, and subchondral sclerosis; and grade III, by marked formation of osteophytes and loss of the joint space, with or without subchondral cysts. These radiographic changes have been shown to be factors in the choice of operative treatment and associated patient outcomes.<sup>12,19</sup>

Anatomic variations of the foot or positional abnormalities of the first metatarsal head have also been implicated in the development of hallux rigidus.<sup>5,7,20</sup> These have included elongation of the first metatarsal head, dorsiflexion of the first metatarsal head, sesamoid abnormalities, a long narrow foot, or a pes planus foot structure.<sup>9</sup> Each of these conditions purportedly increases the stress across the first MTP joint and results in damage to the articular cartilage.<sup>19</sup> Hatrup and Johnson<sup>12</sup> have suggested that it is a combination of trauma, either a single episode or repeated traumatic events, and an anatomic variation of the foot that may predispose an individual to the development of hallux rigidus.

The kinematics of the first MTP joint with hallux rigidus differ markedly from the kinematics of the disease-free joint.<sup>14,28</sup> Shereff and colleagues<sup>28</sup> found significantly less dorsiflexion, displaced centers of rotation, and surface motion characterized by early, noticeable jamming of the articular surfaces in cadaver specimens with hallux rigidus. Kinetic changes, as measured indirectly through plantar pressure assessment, have also been reported with this disorder. Some authors have described increased pressures to be sustained under the lateral metatarsal heads as the person shifts his or her weight to the lateral side of the foot in an attempt to avoid the painful hallux motion.<sup>19,20,27</sup> Patients with symptomatic hallux rigidus have also been found to have greater plantar pressures under the first metatarsal head and hallux.<sup>3,8</sup> Increased pressures under the first metatarsal head have been associated with pes planus foot structures that result in excessive or prolonged pronation during the stance phase of gait. As a consequence, adequate plantar flexion of the first metatarsal head may be prevented with an associated decrease in first MTP dorsiflexion.<sup>1,26,28</sup> Higher pressures may be sustained under the hallux, particularly during toe off in gait, because of the increased lever arm that results from joint inflexibility.<sup>3</sup>

Of greater impact are the functional limitations that accompany hallux rigidus. Daily activities, such as walking, stair climbing, squatting, and kneeling, can be markedly impaired. Gait deviations may be present for reasons described previously. Patients shift their weight to the lateral side of the foot during toe off to compensate for the pain and limitation of dorsiflexion at the first MTP joint.<sup>13,20,27</sup> This adap-

tation may lead to increased loading and pain under the lateral metatarsal heads. Patients with hallux rigidus may also experience difficulty wearing shoes because of mechanical impingement of the dorsal osteophytes against the toe box of the shoe.<sup>27</sup>

Hallux rigidus has been managed using both nonoperative and operative treatment approaches. The goals of nonoperative management are to reduce pain and protect the joint from further trauma. In the early stages of hallux rigidus with only synovitis and generalized soft tissue thickening, rest, ice, the use of nonsteroidal anti-inflammatory drugs (NSAIDs), and physical therapy modalities to relieve the inflammation are recommended.<sup>6</sup> To facilitate resting of the joint, immobilization with or without taping may prove to be beneficial. In cases where articular changes are manifested by bony proliferation first MTP joint range of motion and mobilization treatments may be ineffective.

Over-the-counter or custom insoles and modified footwear are also recommended to prevent excessive dorsiflexion of the first MTP joint and minimize trauma and pain associated with the mechanical impingement of the dorsal osteophytes. Insoles made of carbon-reinforced material that extends under the medial rays of the foot may help limit first MTP joint motion.<sup>16,27</sup> Shoes with a high toe box are recommended to avoid irritation of the dorsal aspect of the toe. Increasing the stiffness of the sole through use of an extended steel or fiberglass shank between the inner and outer soles of the shoe or a rocker outsole modification may provide symptomatic relief and smooth gait transition.<sup>13,16,27,30</sup>

For patients who do not respond to nonoperative treatment, operative intervention may be considered. The goals of surgery are to provide pain relief, improve functional status, and, with the exception of arthrodesis, improve joint motion. The surgical technique will be dictated by the clinical findings and radiographic stage of hallux rigidus.<sup>9,12,19,27</sup> Surgical techniques described for management of hallux rigidus include cheilectomy or exostosectomy, dorsiflexion osteotomy of the proximal phalanx (Moberg procedure), resection arthroplasty (Keller procedure), arthrotomy with synovectomy and debridement, implant arthroplasty, and arthrodesis.<sup>9,20,22,27</sup>

Most follow-up studies following surgical management of hallux rigidus have been retrospective and have assessed outcomes using self-reported measures of pain and disability.<sup>12,19,20</sup> To date, there has been little information on how joint kinematics and plantar pressures are altered during dynamic activities following surgical procedures in human subjects.

