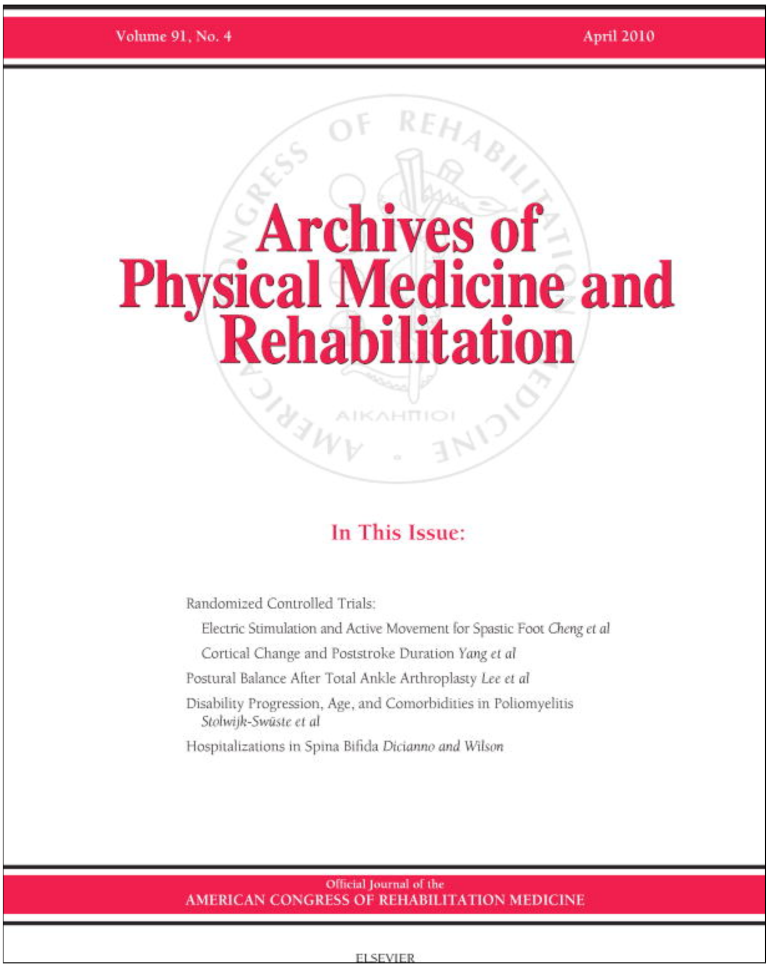
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ORIGINAL ARTICLE

Orthoses Alter In Vivo Segmental Foot Kinematics During Walking in Patients With Midfoot Arthritis

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ABSTRACT. Rao S, Baumhauer JF, Tome J, Nawoczenski DA. Orthoses alter in vivo segmental foot kinematics during walking in patients with midfoot arthritis. Arch Phys Med Rehabil 2010;91:608-14.

Objective: To assess the effect of a 4-week intervention with a full-length carbon graphite (FL) orthosis on pain and function in patients with midfoot arthritis, and to identify alterations in in vivo foot kinematics accompanying FL use in patients with midfoot arthritis. These results have immediate application for enhancing patient care through effective orthotic recommendations.

Design: Experimental laboratory study supplemented by a case series.

Setting: University based clinical research laboratory.

Participants: Patients (n=30) with midfoot arthritis and age-, sex-, and body mass index–matched control subjects (n=20).

Intervention: Four-week intervention with FL orthoses.

Main Outcome Measures: Pain and function were assessed using the Foot Function Index–Revised (FFI-R). In vivo foot kinematics were quantified as peak and total range of calcaneal eversion, forefoot abduction, first metatarsal plantarflexion, and first metatarsophalangeal joint dorsiflexion during walking in 2 conditions: with FL orthoses and with shoes only. A paired *t* test and repeated-measures analysis of variance were used to assess statistical significance (α=.05) of change in FFI-R score and in vivo foot kinematics, respectively.

Results: Significant improvements in pain and function, discerned as lower FFI-R scores ($P<.001$), were noted after the 4-week intervention with FL orthoses. During walking, FL orthosis use resulted in decreased first metatarsophalangeal joint dorsiflexion (P=.024) and first metatarsal plantarflexion range of motion (P=.038), compared with the shoe-only condition.

Conclusions: Orthotic intervention emphasizing a "stiffening" strategy of the first metatarsal and first metatarsophalangeal joint may be valuable in patients with midfoot arthritis and early degenerative changes.

