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Plantar Loading After Chevron Osteotomy Combined With Postoperative Physical Therapy

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ABSTRACT

Background: **Recent pedobarographic studies have demonstrated decreased loading of the great toe region and the first metatarsal head at a short- and intermediate-term followup. The purpose of the present study was to determine if a postoperative rehabilitation program helped to improve weightbearing of the first ray after chevron osteotomy for correction of hallux valgus deformity.** ***Materials and Methods:*** **Twenty-nine patients with a mean age of 58 years with mild to moderate hallux valgus deformity who underwent a chevron osteotomy were included. Postoperatively, the patients received a multimodal rehabilitation program including mobilization, manual therapy, strengthening exercises and gait training. Preoperative and one year postoperative plantar pressure distribution parameters including maximum force, contact area and force-time integral were evaluated. Additionly the AOFAS score, ROM of the first MTP joint and plain radiographs were assessed. The results were compared using Student's t-test and level of significance was set at $p < 0.05$.** ***Results:*** **In the great toe, the mean maximum force increased from 72.2 N preoperatively to 106.8 N 1 year after surgery. The mean contact area increased from 7.6 cm^2 preoperatively to 8.9 cm^2 1 year after surgery and the mean force-time integral increased from 20.8 N*sec to 30.5 N*sec. All changes were statistically significant ($p < 0.05$). For the first metatarsal head region, the mean maximum force increased from 122.5 N preoperatively to 144.7 N one year after surgery and the mean force-time integral increased from 42.3 N*sec preoperatively to 52.6 N*sec 1 year postoperatively ($p = 0.068$ and $p = 0.055$, respectively). The mean AOFAS score increased from 61 points preoperatively to 94 points at final followup ($p < 0.001$). The average hallux valgus angle decreased from 31 degrees to 9 degrees and the average first intermetatarsal angle decreased from 14 degrees to 6 degrees ($p < 0.001$ for both).** ***Conclusion:*** **Our results suggest that postoperative physical therapy and gait training with a Chevron osteotomy may help to improve weightbearing of the great toe and first ray. Therefore, we believe there is a restoration of more physiological gait patterns in patients who receive this postoperative regimen.**

Level of Evidence: IV, Retrospective Case Series

Key Words: Chevron; Plantar Pressure Distribution; Rehabilitation; Physical Therapy

INTRODUCTION

The Chevron osteotomy is a widely accepted method for the correction of mild to moderate hallux valgus deformity.[1,17,30,31] This osteotomy has demonstrated good to excellent results in terms of radiographic correction of hallux valgus deformity as well as functional outcome scores and patient satisfaction rates.[17,24,31,32] However, recent pedobarographic studies have shown that there is decreased loading of the great toe region and the first metatarsal head at short- and intermediate-term followup.[4,5,9,14] Sufficient loading of these structures is essential in order to provide physiological gait patterns.[13] During normal gait, the center of pressure moves rapidly from the heel to the central metatarsal area after heel strike and remains in this area for about one-half of the stance phase before propagating distally and medially toward the great toe.[7] Additionally, the first ray is the most heavily loaded structure during stance phase.[13]

Lateral deviation of the great toe and subluxation of the sesamoids represent pathomorphologic characteristics of hallux valgus deformity.[21] These changes alter kinematics of the first metatarsophalangeal (MTP) joint, leading to reduced force generation capacity of the plantarflexors.[20] Therefore, there is decreased weightbearing through the great toe as well as the first ray in feet with hallux valgus deformity. This has

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been reported by several authors as the reason for lesser toe metatarsalgia.[10,29,34]

During the past decade, many researchers analyzed plantar pressure distribution after the chevron osteotomy for the correction of hallux valgus deformity.[4,5,9,14] These studies revealed decreased loading of the first ray in comparison to the preoperative findings, indicating that the chevron osteotomy may not be sufficient to restore physiologic forefoot function. Kernozeck and Sterriker found decreased load of the great toe region 1 year after Chevron osteotomy compared to the preoperative levels. They concluded that postoperative physiotherapy might improve weightbearing of the great toe and therefore improve functional outcome after chevron osteotomy.[14]

The purpose of this study was to determine if a postoperative rehabilitation program including cryotherapy, lymphatic drainage, manual therapeutic inverventions of the first MTP joint, muscle strenghthening exercises and gait training would improve postoperative first ray weightbearing after the chevron osteotomy for the correction of hallux valgus deformity. Specifically, our aim was to assess the effect of 4 weeks of mobilization in a regular postoperative shoe, followed by a multimodal rehabilitation program on the loading of the first ray at a 1-year followup. Also, clinical and radiographic changes after chevron osteotomy were investigated.