The purpose of this case study is to describe the outcome of nonoperative and operative treatment for an individual with hallux rigidus. The secondary purpose is to describe the preoperative and postoperative kinematic and plantar pressure changes associ-

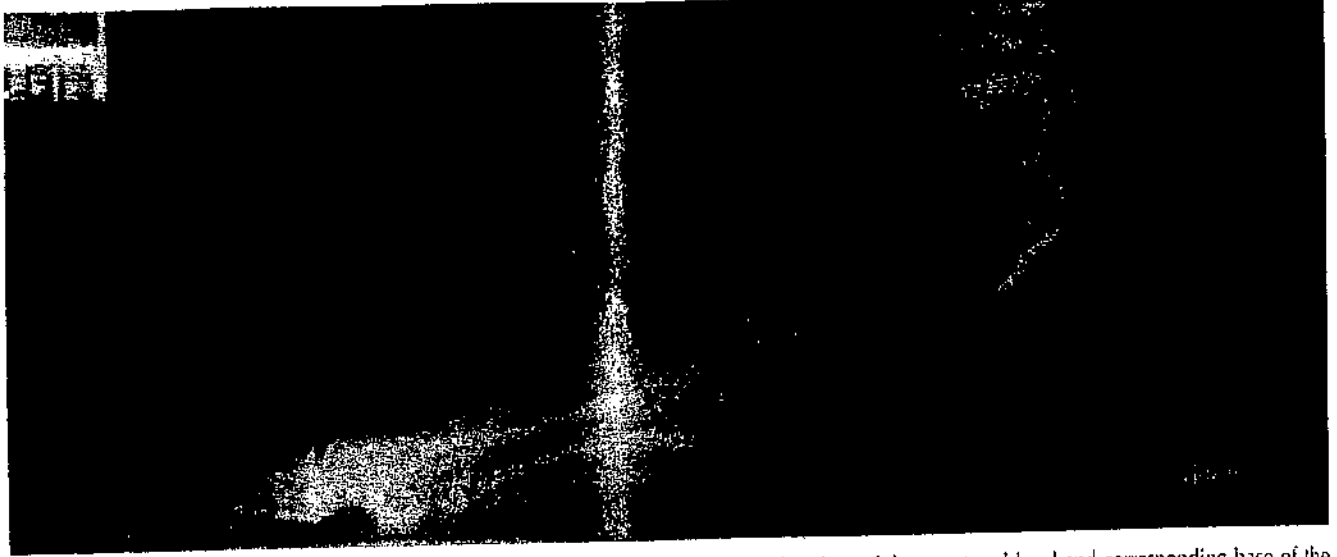


FIGURE 1. Lateral radiograph of the foot that demonstrates an osteophyte at the dorsal surface of the metatarsal head and corresponding base of the proximal phalanx. Narrowing of the joint space and osteophytic changes primarily involving the dorsal aspect of the joint are also seen.

ated with a cheilectomy procedure in this same individual during an 18-month follow-up period.

## METHODS

### Subject

The patient was a 54-year-old man who worked as a shop manager for a maintenance department. He sustained a traumatic dorsiflexion (hyperextension) injury to the right great toe when a heavy object fell on the back of his heel while he was in a squat position. Radiographic findings were negative, and the patient was instructed to apply ice for swelling and take NSAIDs as needed. No other treatment was recommended at that time. During the next 2 years, the patient experienced a progressive loss of great toe motion and increasing pain that prevented his participation in martial arts activity, prompting him to seek an orthopaedic consultation.