Key Words: Arthritis; Orthotic devices; Rehabilitation.

ARTHRITIS OF THE tarsometatarsal joints (midfoot) has emerged as a major clinical challenge because of its increasing incidence compounded by a high potential for chronic secondary disability. The etiology of midfoot arthritis includes primary, inflammatory, and posttraumatic causes.[1,2] In recent years, with the advent of automobile airbags, midfoot injuries have increased both in frequency and severity after vehicular trauma because high impact forces are sustained with the foot against the floorboard.[3,4] In addition, as our population ages, the long-term effects of chronic increased joint loads sustained with high-heeled footwear may also contribute to the development and progression of degenerative midfoot arthritis.[5]

Patients with midfoot arthritis experience foot pain that limits their routine daily activities as well as reduces participation in recreational activities. Because of the complex anatomy and function of the midfoot region,[6] conventional operative treatment is often followed by complications and poor functional outcomes.[4,7,8] For these reasons, noninvasive conservative management in the form of foot orthoses serves as a particularly valuable first line of treatment in this population.

Patients with midfoot arthritis present with foot pain that is localized to the medial tarsometatarsal joints and aggravated by weight-bearing. Concomitant radiographic changes include degenerative changes at the tarsometatarsal joints reflected in joint space narrowing, dorsal bossing and osteophyte formation,[6,9] and low-arched foot alignment.[10] Consistent with these findings, the goal of orthotic intervention is to afford pain relief by limiting motion at the painful tarsometatarsal joints and restoring optimal arch alignment. To this end, arch-restoring devices such as the custom-molded 3Q orthoses are frequently prescribed in this population. The rationale guiding 3Q prescription is that the design features of the 3Q, such as its arch buildup and contoured heel, will favorably influence foot kinematics and thus afford pain relief.[11-13] Evidence in support of this contention comes from studies documenting improved control of calcaneal motion[14-17] and arch alignment,[18] and attendant improvement in patients' symptoms accompanying 3Q use during walking.[19,20]

In contrast to the favorable outcomes reported with 3Q use in patients with rheumatoid arthritis, our clinical experience suggests that patients with midfoot arthritis continue to report pain despite 3Q use. As an alternative, the FL orthosis, an over-the-counter device, has been proposed. The recommendation is based on reports from patients with arthritis of the first metatarsophalangeal (hallux rigidus),[21,22] where the FL has

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List of Abbreviations

ANOVA	analysis of variance
ES	effect size
FFI-R	Foot Function Index–Revised
FL	full-length carbon graphite (orthosis)
MDC_{90}	minimal detectable change at the 90% confidence interval
3Q	three-quarter length (orthosis)

been postulated to control motion of the first metatarsophalangeal joint and first metatarsal during walking. Because the first metatarsal forms the distal articular surface of the tarsometatarsal complex, use of the FL may limit first metatarsal motion during walking. However, objective data examining the effect of the FL on foot kinematics during walking are lacking in patients with midfoot arthritis. In the absence of quantitative data, orthoses prescription is frequently a matter of trial and error, leading to increased costs and prolonged disability. The purpose of this study was 2-fold: (1) to assess the effect of a 4-week intervention with the FL orthosis on pain and functional outcomes in patients with midfoot arthritis, and (2) to identify alterations in in vivo foot kinematics accompanying FL use in patients with midfoot arthritis. These results have immediate application for enhancing patient care through effective orthotic recommendations.

METHODS

Study Design

This study was an experimental laboratory study supplemented by a case series. All procedures were approved by the Institutional Review Boards of Ithaca College and the University of Rochester. Patients were recruited from the Outpatient Orthopedic Clinic at the University of Rochester Medical Center. All patients with midfoot arthritis participated in 2 testing sessions, 4 weeks apart, before and after intervention with the FL. Similar testing has found adequate accommodation to orthoses in 4 weeks.[18] All data were collected at the Movement Analysis Lab, Center for Foot and Ankle Research, at the Department of Physical Therapy, Ithaca College–Rochester Center, Rochester, NY.