MATERIAL AND METHODS

Patient population

The present study was performed with the approval of the Research Ethics Board of our institution, and all participants signed an informed-consent form prior to inclusion. Between October 2006 and December 2007, 29 patients with mild to moderate hallux valgus without radiographic signs of osteoarthritis of the first MTP joint who underwent chevron osteotomy were included in this prospective study. The sampling was performed consecutively. None of the patients had evidence for lower extremity malalignment or other pathologic conditions on the musculoskeletal system that might influence gait patterns (e.g. low back pain, disc herniations, spondyloarthritis or osteoarthritis of the hip, knee, ankle, subtalar, transverse tarsal and tarsometatarsal joint) Nonoperative management, including modification of shoewear, non steroidal anti-inflammatory drugs, orthotic devices, or a combination of these methods, had failed in all patients. The mean age of the patients at the time of surgery was 58 (range, 30 to 73) years and there were 28 females and one male. Two patients were lost for followup. One patient suffered a heart attack and was not able to participate in followup. The other patient moved and was not able for the followup examination. Therefore, 27 patients made up the study population.

Surgical technique

The operations were performed by a foot and anklefellowship trained single surgeon (H.J.T.) as previously described by Trnka et al.[32] In the present study fixation was performed by inserting an oblique compression screw (Charlotte Multi Use Compression Screw, Wright Medical, Arlington, NC) from dorsomedial to plantarlateral.

Postoperative treatment

Postoperatively participants were placed in the Rathgeber™ (OFA Bamberg GmbH, Germany) postoperative shoe for 4 weeks. This shoe allowed for weightbearing of the operated limb while reducing stress to the forefoot region. Additionally, patients received a special compression sock (Gilofamed, OFA Austria) intended to reduce swelling and the need for dressing changes. Patients were instructed to perform passive range of motion exercises of the first MTP joint two times a day for 10 minutes. At 4 weeks after surgery, the patients received a multimodal rehabilitation program including cryotherapy, lymphatic drainage, manual therapeutic inverventions of the first MTP joint, muscle strenghthening exercises and gait training as previously described.[26] Physiotherapy was performed by three licensed physiotherapists following the same treatment protocol. The patients received a mean of 4.2 treatment sessions (range, 3 to 7) based on their individual findings. The sessions took place one time a week for 3 to 6 weeks. The duration of the sessions ranged from 35 to 45 minutes. Also, patients were instructed to do marble pick-up exercise, cold packs, strengthening exercises, and gait training at home.

Measurements

All measurements were taken by an independent observer (R.S.). They included dynamic plantar pressure distribution analysis and clinical assessment using the Metatarsophalangeal-Interphalangeal Score of the American Orthopaedic Foot and Ankle Society (AOFAS). Additionally, first MTP joint range of motion (ROM) measurements were performed. Anteroposterior and lateral radiographs were assessed for the hallux valgus angle and first intermetatarsal angle. All measurements were perfomed preoperatively and 1 year after surgery.

Plantar pressure distribution analysis

The plantar loading parameters were assessed using a capacitive pressure measurement platform (emed-at platform, Novel GmbH, Munich, Germany). The platform has a total area of 610 mm × 323 mm enclosing a 240 mm × 380 mm sensor area. It includes a total of 1,760 sensors, providing a resolution of two sensors per cm^2. The sampling rate of the platform was fixed at 60 Hz and auto triggered upon first contact. The pressure threshold was 10 kilopascal and ranged up to 1,270 kilopascal. The platform had a maximum measurable force of 67,000 Newton with a hysteresis of less than 3%. Because of the depth of the platform of