At initial evaluation, the patient reported pain over the dorsum of the first MTP joint that increased with fast walking and also during activities that required stabilization over the medial aspect of the foot. For this individual, these activities were related to single-limb balancing and kicking activities in karate. On a visual analog scale (VAS) ranging from 0 (no pain) to 10 (worst pain), the patient reported that the pain occurred during his karate activities and was a 10 at its worst. Throughout most of the day, the patient reported a constant, dull ache in the great toe, which he reported was a 5 on the VAS for activities such as walking, stair climbing, and kneeling. The patient also reported increased pain over the plantar aspects of the third, fourth, and fifth metatarsal heads of the same foot. He complained of difficulty fitting into his dress shoes because of the bulbous

prominence of the dorsal surface of the first metatarsal head.

### Clinical Examination

The clinical examination revealed tenderness to palpation over the dorsal aspect of the first MTP joint and in the web space between the first and second metatarsal heads. The axial grind test result of the first MTP joint was negative. This test, which involves compression of the articulating segments combined with small circumferential movement of the first metatarsal head, can be used as a clinical indicator of articular cartilage involvement.<sup>2</sup> Radiographs revealed the presence of osteophytes over the first metatarsal head and base of the proximal hallux, narrowing of the joint space, and "squaring" of the first metatarsal head. These changes were consistent with grade II arthritis<sup>27</sup> (Figure 1).

The non-weight-bearing biomechanical foot examination revealed minimal restrictions (5°) of ankle dorsiflexion with the knee extended. The patient also presented with a forefoot varus deformity of approximately 6°. There was increased dorsiflexion mobility of the first metatarsal head relative to the remaining metatarsal heads. Goniometric measurements of passive range of motion, non-weight-bearing, of the first MTP joint revealed 10° of plantar flexion and 20° of dorsiflexion. The results of the remaining examination were unremarkable for any underlying structural abnormalities. On weight-bearing, the calcaneus remained vertical. No excessive mid-foot pronation, as evidenced by a navicular drop, was observed. Observational gait assessment revealed symmetry in step length at self-selected walking speeds. There was increased external hip rotation on the affected limb during mid-to-late stance, since the

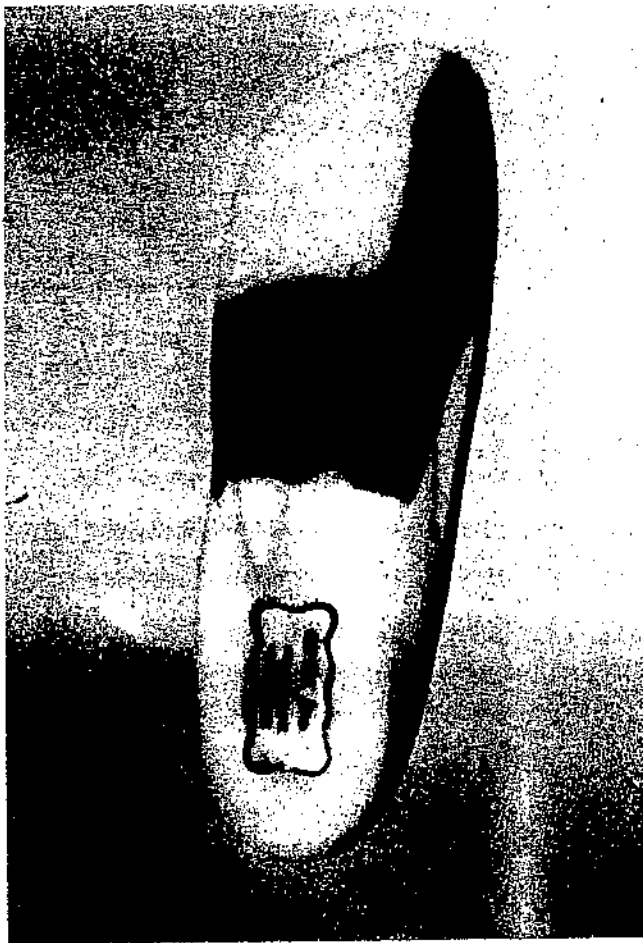


FIGURE 2. Custom orthotics consisting of a full-length insole with a carbon-reinforced Morton's extension under the great toe.

patient appeared to avoid shifting his weight over the medial aspect of his foot.