Participants

All participants had unilateral foot pain localized to the tarsometatarsal region and aggravated by weight-bearing. Anteroposterior and lateral weight-bearing radiographs confirmed the presence of degenerative changes at 1 or more tarsometatarsal joints in all patients. Degenerative changes were assessed using arch alignment, quantified using the calcaneal–first metatarsal angle,[23,24] and Kellgren-Lawrence grades[25] (fig 1). Radiographic evidence of lower-arch alignment was found in patients with midfoot arthritis. As a group, patients with midfoot arthritis demonstrated a mean ± SD calcaneal–first metatarsal angle of 145°±8° compared with normative values of 132°±11°.[23,24] Seventy-five percent of patients showed degenerative changes (Kellgren Lawrence grade 1 and higher) at the tarsometatarsal joint, 40% at the naviculocuneiform joint, 25% at the talonavicular joint, 25% at the subtalar joint, and 4% at the calcaneocuboid joint.[26]

Fig 1. Lateral radiograph demonstrating degenerative changes, osteophyte formation, and dorsal bossing at the first tarsometatarsal joint in a patient with midfoot arthritis.

Patients with midfoot arthritis were invited to participate in this study with the following exclusion criteria: (1) injury or surgery of the lower extremity within the past 6 months; (2) other conditions such as stroke that may affect walking; or (3) use of assistive devices such as a cane or walker. Thirty-two patients met the inclusion criteria defined above, but 2 refused to participate for logistic reasons (lived >2h away), leaving 30 study participants (mean age ± SD [range], 62±7y [47–78y]; mean body mass index ± SD [range], 29.7±5.7kg/m^2 [19.9–33.1kg/m^2]). Twenty-eight (93%) of the 30 participants were women. A subset of the sample, 21 (70%) of 30 patients, comprised previous users of 3Q orthoses who continued to report persistent midfoot complaints.

Intervention

All patients were given 1 pair of FL orthoses[a] with the following design characteristics: (1) orthosis extends from heel to tip of the toes; (2) no arch buildup or contoured heel; and (3) semirigid (according to manufacturer specifications) with a mean thickness of 1.59mm. All patients were encouraged to use the FL during all weight-bearing physical activity over the 4-week intervention period.

Self-Reported Outcomes

Patients' self-reported outcomes before and after intervention with the FL were assessed using the FFI-R, a region-specific instrument with previous established reliability, validity, and responsiveness.[27-29] The FFI-R assesses foot function over the past week in the following subscales: pain, stiffness, activity limitation, and psychosocial issues. The construct validity, internal consistency, and reliability of the FFI-R were established in field testing on a sample of 92 patients, of whom 63 (69%) reported having degenerative arthritis.[30] For these reasons, the FFI-R was used to characterize self-reported foot function in the current study.

The clinical significance of the change in FFI-R scores after intervention was examined using the MDC_{90}. The MDC_{90} was computed as follows:

$$MDC_{90} = SEM \times 1.64 \times \sqrt{2}$$

where SEM refers to standard error of measurement, calculated as $SD\times\sqrt{1-ICC}$. Intraclass correlation coefficients (ICCs) were obtained for FFI-R total scores and component subscales from the literature.[30]

Assessment of In Vivo Foot Kinematics

In vivo foot kinematics during walking were assessed using a previously validated 4-segment kinematic model. Kinematic data were acquired at 98Hz using a magnetic tracking system[b] with small sensors (8×8×18mm).[26,31] Six-degree-of-freedom sensors with nominal static positional accuracy of 1.8-mm root mean square and static angular accuracy of 0.5° root mean square[32] were placed on the subject's skin over the hallux, first and second metatarsal, calcaneus, and tibia and secured with double-sided tape (fig 2). Patient-specific local coordinate systems were established by digitizing anatomic landmarks.[26]

Consistent with previous protocols,[20] after an initial familiarization period, data were collected using the second-step protocol as patients walked at a self-selected monitored walking speed (mean ± SD walking speed: .93±.21m/s and .93±

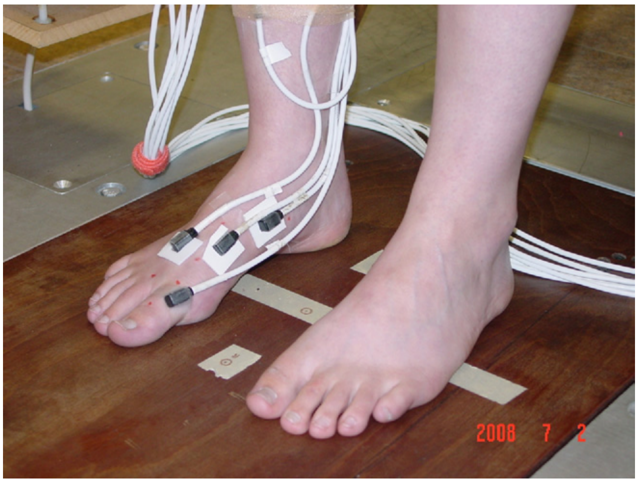

Fig 2. Kinematic model showing electromagnetic sensor placement.

