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Original Research

Does Modified Footwear Improve Gait After Ankle Arthrodesis?

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ABSTRACT

Rocker bottom shoes are commonly recommended for patients who have undergone ankle arthrodesis. Limited data are available to support this recommendation. In the present case-control study, 2 groups of participants were identified for the investigation: a study group (SG) of 9 patients who had previously undergone ankle arthrodesis and a normal group (NG) of 9 healthy volunteers. Gait data were collected using a video recorder while the participants walked barefoot and wearing rocker bottom shoes. These data were analyzed using computer-based gait analysis software. The total motion was calculated and averaged for each group for walking barefoot and wearing rocker bottom shoes. All participants completed the Short Musculoskeletal Function Assessment and the American Orthopaedic Foot and Ankle Society questionnaires. The total motion of the SG wearing rocker bottom shoes increased 4.8° (range 3.4° to 6.9°) on mean average, an improvement compared with walking barefoot ($p < .05$). In the NG, the shoe wear had no effect on the total motion ($p = .59$). Although the total motion in the SG approached the mean average of the total motion of the NG, it remained significantly less than that of the NG ($p < .05$). Additionally, the SG scored worse than the NG on both outcomes questionnaires ($p < .05$). Rocker bottom shoes had no effect on gait velocity. In conclusion, rocker bottom shoes significantly improve the total motion of ankle arthrodesis patients toward normal.

Ankle arthrodesis is recognized as a reliable and safe procedure for the treatment of patients with ankle arthritis for whom conservative management has failed (1–6). The common indications for ankle arthrodesis are post-traumatic arthritis, followed by rheumatoid arthritis, infection, failed ankle arthroplasty, and neuromuscular conditions (1). Many other indications of ankle arthrodesis have been proposed; however, 3 general concepts of ankle arthrodesis have been consistently sought: correction of the deformity, maintenance of stability, and alleviation of pain (7,8).

A common recommendation of foot and ankle surgeons for patients after ankle arthrodesis is to obtain and wear shoes with a rocker bottom sole during ambulation. Rocker bottom shoes (RBSs) have been postulated to create a more natural gait pattern in the immobilized ankle (9); however, limited gait analysis data from ankle arthrodesis patients while wearing RBSs are available.

The primary purpose of the present case-control study was to determine whether the rocker bottom sole modification improves the gait after ankle arthrodesis. In addition, we wished to investigate whether RBSs cause changes in the gait patterns of a normal population and to evaluate the functional outcome of the ankle arthrodesis patients compared with a normal population. We undertook the present study to determine whether RBSs can improve the gait of ankle arthrodesis patients toward normal.

Patients and Methods

Our institutional review board approved the present case-control study, before we initiated testing. Two groups of participants were identified: a study group (SG) and a normal group (NG). The SG included patients who had previously undergone ankle arthrodesis for post-traumatic arthritis. It was determined a priori that a sample size of 8 was required for 80% power. A total of 36 patients were identified from the trauma registry at our level I trauma center and were interviewed to solicit interest in participation. To meet the inclusion criteria, the participants had to have undergone ankle arthrodesis for painful ankle arthrosis and to have radiographic evidence of united fusion. Also, ankle arthrodesis had to have been performed, at a minimum, 1 year before testing. All arthrodesis procedures were performed from July 1, 2006 to December 31, 2011. All patients were required to have been ambulating without an assistive device for a minimum of 6 months. They were required to have a leg length discrepancy of <2 cm and to have demonstrated both radiographic and clinical union. The leg length discrepancy was measured using corrective blocks before testing. Union was evident on plain radiographs, with demonstration of trabeculae crossing the tibiotalar–fusion interface. Clinical union was demonstrated by the absence of tenderness to palpation of the fusion site at the most recent follow-up visit. The identified participants were excluded if they had sustained other injuries or if they had undergone any other surgeries to the bilateral lower extremities, regardless of the chronology.

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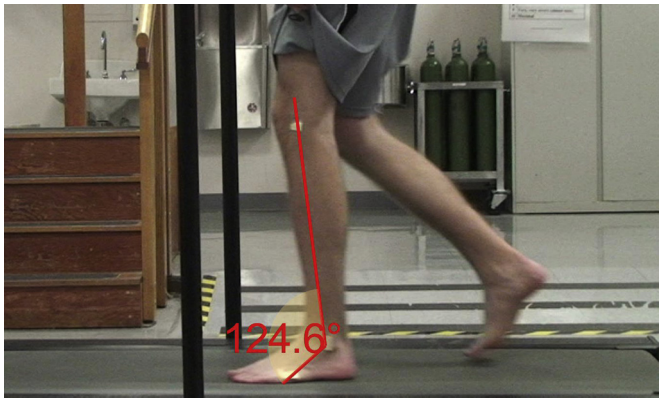

Fig. 1. Example of skin markers placed for measurement of sagittal plane motion with representative angle measurement.

Nine patients, with a mean age of 56.1 (range 42 to 65) years, were available for the SG. The right ankle had been fused in 6 participants (66.67%) and the left in 3 (33.33%). The NG of 9 individuals, with a mean average age of 27.4 (range 25 to 31) years, and with completely normal lower extremities, consisted of healthy hospital personnel volunteers. The mean age of the SG participants was intentionally different from that of the NG participants. Of the 9 SG participants, 5 (55.56%) were male and 4 (44.44%) were female. In the NG, 6 participants (66.67%) were male and 3 (33.33%) were female.