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18 mm, the test arrangement enclosed the whole platform in the center of a polyethylene ramp with a length of seven meters. Patients were able to cross the plate in both directions. The validity, reliability and repeatability of the emed system (Novel GmbH) has previously been investigated.[12,23,33] Those studies revealed high validity, reliability and repeatability if more than three measurements were taken thus five measurements per foot were recorded. In order to provide valid and reliable results the mid-gait method was chosen for this study. Putti et al. investigated the repeatability of measurements of the emed® system by having patients walk at normal speed on two separate occasions, approximately 12 days apart.[23] The results of this study revealed good repeatability. In the present study, patients were instructed to walk at normal speed and keep their velocity constant. Data was collected and stored for further analysis. Analysis of the records was performed with the emed/D software.[18] An average of the five datasets was calculated by the software and the foot was divided into geometric regions of interest according to the anatomical areas of the great toe, second toe, first metatarsal head, second metatarsal head as well as total object. (Figure 1) The following variables for each region were generated by the software: maximum force (N), contact area (cm^2), and force-time integral (N*sec). Maximum force was defined as the greatest vertical force that acted on a certain area during stance phase and indicated its load.[2] In the present study, maximum force was measured to determine the load changes of certain regions of interest. Contact area was the area of contact of the foot to the supporting surface during stance phase. Force-time integral (impulse) was the area under the curve of a force-time curve.[22] It indicated the load of a certain area in relation to the time the area was loaded. Based on these parameters, conclusions about the changes of load to certain areas as well as the time a certain area was loaded could be made.

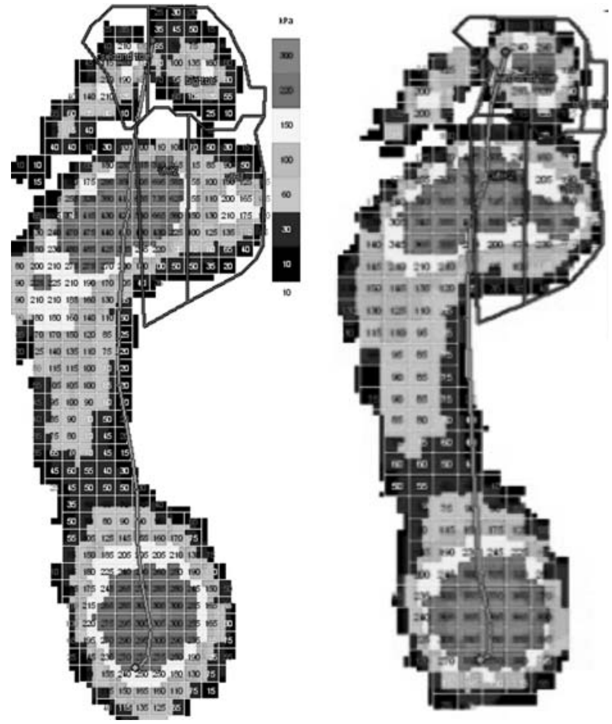

Fig. 1: Plantar pressure distribution in a patient preoperatively and one year after surgery. The foot is divided in regions of interest (big toe, second toe, first metatarsal head (MH 1), second metatarsal head (MH 2) and total object).

Clinical assessment

Clinical assessment included the use of the AOFAS Metatarsophalangeal-Interphalangeal score according to Kitaoka et al.[15] This 100-point scoring system is based on a questionnaire combining subjective and objective data, including the clinical parameters of pain; function and alignment. Additionally, first MTP joint passive ROM was measured with a goniometer as recommended by the AOFAS.[28] Patients were asked to rate their satisfaction with regard to the overall result of the operation and to rate the apperance of the foot as excellent, good, fair, or poor.

Radiographic assessment

Anteroposterior and lateral radiographs were assessed preoperatively and one year after surgery. All radiographs were obtained under weightbearing conditions. The hallux valgus angle and the intermetatarsal angle were evaluated as described by Miller et al.[19] This method has been shown to be the most precise and least biased by postoperative effects.[25] The sesamoid position was evaluated by measuring the position of the medial sesamoid relative to the same bisecting line of the first metatarsal shaft and was classified as grade 0 to 3.[28]

Statistical methods

Plantar pressure parameters, AOFAS Score, ROM of the first MTP joint and radiographic parameters were each compared with a Student's (dependent) t-test. Statistical analysis was performed using SPSS version 16.0 (SPSS Inc., Chicago, IL) as well as Excel for Mac (The Microsoft Corporation, Redmond, WA). The level of significance was defined as alpha > 0.05.