.18m/s in FL and shoe conditions, respectively; P=.89). In an attempt to eliminate the possibility of confounding resulting from differences in patients' footwear, all kinematic testing was performed using standard laboratory-issued footwear. Each patient was fitted with appropriate-sized, neutral cushioning, standard-width sneakers. To accommodate sensors, footwear was modified by cutting windows.[20] All patients were tested in the shoe and FL conditions, presented in random order. If they were previous users of the 3Q orthoses, they were tested in the 3Q orthoses.

As detailed in previous studies,[26] kinematic data were low-pass filtered using a fourth-order Butterworth filter with a cutoff frequency of 6Hz and analyzed using MotionMonitor software.[c] Euler angles, representing 3 sequential rotations (Z-X-Y), were used to describe joint motion throughout stance. Dependent variables of interest (fig 3) included total range of motion and peak motion of the following: calcaneal eversion, forefoot abduction, first metatarsal relative to calcaneus, first metatarsal plantarflexion (relative to the lab coordinate system), and first metatarsophalangeal joint dorsiflexion. Peak motion provides information about position or alignment of the segments of the foot, while range of motion provides information about the total excursion of the segment. Peak values for all dependent variables were referenced to subtalar neutral.[26,33] A single tester (S.R.) determined subtalar neutral for all subjects while they stood in a bilateral weight-bearing stance.

Statistical Analysis

Data were assessed for normality and variance homogeneity. FFI-R scores before and after intervention were compared using a paired t test. In addition, MDC_{90} scores were computed for each subscale as well as the total FFI-R score. Separate 1-way, repeated-measures ANOVAs were used to assess the effect of orthoses (FL or shoe) on each dependent variable characterizing in vivo foot kinematics (α=.05). Pearson product-moment correlation (r) was used to assess the relationship between in vivo foot kinematics and patients' self-reported foot function. Statistical significance (H_o: ρ=0) was assessed using approximate tests based on the Fisher z transformation (α=.05). In the subset of patients who were previous users of 3Q, a secondary analysis, in the form of a repeated-measures ANOVA, was undertaken to assess the effect of orthoses (FL, 3Q, and shoe) on each dependent variable characterizing in vivo foot kinematics (α=.05). Bonferroni-adjusted comparisons were used to assess the statistical significance of pairwise comparisons.

RESULTS

Self-Reported Outcomes

Patients' self-reported outcomes, characterized by total FFI-R scores, were significantly lower after the 4-week intervention compared with baseline values (P<.001) (table 1). Lower scores are indicative of alleviation of symptoms. The 20% improvement in total score (ES=.70) was driven by a 25% reduction in pain (P<.001, ES=.84) and a 24% reduction in activity limitation (P<.001, ES=.57). The clinical relevance of these changes was explored using the MDC_{90}. Seventy-one percent of patients showed improvements in total FFI-R score equal to or greater than the MDC_{90}. On average, clinically relevant improvements were noted in the pain, disability, and activity limitation subscales as well as in the total FF-R score. Changes in stiffness and psychosocial subscales were statistically significant but did not reach magnitudes that may be considered clinically relevant (see table 1).

In Vivo Kinematics

Comparison between shoe and FL. Decreased first metatarsophalangeal joint dorsiflexion range of motion (P=.024) and first metatarsal plantarflexion range of motion (P=.038) were noted during walking with the FL compared with the shoe-only condition (table 2). No evidence was found for differences in peak motion when using the FL compared with the shoe-only condition: peak first metatarsophalangeal joint dorsiflexion (20.7°±5.9° and 18.6°±6.5° in shoe and FL conditions, respectively; P=.08), peak first metatarsal plantarflexion (−0.4°±8.0° and −0.4°±8.3° in shoe and FL conditions, respectively; P=.957), peak first metatarsal–calcaneus dorsiflexion (14.6°±6.0° and 13.5°±5.6° in shoe and FL conditions, respectively; P=.334), peak forefoot abduction (6.9°±7.6° and 7.2°±5.8° in shoe and FL conditions, respectively; P=.834), peak calcaneus eversion (4.9°±6.5° and 6.0°±6.2° in shoe and FL conditions, respectively; P=.12) in shoe and FL conditions, respectively; P=.12), and peak ankle dorsiflexion (2.9°±8.4° and 3.2°±7.0° in shoe and FL conditions, respectively; P=.823).