All participants were asked to present to the hospital's department of physical medicine and rehabilitation. The data were gathered from January 2012 through May 2012. After obtaining informed consent for participation, the demographic data were recorded. The participants were asked to complete the Short Musculoskeletal Function Assessment (SMFA) and the American Orthopaedic Foot and Ankle Society (AOFAS) questionnaire (10) at the beginning of the visit. Markers were then placed on the lower extremities of all participants at the same anatomic locations to allow for consistent angle measurements: the lateral knee, lateral malleolus, and head of the fifth metatarsal (Fig. 1). When the shoes were in place, the head of the fifth metatarsal could be palpated in all participants, and the marker was placed on the shoe at the corresponding area. All participants were then video recorded while walking on a treadmill at a self-selected pace while barefoot and while wearing RBSs. These data were analyzed using a computer gait analysis program (Dartfish® gait analysis software, Fribourg, Switzerland). Using the anatomic markers, the angles of heel strike, foot flat, and toe off for both groups while walking barefoot and wearing RBSs were measured. Multiple heel strike, foot flat, and toe off angles were measured for each subject and then averaged. The total motion was averaged for each subject by subtracting the heel strike from the toe off (Figs. 2 and 3). The velocity of both groups was measured in meters per second. This was achieved by measuring the participant's stride length and calculating the steps per minute.

Independent Student's *t* test statistical analysis was performed to compare the differences in total motion between the NG and SG while walking both barefoot and wearing RBSs. The changes in total motion within the 2 groups were analyzed using paired Student's *t* tests. A Mann-Whitney *U* analysis was performed of the SMFA and AOFAS survey results to compare the scores of the NG versus the SG. The gait velocities were compared among the groups and between the groups using independent and paired *t* tests, respectively. All statistical analyses were evaluated using the SPSS software program, version 15.0 (SPSS Inc, Chicago, IL), with the level of statistical significance set at $p \leq .05$.

Results

The total motion of the SG improved while wearing RBSs; however, the RBSs had no effect on the NG (Table 1). In the SG, the total motion was 3.9° (range 2.9° to 5.0°) while barefoot and 8.7° (range 7.1° to 10.0°) while wearing RBSs, demonstrating an increase in total motion of 4.8° (range 3.4° to 6.9°) ($p < .05$). The motion increase in the SG while wearing RBSs demonstrated a mean average total motion that approached the total motion average in the NG while barefoot (11.3° [range 8.2° to 14.6°]) and wearing RBSs (11.0° [range 9.1° to 14.2°]). Despite this improvement toward normal, the differences between the SG wearing RBSs and the NG, both barefoot and wearing RBSs, remained significantly different statistically (Table 2; $p < .05$ for both). The modified shoe wear had no effect on total motion in the NG ($p = .59$).

Walking barefoot, the mean average velocity of the NG was 0.75 (range 0.70 to 0.81) m/s and the mean average of the SG was 0.58 (range 0.34 to 0.86) m/s ($p = .07$). Similarly, wearing RBS, the mean average velocity of the NG was 0.75 (range 0.70 to 0.80) m/s and of the SG was 0.62 (range 0.34 to 0.83) m/s ($p = .145$). Neither the NG nor the SG had a significant change in velocity while wearing the RBSs compared with their respective groups while walking barefoot ($p = .10$ for the SG; $p = .92$ for the NG). On average, the SG scored worse than the NG on the AOFAS questionnaire ($p < .05$) and on every section of the SMFA ($p < .05$).

Discussion

Ankle arthrodesis is an acceptable and reliable procedure for the treatment of refractory ankle arthritis (1–6). Much has been published on the clinical effects of ankle arthrodesis (1,3–8,11–16), and some of the published studies have demonstrated significant physiologic gait changes after ankle arthrodesis (4,6–8). These adverse effects could result, in part, from the decrease in ankle dorsiflexion and plantarflexion (approximately 10° and 6°, respectively), which have been shown to occur after arthrodesis (6). It has also been shown that an approximately 7% to 10% increase occurs in energy expenditure during gait in patients with ankle arthrodesis (14,16). The present study was undertaken to evaluate the effects of the common recommendation of RBSs use by those who have undergone ankle arthrodesis.

The present study investigated the change in total motion during gait before and after wearing RBSs. The observed significant increase in total motion within the SG was an increase toward normal; however, it was still significantly different from normal. We recognize,

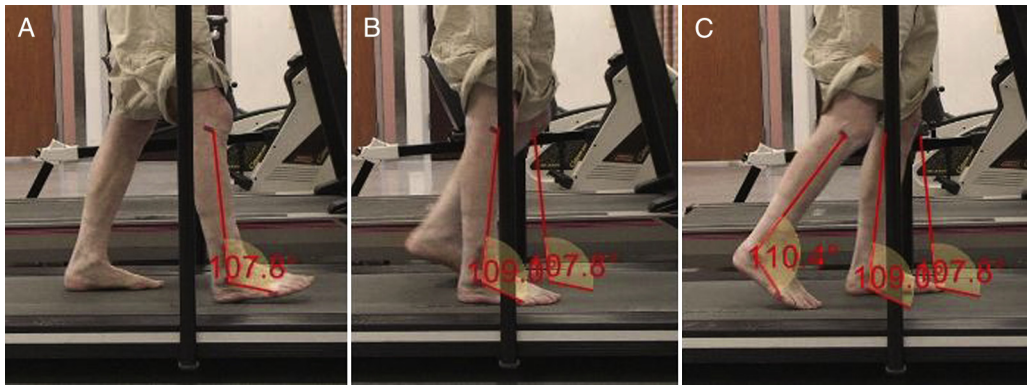

Fig. 2. (*A* to *C*) Progression from heel strike to toe off in an ankle arthrodesis patient walking barefoot; in this example, the patient's total motion measured 2.8°.