### Nonoperative Management

For this patient, the goals of nonoperative management were to decrease the inflammation and pain and protect the joint from further trauma by limiting dorsiflexion. An anti-inflammatory dose of NSAIDs, 2400 mg/d for 3 weeks, was initiated to alleviate the inflammatory components of the disease. High-impact activities were discouraged. Custom orthotics that consisted of a full-length insole with a carbon-reinforced Morton's extension under the great toe were fabricated (Figure 2). The purpose of this extension was to minimize the bending stress at the great toe during the later phase of stance and to prevent the mechanical impingement of the dorsal osteophytes at the end range of toe motion.<sup>9,24,27</sup> Footwear with a soft rubber sole was recommended to decrease impact loading of the foot. A larger toe box was also recommended to accommodate the prominent dorsal osteophyte deformity.<sup>27</sup> Additionally, the outer soles of selected shoes were modified with an extended rigid shank to prevent excessive dorsiflex-

ion of the first MTP (Figure 3). The patient was instructed in stretching techniques for the gastrocnemius and soleus muscle. Because of the nature of the osseous changes at the first MTP joint, range of motion and other mobilization techniques were not prescribed.

### Operative Management

For 6 months, the patient reported minimal relief with nonoperative strategies. He reported that the pain and discomfort that he experienced in his great toe significantly influenced his ability to participate in any recreational activities. There was only a slight improvement in VAS scores (4/10) for daily activities. Pain continued (10/10) for recreational activities as described previously. The patient also did not want to be limited to wearing specialized footwear.

Surgical options were presented to the patient, and a cheilectomy was recommended. This procedure involves resections of the dorsal exostosis or osteophyte formation at the first metatarsal head and base of the proximal phalanx.<sup>12,19</sup> Loose bodies are removed, and a synovectomy is performed. The goal of this surgery is to restore motion by removing the mechanical block that limits dorsiflexion and to relieve symptoms that reflect pressure from footwear over the dorsal bony prominence of the first metatarsal head.<sup>18-20</sup> At this patient's stage of hallux rigidus, a cheilectomy may be preferred over other procedures because it avoids the shortening of the hallux and loss of motion found after resection arthroplasty and arthrodesis and the possible implant failure with Silastic prostheses.<sup>12,20</sup>

### Postoperative Management

The goals of postoperative management were to decrease pain and inflammation, increase joint motion, and use the motion gained through surgery during functional activities. Following surgery, the patient was allowed to ambulate with crutches, weight-bearing as tolerated in a stiff-soled shoe for the first 5 days. When not walking, the patient was instructed to keep the leg elevated. After 5 days, the patient returned to the orthopaedic surgeon for dressing changes and was instructed to wear a soft, flexible rubber-soled shoe to maintain the motion of the joint that was achieved intraoperatively. The patient was also allowed to progress to full weight-bearing without assistive devices. Physical therapy began on postoperative day 5, and the patient was seen once a week for 6 weeks. Treatment consisted of modalities for edema control and pain relief, active and passive range of motion, mobilization techniques, and functional activities that stressed weight transfer to the medial forefoot and hallux. Gait re-education was also emphasized with the goal of minimizing the