RESULTS

Plantar pressure assessement

A comparison of plantar pressure measurements is presented in Figure 2.

The maximum force for the great toe region significantly increased between the preoperative and one-year postoperative assessments ($p = 0.005$). There was a trend toward increased maximum force at the region of the first metatarsal head and the total foot. ($p = 0.068$ and $p = 0.079$, respectively)

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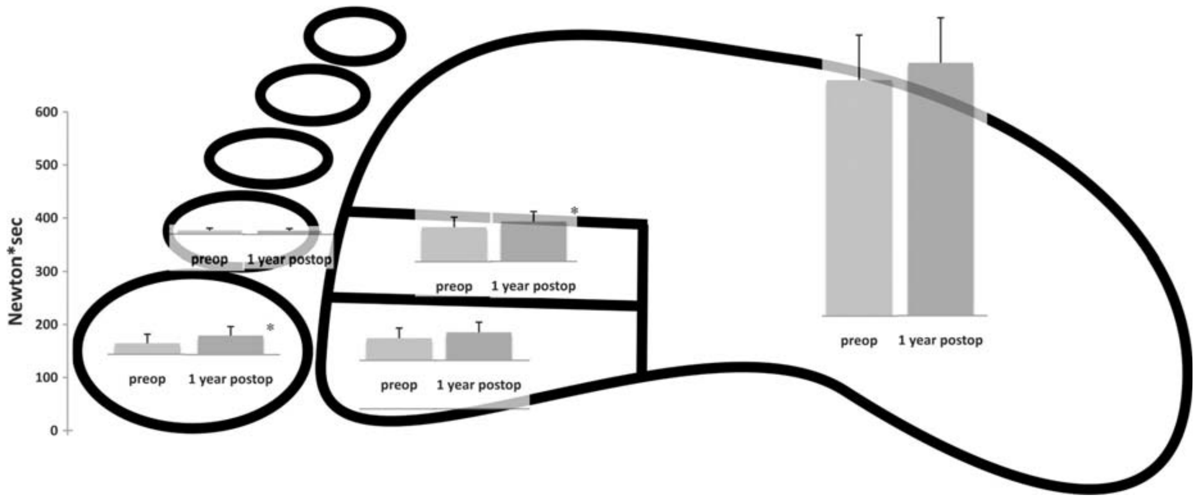

Fig. 2: This table shows changes of force time integral for the regions of interest. The light gray bars represent the preoperative investigation and the dark gray bars the investigation performed at one year after surgery. The star (*) indicates statistically significant changes ($p < 0.05$).

The mean contact area demonstrated significant changes between the preoperative and one-year postoperative measurements for the total foot and great toe region. There was an increase in the mean from 119.2 ± 12.6 cm^2 to 122.7 ± 12.1 cm^2 for the total foot ($p = 0.010$) and an increase in the mean from 7.6 ± 2.3 to 8.9 ± 2.2 cm^2 ($p = 0.014$) for the great toe region. The contact area changes for the other regions of interest were not found to change.

The mean force-time integral changed significantly from 20.8 ± 11.2 N*sec preoperatively to 30.5 ± 17.9 N*sec at one-year followup for the great toe region ($p = 0.032$). Also, there was a significant increase of this parameter for the second metatarsal head region from 63.5 ± 19.4 N*sec to 73.6 ± 20.0 N*sec ($p = 0.022$). For the first metatarsal head region this parameter increased from 42.3 ± 21.3 N*sec to 52.6 ± 18.7 N*sec. However, this change was not statistically significant ($p = 0.055$). Additionly, the changes for the total foot reagion and the second toe region were not significant (Figure 2).

Clinical outcome

The patient-rated outcome was excellent for 23 patients (85.1%), good for three (11.1%) and fair for one (3.8%) patient. None of the patients rated the overall result of the operation or the apperance of the foot as poor. The mean total AOFAS score improved significantly from 61 (range, 40 to 80) points preoperatively to 94 (range, 80 to 100) points at the time of followup (p < 0.0001).