Comparison between shoe, 3Q, and FL. In a subset of patients who were previous users of the 3Q (n=21), 1-way repeated-measures ANOVA indicated significant effects of orthoses on peak first metatarsophalangeal joint dorsiflexion, peak first metatarsal plantarflexion, and peak calcaneus eversion (table 3). Subsequent post hoc testing using Bonferroni-adjusted P values revealed significant differences between 3Q and FL conditions, and similar trends were noted for comparisons between 3Q and shoe conditions. Based on the 1-way ANOVA, no evidence was found for the effect of orthoses on range of motion during walking: first metatarsophalangeal joint range (20.1°±6.1°, 17.4°±5.9°, and 20.0°±7.2° in shoe, FL, and 3Q conditions, respectively; P=.482), first metatarsal range (56.8°±9.4°, 52.1°±9.0°, and 53.2°±9.0° in shoe, FL, and 3Q conditions, respectively; P=.204), first metatarsal–calcaneus range (18.2°±5.0°, 17.1°±5.3°, and 17.5°±6.2° in shoe, FL, and 3Q conditions, respectively; P=.321), forefoot abduction range (8.2°±3.9°, 7.9°±4.8°, and 8.7°±3.8° in shoe, FL, and 3Q conditions, respectively; P=.486), calcaneus eversion range (9.2°±4.0°, 9.7°±3.9°, and 9.5°±3.7° in shoe, FL, and 3Q conditions, respectively; P=.918), and ankle dorsiflexion range (14.4°±5.0°, 15.3°± 4.3°, and