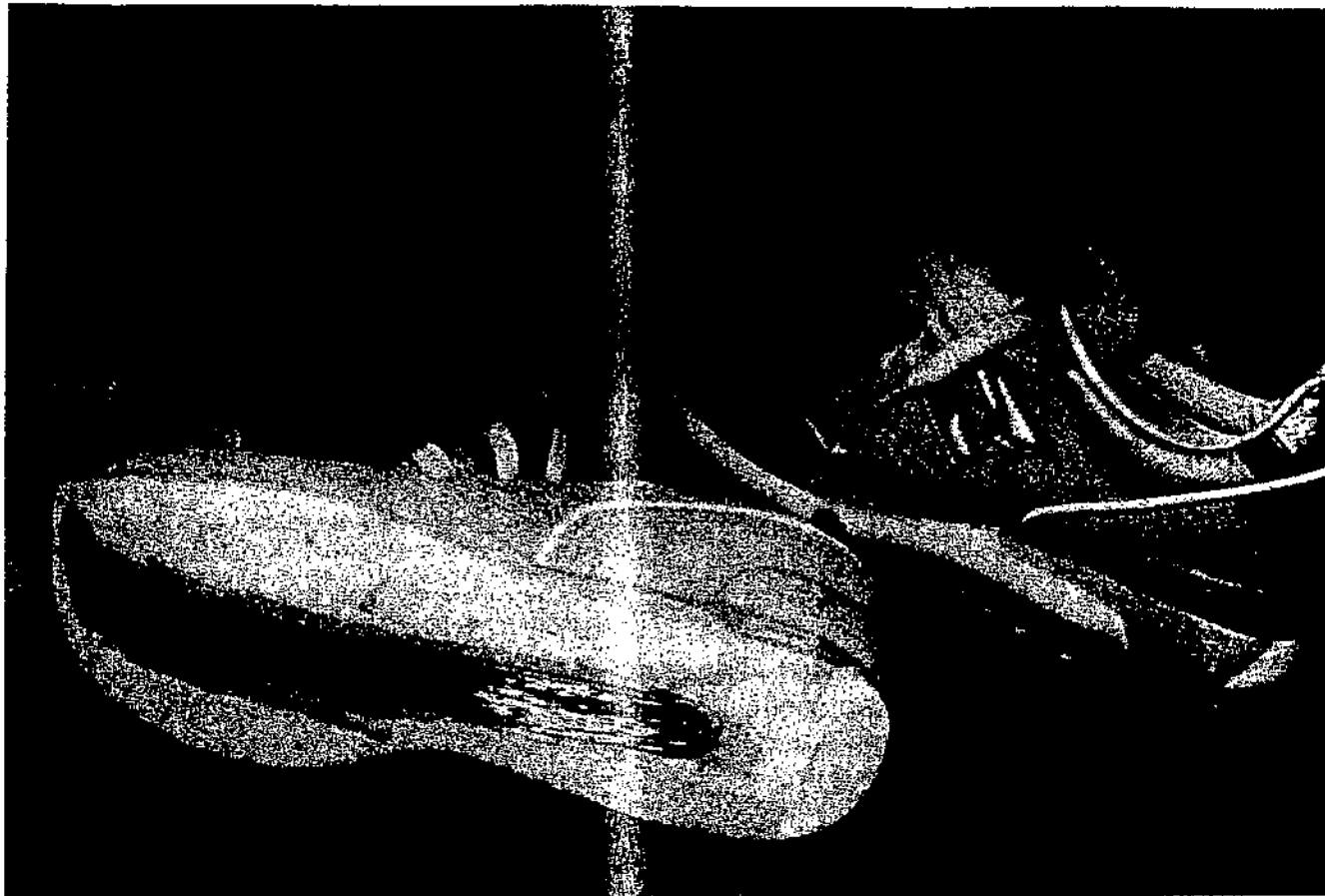


FIGURE 3. Footwear modified with an extended rigid shank and rocker outer sole.

deviations that were seen preoperatively and presumed to be in response to avoiding the painful motion of the first MTP joint. The patient was encouraged to shift weight over the medial aspect of the foot and use great toe motion during push off, as symptoms permitted. By week 6, the patient was able to walk without excessive right hip external rotation during stance, but he did revert to this pattern when he experienced pain in his toe.

The sutures were removed after 3 weeks, and the patient was allowed to return to his recreational activities within 8–12 weeks, as symptoms permitted. At the time of discharge from physical therapy, goniometric passive range of motion, non-weight-bearing, was measured at 30° plantar flexion and 60° dorsiflexion. The VAS score for daily activities was 3/10. Overall, the patient stated he was pleased with his progress to date and reported only an occasional ache in the toe that varied with weather changes.

### Kinematic Analysis and Plantar Pressure Assessment

Three-dimensional joint kinematics and plantar pressure patterns were assessed preoperatively and again postoperatively at 6 and 18 months following surgery to determine the effect of the cheilectomy on joint motion and plantar pressure changes, re-

spectively. Three-dimensional kinematics were assessed using the Flock of Birds electromagnetic tracking device (Ascension Technology, Burlington, Vt). This device provides position and orientation data during static and dynamic activities. The techniques used in the present study have been shown to provide reliable and valid data.<sup>25,31</sup>

Receivers were placed on the skin overlying the proximal hallux, first metatarsal head, and medial calcaneus (Figure 4). Anatomically based local coordinate systems were defined by digitizing 4 noncollinear points on each of the hallux and first metatarsal segments. The resulting coordinate systems had the positive y-axis directed posteriorly within the long axis of the segment; the positive x-axis was directed laterally, and the predominant direction of the positive z-axis was inferior (Figure 5). Descriptions of the angular orientation of the local coordinate system for the hallux were specified relative to an initial coincident alignment of the local coordinate system for the first metatarsal head. Using a custom software program, orientation data were derived for the clinical tests of active range of motion with the patient weight-bearing, passive range of motion with the patient weight-bearing, passive range of motion with the patient non-weight-bearing (ankle and subtalar joints maintained in neutral), and during a heel rise.



