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The effects of heel-elevated total contact insole on rearfoot pressure reduction in heel injury patients who had neurosensory impairment after receiving reconstructive flap operations

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KEYWORDS

Total contact insole
Plantar pressure
Reconstructed heel

ABSTRACT

Objective: To evaluate the effects of a custom-molded heel-elevated total contact insole (TCI) on rearfoot pressure reduction and heel cushion for patients with heel-reconstruction.
Methods: Eleven patients with unilateral heel-reconstruction were recruited in this study. Maximal force and plantar pressures (peak pressure and pressure-time integral) at three different areas (heel, midfoot, and forefoot) were measured under 3 randomized conditions (shoe-only, flat insole, and heel-elevated TCI) after wearing a heel-elevated TCI for 3 months. Ulceration inspection and pain intensity were evaluated before and 3 months after wearing a heel-elevated TCI.
Results: Pain intensity was decreased and walking velocity was improved in all patients ($p<0.01$), and ulcerations were completely healed in all of the five patients who had heel ulcers 3 months after wearing heel-elevated TCIs. Compared to shoe-only condition, the heel-elevated TCI was effectively reduced maximal force and plantar pressures in heel area ($p<0.01$) while part of the body weight was shifted from heel to midfoot and forefoot. Plantar pressures in heel area were more effectively reduced in the heel-elevated TCI than in the flat insole ($p<0.05$).
Conclusion: These findings suggested that heel-elevated TCI provided more effective heel pressure reduction and shock absorption, and resulted in improvement of clinical symptoms.

1. Introduction

With the improvement in heel reconstructive surgery, the flap survival on heel injury patients has been excellent [1–3]. However, the reconstructed heels from severe trauma still lack some important characters such as cushioning effect and shock absorption, particularly in heel area [1]. The force exerted on the heel area is ranging from 70% to 100 % of the body weight [4]. The heel pad is constituted by special structured fat cells and fibrous septa. The fibrous septa further divide the fat cells to chambers [5,6]. While the fat cells dissipate the stresses, the fibrous septa formed by elastic fibers absorb the shock by attenuating peaks of impact forces and dampening vibrations, and thus provide a subtle mechanism in pressure adaptation [5,6]. In heel injured patients, such cushioning effect provided by the heel pad is difficult to be completely restored by the reconstructive surgery. Therefore, abnormal pressure distribution occurs, and leads to pain and skin ulcer which prevent patients from symmetric gait and resulting in gait abnormalities [7,8]. Even after heel reconstruction, the abnormal gait was still observed [9]. Heel injury patients may encounter great challenges even after a successful reconstructive surgery.

The total contact insoles (TCIs) are custom-molded device which is designed according to not only the plantar geometry of the patient's feet but also the accommodative arch-support and heel-cup mechanism. Many satisfactory results from studies on application of TCIs in diabetic patients have been demonstrated, such as cushioning effect [10,11], pressure redistribution [12,13], and ulceration treatment on insensitive feet [14]. However, there was little documentation regarding the application of TCI in heel injury patients.

In our previous study, gait symmetry could be restored in these patients by using heel-elevated TCI [9]. In this study, we would like to further evaluate the clinical outcomes and pressure reduction pattern before and after applying heel-elevated TCI we designed. Therefore, this study was to investigate the effects of the heel-elevated TCIs on heel cushion and plantar pressure distribution, and also prove the benefit of heel-elevated TCI from clinical aspect.

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2. Methods

2.1. Participants

Eleven patients who received unilateral flap reconstruction surgeries after traumatic heel injuries with pain, gait abnormalities with or without ulceration were recruited for this study. All the patients were referred form the Department of Plastic and Reconstructive Surgery. They wore sports shoes with flat insole after surgery and five of them had ulceration for over one year. Patients with any other physical impairment that could affect their gait patterns were excluded. The average age was 39.4 years (ranged, 18–66 years). The causes of trauma were traffic accident (n=9) or machinery insult (n=2). The period after reconstructive surgery of these patients ranged from 5 months to 10 years. Normal reference plantar pressures data were recorded from 15 sex- and age-matched healthy subjects. This study was approved by the local medical ethics and the human clinical trial committees (Chang Gung Memorial Hospital), and all participants signed the informed consent.

2.2. Intervention by orthotic insole

Three insole conditions (shoe-only, flat insole, and heel-elevated TCI) using same type high quarter shoes were evaluated for each patient. The flat insole was made of Plastazote Poron material (durometer 30, shore A, polyethylene) as the contoured insole, with a 6.4 mm thickness (Fig. 1A). The heel-elevated TCIs were custom made over the plaster replica by the pedorthic technicians of our department. The patients' foot were first kept in subtalar neutral position, and molded with Foamart foot impression foam to make negative molds. Positive molds were then made by plaster of Paris from the negative molds. There were totally four layers of heel-elevated TCI. The TCI was then made with the contact layer consisting of Plastazote Poron, the middle layer with Plastazote, and the base with semiflexible material of microcell-pull and Plastazote no. 3 (material of insole supplied by Acor Orthopaedic, Ohio, USA). On the forefoot portion of the insole, a ridge was created at the sulcus of the toes in order to provide anti-shearing force which prevented the foot from shifting forward. The rear portion of the insole was elevated to 2.5-3 cm in height (Fig. 1B) [9].