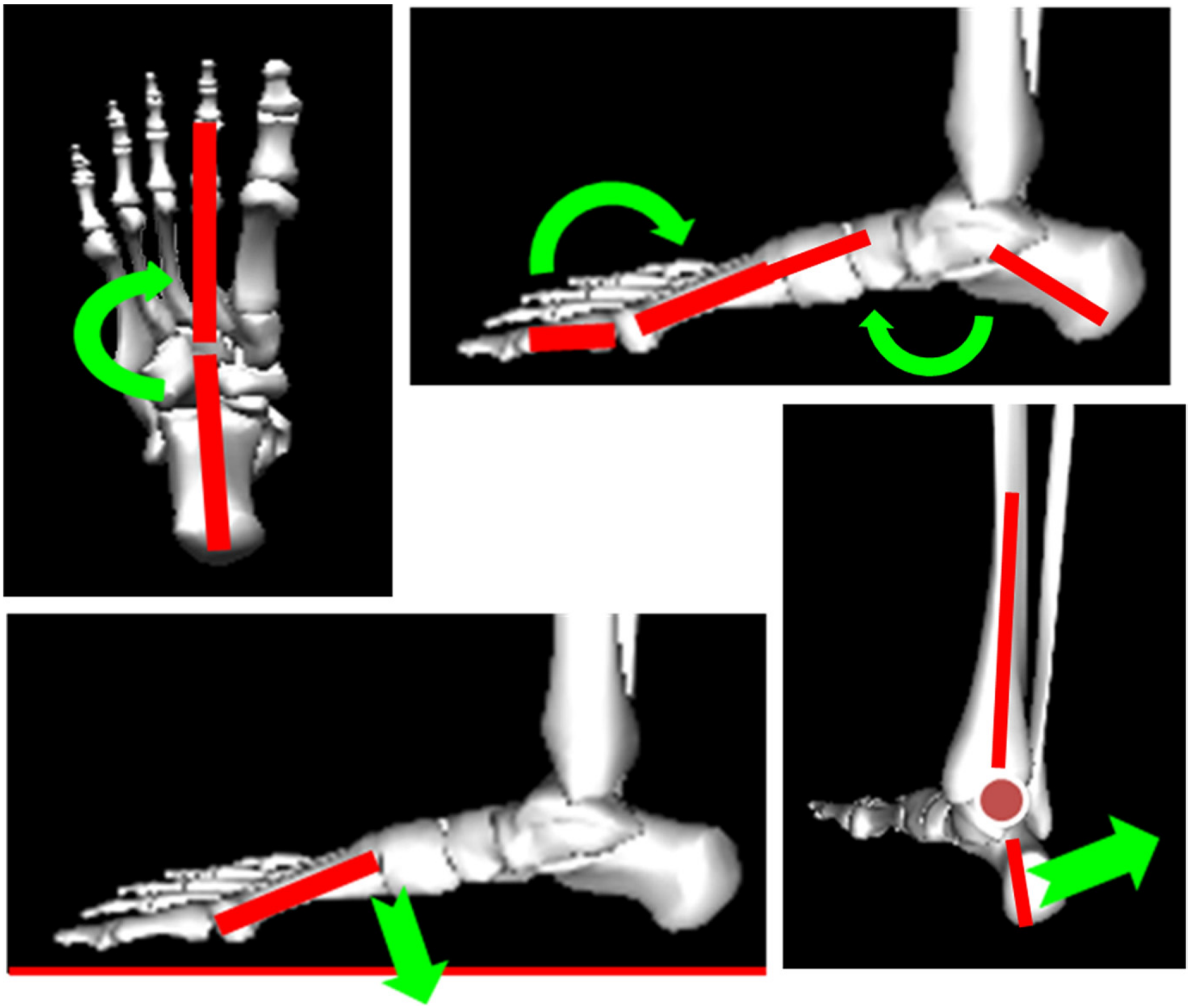

Fig 3. Kinematic dependent variables used in the current study. Clockwise from top left: forefoot abduction, first metatarsophalangeal joint dorsiflexion, dorsiflexion of first metatarsal relative to calcaneus, calcaneal eversion, and first metatarsal plantarflexion.

14.5°±5.4° in shoe, FL, and 3Q conditions, respectively; P=.599).

Relationship between self-reported outcomes and in vivo foot kinematics. Foot pain, characterized by the pain subscale of the FFI-R, was directly related to sagittal plane range of motion of the first metatarsal relative to the calcaneus in the shoe (r=.42, P<.01). Without the outlier indicated by an asterisk in figure 4, sagittal plane range of motion of the first metatarsal relative to the calcaneus explained 36% of the variance in pain subscale score (r=.60, P<.01).

Table 1: Patients' Self-Reported Outcomes, Characterized Using the FFI–R Subscale and Total Scores, at Baseline and After 4-Week Intervention With FL

Subscale	Baseline	After	*P*	MDC_{90}	ES
Pain	41±13	31±11	<.001	5	.84
Stiffness	36±13	32±12	.040	6	.31
Disability	44±14	36±14	<.001	7	.60
Activity limitation	39±19	30±13	<.001	7	.57
Psychosocial issues	32±12	28±11	.016	7	.32
Total score	39±12	31±10	<.001	5	.70

NOTE. Values are mean ± SD or as otherwise indicated.

DISCUSSION

The key findings of this study indicate that a 4-week intervention with the FL may offer symptomatic relief in patients with midfoot arthritis. In terms of in vivo segmental foot kinematics, use of the FL resulted in decreased first metatarsophalangeal joint and first metatarsal range of motion during walking, compared with the shoe-only condition. Improved control of first metatarsal and first metatarsophalangeal joint motion may be a key factor mediating pain relief in patients with midfoot arthritis.

Patients with midfoot arthritis reported significant pain and limitations in functional mobility, reflected as high preintervention total FFI-R scores, compared with previously reported

Table 2: In Vivo Kinematics, Expressed in Degrees of Motion During Walking, in the Shoe and FL Conditions

Measures	Shoe	FL	*P*
Peak MTP1 dorsiflexion	20.7±5.9	18.6±6.5	.080
MTP1 range	20.8±5.7	17.6±5.8	.024
Peak MT1 plantarflexion	−0.4±8.0	−0.4±8.3	.957
MT1 range	56.8±9.4	52.1±9.0	.038
MT1-calcaneus dorsiflexion	14.6±6.0	13.5±5.6	.334
MT1-calcaneus range	18.1±6.8	17.6±5.5	.765
Peak forefoot abduction	6.9±7.6	7.2±5.8	.834
Forefoot abduction range	8.3±4.0	7.6±4.1	.171
Peak calcaneus eversion	6.0±6.2	4.9±6.5	.120
Calcaneus eversion range	9.3±4.0	9.2±3.9	.913
Peak ankle dorsiflexion	2.9±8.4	3.2±7.0	.823
Ankle dorsiflexion range	15.4±4.0	15.6±4.6	.817

NOTE. Values are mean ± SD or as otherwise indicated; n=30. Abbreviations: MT1, first metatarsophalangeal joint; MTP1, first metatarsophalangeal.

values in asymptomatic control subjects.[26] Compared with previous studies reporting foot pain and function in patients with midfoot arthritis (mean pain score, retrospectively assigned using FFI: 52.8),[10] patients in the current study demonstrated less severe symptoms (mean pain score, using FFI-R: 41.1). The difference in severity in the patients in this study may be explained by the fact that previous reports primarily studied preoperative patients with midfoot arthritis, and the current study may represent a relatively high functioning cohort of patients with midfoot arthritis and early degenerative changes.