FIGURE 4. Photograph showing location of motion receivers over the proximal phalanx of the hallux, first metatarsal head, and medial aspect of the calcaneus.

These tests were selected because they represent the variety of clinical measurements used to assess motion of the first MTP joint. Motion of the hallux with respect to the first metatarsal head was also assessed during gait. For the gait trials, the patient walked at self-selected speeds past the transmitter, with the examiner ensuring that the second step occurred within the optimum range of the transmitter (range, 22.5–64.0 cm). The patient was provided practice walks until a consistent walking pattern was obtained. Three walking trials were collected for each test session. In a pilot study comparing motion of the first MTP during the second step and motion during subsequent steps, no differences were found between the second step and subsequent steps in 12 subjects. On the basis of this analysis and results of previous investigations,<sup>4,25</sup> the second step was used to acquire motion data of the first MTP during gait. Data were collected at 100 Hz and filtered using a fourth-order digital (Butterworth) filter with a 6-Hz cutoff frequency. Further explanation of data reduction methods have been described in a previous investigation.<sup>25</sup>

All angular data are reported as the mean of the middle 3 (of 5) trials performed for each clinical test and walking trials. Taking into consideration the predominant motion of the first MTP joint during gait and the application of our findings to clinically based measures, the kinematic analysis focused on the dorsiflexion component of rotation about the x-axis.

Plantar pressures during gait were assessed during walking trials using the BTE dynamic pedobarograph (Baltimore Therapeutics, Baltimore, Md) pressure measurement device. The pedobarograph, with a sensor resolution of 2 × 3 mm, measures pressures at the foot-floor interface. This device has been shown to provide reliable and accurate data in previous clinical trials.<sup>15,22</sup> Similar to the methods used for

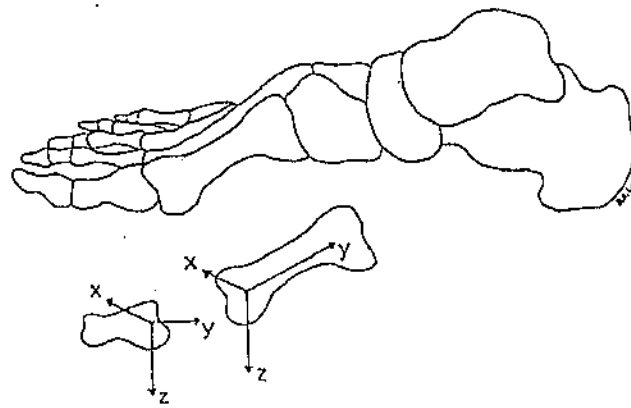


FIGURE 5. Illustration showing the local anatomical coordinate system for the hallux and first metatarsal segments. The positive x-axis was directed laterally; the positive y-axis was directed posteriorly, within the long axis of the hallux and metatarsal segments; and the positive z-axis was directed inferiorly. Dorsiflexion rotation of the hallux with respect to the first metatarsal head was described about the x-axis. (Reproduced, with permission from Nawoczenski DA, Baumhauer JF, Umberger BR. Relationship between clinical measurements and motion of the first metatarsophalangeal joint during gait. *J Bone Joint Surg Am.* 1999;81:370–376.)

assessing first MTP joint motion during gait with the electromagnetic tracking device, the second step of each walking trial was used to acquire plantar pressure measurements.<sup>4,23</sup> For the purpose of analysis, the plantar aspect of the foot was partitioned into 4 regions: the heel, the lateral forefoot (metatarsal heads 3–5), the medial forefoot (metatarsal heads 1–2), and the hallux. Peak plantar pressures were derived for each region and expressed in kilopascals. Measurements recorded at 6 months were expressed as percent change over preoperative values. Pressure patterns were also compared between left and right feet to account for any differences in self-selected walking speeds throughout 18 months.

Means and SDs were calculated for all reported variables. Intraclass correlation coefficients were calculated<sup>17</sup> to provide an estimate of the degree of similarity among trials. A 1-way, repeated-measures analysis of variance was used to assess differences between preoperative and postoperative kinematic measurements at 6 and 18 months. Follow-up comparisons were conducted with use of the Tukey test with an experiment-wise error rate at the .05 level. A paired test was used to determine if there were side-to-side differences for peak plantar pressures.