The mean ROM of the first MTP joint changed from 71 (range, 35 to 140) degrees preoperatively to 70 (range, 40 to 90) degrees 1 year after surgery ($p = 0.748$). The mean isolated dorsiflexion increased from 39 (range, 15 to 60) degrees to 43 (range, 40 to 90) degrees at followup ($p = 0.157$), and the mean isolated plantarflexion decreased from 32 (range, 15 to 115) degrees to 27 (range, 10 to 40) degrees at followup ($p = 0.209$).

Radiographic results

Significant differences were observed between the mean preoperative and 1-year followup measurements for the first intermetatarsal angle, the hallux valgus angle, and sesamoid positions. The mean intermetatarsal angle was 14 (range, 11 to 18) degrees preoperatively and 6 (range, 2 to 12) degrees at 1-year followup ($p < 0.0001$). The mean hallux valgus angle was 31 degrees (range, 20 to 50) preoperatively and nine degrees (range, −2 to 28) at 1-year followup ($p < 0.0001$). The mean correction was 8 ± 5 degrees for the first intermetatarsal angle and 23 ± 7 degrees for the hallux valgus angle. The mean sesamoid position was grade 2.2 ± 0.6 (range, 1 to 3) preoperatively and grade 0.2 ± 0.4 (range, 0 to 1) at the time of followup ($p < 0.0001$). There were no non-unions, loss of correction nor cases of avascular necrosis.

DISCUSSION

This study investigated plantar pressure changes after chevron osteotomy in patients who received a special postoperative regimen including cryotherapy, lymphatic drainage, manual therapeutic inverventions of the first MTP joint, muscle strenghthening exercises and gait training. Measuring plantar pressure provides an indication of foot and ankle function during gait. In the present study, plantar pressure measurements were performed to investigate the changes of gait before and after chevron osteotomy for correction of hallux valgus with respect to the functional restoration of the operated area.[22] In addition, clinical and radiographic changes were assessed as well.

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Recent attention has been focussed on the evaluation of plantar pressure changes after chevron osteotomy.[4,5,9,14] In a prospective study, Kernozek and Sterriker investigated 25 patients with mild to moderate hallux valgus deformity before and one year after chevron osteotomy. They found significantly decreased loading of the hallux region 12 months after surgery compared to the preoperative values[14] despite adequate radiographic correction. They concluded that the chevron osteotomy failed to influence central metatarsal forefoot pressure distribution and did not resolve transfer metatarsalgia nor restore weightbearing of the first ray. However, the postoperative treatment of this patient population differed from the methods used in the present study. First, patients wore a postoperative shoe for 6 weeks. Also, they did not receive any kind of rehabilitation program postsurgically.

Bryant et al. performed pedobarographic assessments of 31 patients who underwent an Austin osteotomy for mild to moderate hallux valgus deformity. The hallux region showed decreased loading at 3, 6, 12, 18, and 24 months after surgery compared to the preoperative level. The lowest values were reached at three months after surgery and increased throughout the postoperative period. However, at the final postoperative investigation, 24 months after surgery, decreased loading of the hallux remained.[4] Again, the postoperative treatment regimen differed from ours. Patients did not undergo any kind of physiotherapy interventions postsurgically.

Guesgen et al. investigated 60 patients at a mean of 3 years after chevron osteotomy for hallux valgus. They reported that only 53% of the patients used their great toe for push-off if the postoperative hallux valgus angle was less than 20 degrees. Moreover, if this angle was greater than 20 degrees, only 39% of the patients used their great toe for push-off. The postoperative regimen of the patients of this study included the use of crutches combined with a forefoot relief shoe for 6 weeks.[9] No formal postoperative therapy was performed in this patient population.