Women comprised 28 (93%) of the 30 subjects in the study sample, consistent with the sex distribution reported by previous studies in patients with midfoot arthritis as well as rheumatoid arthritis.[10,34,35] Contrary to our expectation that most patients would have posttraumatic midfoot arthritis,[2] none of our patients recalled a major traumatic event leading to their midfoot symptoms. A follow-up review of the more recent literature revealed that our study sample is similar in terms of etiology and patient demographics to that reported in more recent cohorts.[10,34] The study sample may reflect the changing demographic presenting with midfoot problems. The absence of major trauma combined with the sex distribution may implicate the potential role of chronically increased joint loads sustained with poor footwear choices,[5] in the development of midfoot arthritis.

Table 3: In Vivo Peak Segmental Motion During Walking, Expressed in Degrees, in the Shoe, FL, and 3Q Conditions

Measures	Shoe	FL	3Q	*P*
Peak MTP1 dorsiflexion	20.8±7.5	17.8±5.6	22.3±5.5*	.022
Peak MT1 plantarflexion	−0.6±5.7	−0.2±5.1	−3.9±4.4*	.035
MT1-calcaneus dorsiflexion	15.1±4.6	13.8±6.2	15.5±5.2	.395
Peak forefoot abduction	6.7±7.2	7.1±5.2	3.8±4.8	.121
Peak calcaneus eversion	4.8±5.1	5.1±4.5	2.6±5.6*	.019
Peak ankle dorsiflexion	2.7±7.8	3.1±7.3	2.0±8.0	.391

NOTE. Values are mean ± SD or as otherwise indicated; n=21. Abbreviations: MT1, first metatarsophalangeal joint; MTP1, first metatarsophalangeal.
*Indicates significant difference between 3Q and FL conditions, based on post hoc testing using Bonferroni-adjusted *P* values. Similar trends were noted for comparisons between 3Q and shoe.

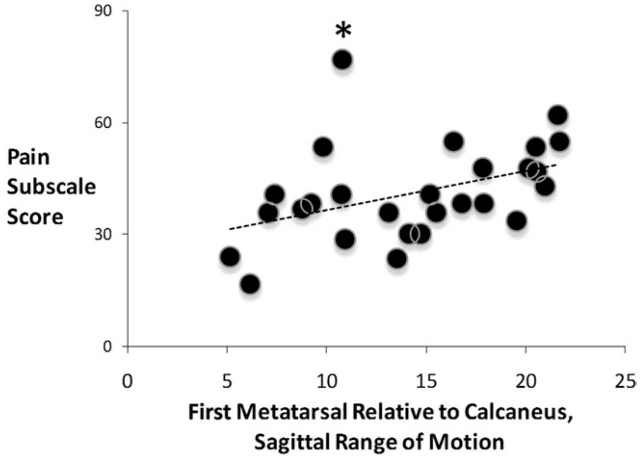

Fig 4. Relationship between pain and segmental foot kinematics in patients with midfoot arthritis. Pain subscale scores from the FFI-R are plotted on the ordinate, and sagittal plane range of motion of the first metatarsal relative to the calcaneus is plotted on the abscissa.

The findings of the current study indicate that use of the FL orthoses may contribute to symptomatic relief, reflected as a reduction in the FFI-R total score. The 20% improvement in total score (ES=.70, $P<.01$) was driven by a 25% reduction in pain ($P<.001$, ES=.84) and a 24% reduction in activity limitation ($P<.001$, ES=.57). Three of 5 subscales of the FFI-R showed a reduction in score greater than the MDC_{90}, indicative of a clinically relevant change. The ESs for self-reported foot function were consistent with previous reports; in patients with rheumatoid arthritis treated with custom-molded orthoses, Woodburn et al[20] found a 23% improvement in composite FFI score at 30-month follow-up. Similarly, in patients with rheumatoid arthritis treated with foot orthoses, de P. Magalhães et al[35] reported a 26% improvement in FFI score at 4-week follow-up.