## RESULTS

### Kinematic Analysis

The mean of 3 trials is reported for all dependent measures. Intraclass correlation coefficients (3,3) varied between 0.97 and 0.99 for within-day measurements. Figure 6 represents preoperative and postoperative peak dorsiflexion values and SDs for the clinical tests and walking trials. For all clinical tests and

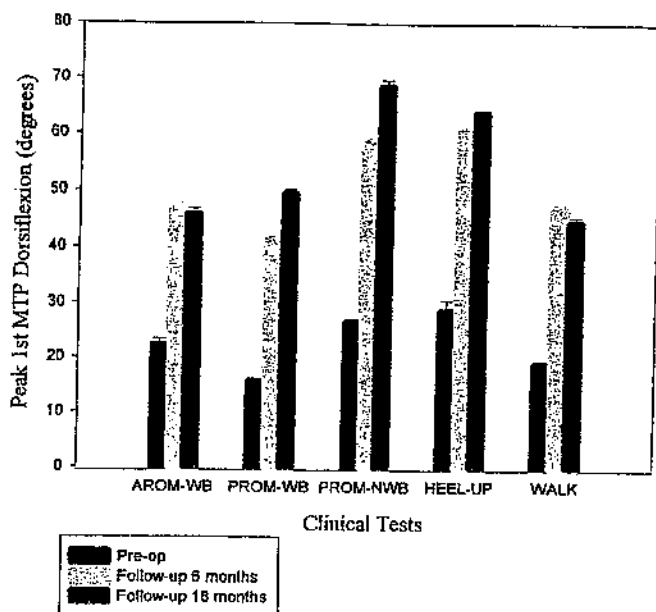


FIGURE 6. Means and SDs for peak dorsiflexion values during the clinical tests and walking trials. AROM indicates active range of motion, weight-bearing; PROM-NWB, passive range of motion, non-weight-bearing; and PROM-WB, passive range of motion, weight-bearing.

walking trials, there was a significant increase in peak dorsiflexion between preoperative and postoperative measurements ( $P < .001$ ). Tukey post hoc analysis revealed these differences to exist between preoperative and postoperative measurements at 6 and 18 months. The magnitude of change varied according to the clinical test and ranged between  $20^\circ$  for active range of motion and  $38^\circ$  for passive range of motion, non-weight-bearing. With the exception of passive range of motion, non-weight-bearing, which was found to increase at 18 months, the increase in motion demonstrated at 6 months was retained at the 18-month follow-up.

Preoperative and postoperative plantar pressure patterns and percent changes are presented in the Table. Preoperative plantar pressure assessment demonstrated minimal loading on the medial aspect of the patient's foot, particularly at metatarsal heads 1-2 and hallux regions. At the 6-month follow-up, peak pressures were found to increase across all regions of

the foot over preoperative values. Greatest changes were noted at metatarsal heads 1-2 (increase 68%) and hallux (increase 247%). Although the subject was instructed to walk at self-selected speeds and the second step recorded for each test, an assessment of walking speed showed increases of 15 and 11% at 6 and 18 months, respectively, when compared with preoperative assessment. It is possible that observed plantar pressure changes were due to faster walking speeds. Therefore, as a basis for comparison, pressure patterns are also noted for the noninvolved foot. Visual inspection of the data reveals pressure patterns of the operative foot that are similar to the nonoperative side, particularly at the 18-month examination. Paired  $t$  tests revealed significant side-to-side difference only at the 6-month follow-up for plantar pressures under the hallux ( $t = -4.11$ ;  $df = 2$ ;  $P < .05$ ).

Subjectively, at both the 6- and 18-month follow-up testing, the patient reported his pain to be a 2 of 10 on the VAS for daily activities, including walking, stair climbing, and kneeling. He reported an occasional sharp pain in his first MTP joint during some of his martial art maneuvers that required a sudden weight shift over the medial side of his foot. At the 18-month follow-up, the patient had returned to full participation in martial arts and all recreational activities. He also reported that he was now able to wear footwear without special modifications for most of his activities.