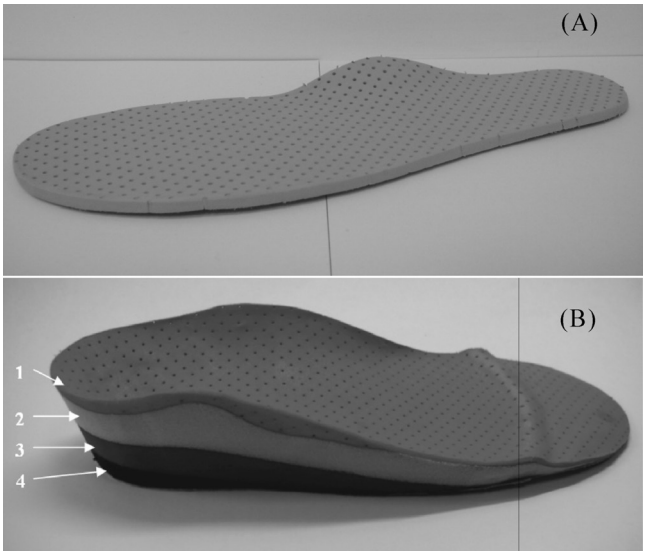

Fig. 1. (A) Conventional flat insole; (B) Heel-elevated total contact insole.

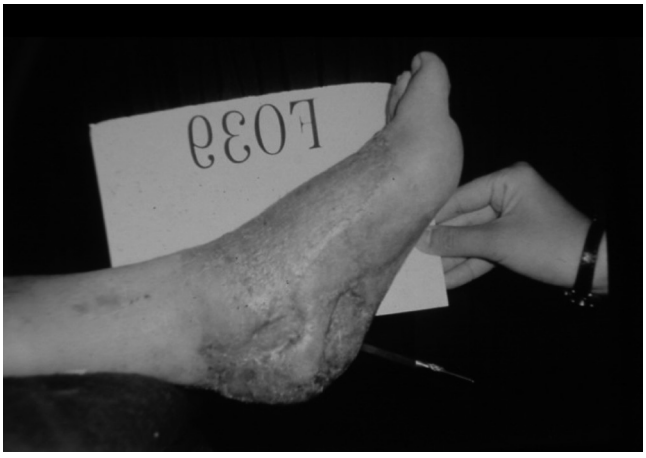

Fig. 2. Subjects with heel flap reconstruction receiving monofilament test.

2.3. Procedure

All patients received clinical evaluation for heel ulcer formation and pain grade before and after fitting with heel-elevated TCI for three months. Semmes-Weinstein monofilaments test for heel sensory perception evaluation was performed only before fitting with heel-elevated TCI. Plantar pressure measurements were applied at 3 month after the patient adapted to the prescribed insole. The healthy subjects only received plantar pressure measurements in shoe-only condition as normal reference.

2.3.1. Clinical Evaluation

Heel ulceration size was measured by using Wound Stick® Measuring System (USMS, Florida, USA) and recorded in cubic centimeters (length × width × depth). The pain during walking was graded by the 11-point numeric rating scale (NRS-11) [17], ranged from 0 to 10 ('no pain' to 'worst pain imaginable').

Semmes-Weinstein monofilaments (North Coast Medical, CA, USA) were used to evaluate the sensory perception over calcaneal bone of the heel, which were used for detecting the existence of minimum level of protective sensation (Fig. 2). Different sizes of Semmes-Weinstein monofilaments represented different weights when applied on the heel. The bigger the size number, the larger the force against the heel. The 5.07 filament exerted 10 g of force and the failure to detect its application indicated the loss of minimum level of protective sensation [18].

2.3.2. Plantar Pressure Measurements

Plantar pressure was measured by using Pedar in-shoe pressure measuring system (Novel GmbH, Munich, Germany). The Pedar in-shoe system is widely regarded as an accurate, reliable and valid measure of in-shoe pressure [19,20]. The Stride Analyzer (B & L Engineering; Tustin, California, USA) was used to measure walking velocity. Light sensitive triggers initiated and terminated data collection as the subject traversed the length of the walkway.

Prior to data acquisition, flexible pressure-measuring insole was placed between the plantar surface of the foot and the insole. After that, patients with heel-reconstruction were instructed to walk freely for about 5 minutes to reproduce their typical gait, and then they were required to walk on a 10 meter level walkway in the gait laboratory at comfortable speed. Three insoles conditions were randomly tested in repeated trials. In each walking trial, data of the middle five steps were collected. Data of three successful trials were accepted. Average data of these three trials were used for statistical analysis.