In terms of in vivo segmental foot motion, patients with midfoot arthritis demonstrated a reduction in first metatarsophalangeal joint dorsiflexion range of motion and first metatarsal plantarflexion range of motion during walking with the FL compared with the shoe-only condition. Previous studies have hypothesized that use of the FL will block motion at the first metatarsophalangeal joint and consequently limit peak first metatarsophalangeal joint dorsiflexion at the push-off phase of walking.[36] While our results do not indicate that the FL limits peak dorsiflexion at the first metatarsophalangeal joint compared with the shoe-only condition, our findings suggest that the FL may mimic a "stiffening" strategy by restricting first metatarsophalangeal joint dorsiflexion range of motion and first metatarsal plantarflexion range of motion during walking compared with the shoe-only condition. The reduction in first metatarsal plantarflexion range of motion may be analogous to the reduction in knee flexion demonstrated by patients with patellofemoral pain during walking.[37] At the knee joint, the reduction in knee flexion accompanying a stiffening strategy may be indicative of the patients' attempt to reduce compressive loads across the patellofemoral joint.[38] Similarly, in patients with midfoot arthritis, the reduction in first metatarsal motion may be a strategy to limit articular stress at the tarsometatarsal joints because the first metatarsal forms the distal part of the tarsometatarsal articulation. The stiffening strategy, reflected in reduced first metatarsal motion, may be particularly valuable in patients with early degenerative changes, who may subject their feet to more physical activity and consequent joint stress because of their higher level of physical functioning.

Consistent with the theory highlighting the importance of first metatarsal control in patients with midfoot arthritis during walking, we noted a modest positive relationship between foot pain, characterized by the pain subscale of the FFI-R, and sagittal plane range of motion of the first metatarsal relative to the calcaneus in the shoe-only condition. Increasing motion was associated with higher pain scores. Orthotic intervention emphasizing a stiffening strategy of the first metatarsal may be valuable in patients with midfoot arthritis and early degenerative changes. An additional consideration in the choice of orthotic device may be the cost of intervention, particularly because there are wide discrepancies in the direct costs of custom-molded (~$300) versus over-the-counter orthoses (~$80), as well as in the indirect costs associated with orthoses fabrication and fitting time.

Twenty-one (70%) of the 30 patients in the study sample had been previous users of the 3Q orthoses. This fact did not appear to influence baseline or change in FFI-R scores, as both groups showed similar improvement in the pain subscale (10 points), activity limitation subscale (9 points), and total FFI-R score (8 points). In agreement with recent reports, use of 3Q orthoses was accompanied by improved rearfoot (calcaneus) alignment during walking.[20] However, in patients with midfoot arthritis, increased peak first metatarsophalangeal joint dorsiflexion, peak first metatarsal plantarflexion, and peak calcaneus eversion were noted during walking in the 3Q orthoses compared with the shoe-only condition. Design features of orthoses, such as arch buildup and contoured heel cup, may contribute to the altered segmental foot kinematics observed during walking.[18,20,39] While restoration of foot alignment using 3Q orthoses has been accompanied by positive self-reported outcomes in patients with rheumatoid arthritis and flexible valgus deformity,[20] their extrapolation to patients with midfoot arthritis may not be justified.

Study Limitations

The primary limitation of the current study is that we did not compare the outcomes after the use of 3Q versus FL orthoses in a randomized controlled trial; therefore, direct comparisons of outcomes between the 2 orthoses is beyond the scope of our study. The current study provides preliminary evidence supporting the use of FL orthoses in patients with midfoot arthritis (level 4 evidence). In addition to altering foot motion, orthoses may afford pain relief by altering the distribution of loads sustained at the foot-shoe interface.[40] Future studies using a randomized controlled trial and longer-term follow-up are indicated to provide stronger evidence through direct comparison of different orthotic designs.

CONCLUSIONS

The chief findings of our study were that a 4-week intervention with the FL may offer symptomatic relief in patients with midfoot arthritis. Use of the FL foot plate resulted in decreased first metatarsophalangeal joint and first metatarsal range of motion during walking, compared with the shoe-only condition. Improved control of first metatarsal and first metatarsophalangeal joint motion may be a key factor mediating pain relief in patients with midfoot arthritis. Additional studies using a randomized controlled trial and longer-term follow-up are indicated to provide stronger evidence through direct comparison of different orthotic designs.

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Suppliers

a. Wrymark Inc, 11833 Westline Industrial Dr, St Louis, MO 63146.
b. Flock of Birds; Ascension Technology Corp, PO Box 527, Burlington, VT 05402.
c. Innovative Sport Training, 3711 N Ravenswood Ave, Chicago, IL 60613.