## DISCUSSION

Nonoperative treatment should be the first course of management for patients with hallux rigidus. In the presence of osteophytes, the primary goals of nonoperative treatment are to prevent excessive dorsiflexion that may cause further trauma to the joint, decrease pain associated with movement or poorly fitting footwear, and provide options that will enable the individual to maintain his or her lifestyle. The patient in this case study was managed nonoperatively using NSAIDs, insole and outsole footwear modifications, and activity modifications. Because of first MTP joint motion restrictions, continued pain, and an inability to fully participate in his recreational ac-

Means and SDs for peak plantar pressures (kilopaseals) during gait at 4 regions of the right and left feet.\*

Foot region	Preoperative examination		6-Month follow-up examination		18-Month follow-up examination	
	Right	Left	Right	Left	Right	Left
Heel	578 ± 147	794 ± 128	757 ± 27 (†31%)	794 ± 68	892 ± 109	1003 ± 113
Metatarsal heads 3-5	637 ± 49	565 ± 50	825 ± 21 (†30%)	676 ± 49	863 ± 192	918 ± 239
Metatarsal heads 1-2	489 ± 93	640 ± 103	826 ± 28 (†68%)	818 ± 44	885 ± 175	1268 ± 227
Hallux	72 ± 39	630 ± 281	250 ± 5 (†247%)	500 ± 107†	734 ± 208	764 ± 29

\* Mean values are based on 3 trials. Percent change expressed as percentage of preoperative measurement.

† Significant side-to-side differences ( $P = .05$ ).

tivities, the patient elected to have a cheilectomy procedure.

One advantage of a cheilectomy over other surgical approaches for treatment of hallux rigidus is that the cheilectomy permits the later use of any other procedures should the outcomes be unsatisfactory.<sup>6,20</sup> In this case study, the outcomes of the cheilectomy proved to be successful. This success was measured by the patient's self-reported measures of pain and a return to full participation in recreational activities. Kinematic and plantar pressure analyses at both the 6- and 18-month follow-up examination also support positive outcomes, as measured through an increase in first MTP joint motion (Figure 6) and plantar pressure changes (Table). There was a significant increase in first MTP joint peak dorsiflexion (Figure 6), with mean changes ranging from 20–38° over preoperative values. Motion gains were retained at the 18-month follow-up examination. It was presumed that this increase in motion was favorable for the patient in his daily and recreational activities. The alterations in plantar pressure patterns toward greater medial forefoot loading were also considered to be positive responses for this patient. Before surgery, minimum pressures were taken on the medial aspect of the foot because of the pain in the first MTP joint. Follow-up findings suggest that the patient was able to sustain higher pressures on the medial forefoot and hallux in gait without an increase in pain. Interestingly, the patient no longer complained of pain under the lateral metatarsal heads at the time of the follow-up examination.

The success of the cheilectomy in this case study may be attributed to a number of factors. As indicated in the biomechanical foot examination, the patient did not have notable underlying structural abnormalities of the foot that could have adversely influenced outcome measures. Structural abnormalities such as forefoot varus or rearfoot varus, for example, will likely persist after surgical removal of the dorsal osteophytes. If not accounted for, the compensatory foot motions, such as abnormal pronation, may continue to cause irritation and restriction of first MTP joint motion, especially during late stance. In these cases, modified insoles may be needed to accommodate the underlying deformity.

The motion that was achieved during surgery and maintained in follow-up assessment may have been aided through postoperative treatment that not only stressed increased joint motion but also focused on functional activities that used first MTP joint motion. These activities included overhead reaching, stair climbing, squatting, and half-kneeling. Emphasis was also directed to gait re-education that included facilitation of weight shifting from the lateral to medial side of the foot and single-limb stabilization activities. Frequently, the patient is unaware of abnormal and often subtle gait patterns that have become habitual

over time in response to avoiding pain in the first MTP joint. Gait re-education is a critical component of postoperative management that should not be overlooked.

## CONCLUSIONS

Nonoperative management may not always result in a favorable outcome for patients with hallux rigidus. Loss of motion, persistent pain, and limitations in daily or recreational activities may warrant surgical intervention. This case study demonstrated a successful outcome following a cheilectomy procedure, as measured through self-reported measures of pain and return to activities and through kinematic and plantar pressure changes. These changes were observed at both the 6- and 18-month follow-up examination.

Successful outcome may be due to a number of factors, including physical therapy directed to maintaining motion gained through surgery and the use of first MTP joint motion through functional activities and gait re-education.

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