In a retrospective study, Cancilleri et al. performed a comparison of plantar pressure characteristics of patients who underwent a biplanar Austin osteotomy and a Boc modification of the Austin osteotomy in 60 patients. They hypothesized that the Boc modification, characterized by relative shortening and plantarflexion of the first metatarsal head, would help to restore forefoot function because previous studies demonstrated that the biplanar Austin osteotomy fails to restore normal biomechanics. At an average followup of 37 months, plantar pressure assessment revealed that both procedures failed to restore physiological forefoot loading. Patients of both groups were placed in forefoot relief shoes for 4 weeks postoperatively and ROM exercises were initiated by the surgeon and continued for 1 month. However, patients of this study did not receive any kind of rehabilitation program.[5]

In the present study, a significant increase in the mean maximum force as well as the mean force-time integral for the great toe region was found, indicating improved loading of the hallux. Also, we found a trend for those parameters to increase for the first metatarsal head region. This represents improved weightbearing of the first ray. Since this structure is the most heavily loaded structure of the foot during gait, proper weightbearing is essential in order to provide physiological gait patterns.[8,13] Dereased load of the great toe has been shown to cause metatarsalgia.[29] Therefore, it is essential to improve weightbearing of this structure when performing hallux valgus surgery.

Postoperative physiotherapy is a well established method to help restore function after surgical intervention of disorders of the musculoskeletal system. The benefits of postoperative physiotherapy have been reported for nearly all orthopaedic surgery subspecialties.[3,6,11,16,27] However, it is not a standard intervention after hallux valgus surgery.

In agreement with other studies we found significant improvement of radiographic as clinical parameters. In the present study the mean AOFAS score improved significantly from 61 points preoperatively to 94 points at one year after surgery and the mean intermetatarsal angle decreased from 14 degrees to 6 degrees. In a retrospective study of 43 patients Trnka et al. reported of an AOFAS score of 91 points two and five years after chevron osteotomy and an intermetatarsal angle that decreased from 13 degrees to 8 degrees and 9 degrees respectively.[31] A more recently published study of Potenza et al. revealed an AOFAS score of 46 preoperatively and 88 points at a mean of 30 months postoperatively. The average intermetatarsal angle decreased from 13 degrees preoperatively to 7 degrees at followup. In a retrospecitve study where plantar pressure distribution was assessed as well Bryant et al. found a decrease of the intermetatarsal angle from 13 degrees to 6 degrees.[4] Cancellieri et al. assessed plantar pressure distribution, AOFAS score and radiographic changes in 60 patients who unterwent biplanar Austin osteotomy or the triplanar Boc type modification of Austin osteotomy.[5] They found at a mean of 43 months postoperatively an improvement of AOFAS score from 46 points to 81 and 86 points, respectively. Mean intermetatarsal angle decreased from 13 degrees to 8 degrees for both groups. The clinical and radiographic results of these studies, as well as the present study, indicate that the chevron osteotomy is an excellent technique to restore forefoot alignment and improve clinical parameters. However, forefoot function is not restored by the osteotomy alone.

Limitations of this present study include the absence of a control group that did not receive physiotherapy after chevron osteotomy. However, we believe it would be quite difficult to acquire a proper control group in order to compare plantar pressure parameters. The patients of the control group would have to have not only the same weight and foot size but also the same foot geometry. In the clinical setting, it is almost impossible to find such a patient group. However,

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our future research will focus on the implementation of a control group in order to perform a randomized controlled trial. Another limitation is that the postoperative regimen included two variables that could have affected the outcome. These variables were the implementation of passive range of motion exercises and the actual physical therapy program. It was not possible to separate the impact on the outcome of the isolated intervention.

CONCLUSION

We believe that a multimodal rehabilitation program helped to improve load distribution of the great toe and the first ray respectively after chevron osteotomy. Since the first ray is the most heavily loaded structure of the foot, sufficient weightbearing is essential to provide physiological gait patterns.[5,10,13,20] Decreased weightbearing of the great toe as well as the first ray is reported by many authors of reason for lesser toe metatarsalgia.[10,29,34] Increased weightbearing of these structures may have a positive influence on metatarsalgia. Surgical procedures aim to re-establish the normal plantar pressure distribution that is altered by hallux valgus deformity. The chevron osteotomy alone has been unable to restore physiological forefoot loading.[5,14] Postoperative physical therapy may lead to a restoration of plantar pressure distribution after chevron osteotomy for the correction of hallux valgus deformity.

EDITOR’S NOTE

The authors are to be congratulated for quantitatively documenting pressure changes of the forefoot after Chevron bunionectomy followed by a formal physical therapy program. However, without a control group, it is difficult to conclude that the findings are attributable just to the physical therapy and not a slightly different surgical technique. The results of their prospective randomized trial will be very interesting.

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