Clinical Biomechanics 27 (2012) 196–201

Contents lists available at SciVerse ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Dynamic impression insole in rheumatoid foot with metatarsal pain

Bao-Chi Chang [a,b,1], Jia-Yi Wang [c], Biing-Shiun Huang [a,b], Hsiao-Yi Lin [b,d,1], Winson C.C. Lee [e,*]

[a] Rehabilitation Center, Taipei Veterans General Hospital, Taiwan, R.O.C.
[b] National Yang-Ming University, School of Medicine, Taiwan, ROC
[c] Graduate Institute of Medical Sciences, College of Medicine, Taipei Medical University, Taipei, Taiwan, ROC
[d] Division of Allergy, Immunology and Rheumatology, Department of Medicine, Taipei Veterans General Hospital, Taiwan, ROC
[e] Department of Health Technology and Informatics, The Hong Kong Polytechnic University, Hong Kong

ARTICLE INFO

Article history:
Received 19 February 2011
Accepted 8 August 2011

Keywords:
Rheumatoid arthritis
Metatarsalgia
Pressure measurement
Insole

ABSTRACT

Background: Custom molded insoles with metatarsal supports are used to redistribute excessive loading under the metatarsal heads in patients with metatarsalgia. However, these pressure reductions are usually insufficient for the rheumatoid foot with painful deformed metatarsal heads. We developed an effective insole made by sequential foam padding under successive walking impression.
Methods: Seventeen consecutive rheumatoid arthritic outpatients with metatarsal pain participated in this repeated measures study of 7-mm flat Ethylene Vinyl Acetate, custom molded and dynamic impression insoles. Peak plantar pressure, pressure-time integral, contact area and mean force were measured by a Pedar-X mobile system. Pain levels were assessed using a Visual Analog Scale (0–10).
Findings: Compared to the Ethylene Vinyl Acetate control, the metatarsal head peak pressure and pressure–time integral were significantly reduced in dynamic impression insoles by 46.3% ($P<0.001$) and 48.9% ($P<0.001$), respectively. Compared to the custom molded insole, the dynamic impression insole significantly reduced 18.3% of peak pressure ($P<0.001$) and 20.1% of pressure–time integral ($P<0.001$) by increasing 8.1% of contact area ($P=0.005$) at the metatarsal heads, but there were no significant differences in all variables at the heel. After using the dynamic impression insole, the mean pain score was significantly reduced from 7.6 to 1.1 ($P<0.001$), and six participants experienced total pain-relief in walking.
Interpretation: Dynamic impression insoles effectively relieve metatarsal pain because of a larger weight-bearing area. Forefoot shape during walking should be taken into consideration in orthotic designs for maximum pressure reduction. Consequently, we recommend using materials with memory properties to dynamically accommodate painful metatarsal heads.

1. Introduction

The prevalence of rheumatoid arthritis (RA) is approximately 0.8%, ranging from 0.3% to 2.1% of the population (Fauci et al., 2008). Involvement of metatarsophalangeal joints has been reported to be as high as 80% to 92% during the course of the disease (Speigel and Spiegel, 1982; Vainio, 1975). The most common forefoot deformities are hallux valgus and claw/hammer toes with dorsal subluxation or dislocation of the lesser metatarsophalangeal joints (Jeng and Campbell, 2008). Toe deformities may cause prominence of the metatarsal heads (MTH) and distal displacement of fat-pad cushion beneath the MTH, resulting in the metatarsal pain in RA patients (Sumpio, 2000). Foot pain frequently leads to limitation of activities of daily life and deterioration of life quality (Kerry et al., 1994; van der Leeden et al., 2006).

Plantar pressure analyses have been widely applied to biomechanical research and orthotic evaluation in rheumatoid foot (Hodge et al., 1999; Otter et al., 2004). In RA with forefoot pain, metatarsophalangeal subluxation and erosion have been related to increased pressure under the forefoot (van der Leeden et al., 2006). Even though RA patients with metatarsal pain may not have particularly high peak pressure, a decrease in plantar pressure still reduces subjective ratings of pain in their walking (Hodge et al., 1999). Foot orthoses have been commonly used in clinical practice to reduce plantar pressure and subsequent pain in management of rheumatoid foot (Clark et al., 2006). The main strategies are to shift the excessive MTH forces by custom insoles with a metatarsal dome or a metatarsal bar placed proximal to MTH (Chalmers et al., 2000; Hodge et al., 1999; Jackson et al., 2004; Postema et al., 1998). Nevertheless, both types of metatarsal pads need to be appropriately positioned to achieve their effectiveness (Clark et al., 2006). Previous studies of RA patients with metatarsalgia (Hodge et al., 1999; Jackson et al., 2004) reported that

* Corresponding author.
E-mail address: htwinson@inet.polyu.edu.hk (W.C.C. Lee).
[1] Equal contributions.

0268-0033/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.clinbiomech.2011.08.005

Table 1
Demographic characteristics of subjects (n = 17).

Characteristics	Mean (SD)	Range
Age (years)	58.6 (10.1)	42–74
Body weight (Kg)	54.6 (9.9)	35–73
Body height (cm)	155.6 (6.7)	143–168
Body mass (Kg/m^2)	22.5 (3.6)	14.6–28.9
Disease duration (years)	16.3 (7.1)	6–32

the metatarsal padding provides 11.3% to 21.8% peak pressure reduction at the MTH. However, the force redistribution with the use of metatarsal support may cause a discomfort in the area proximal to MTH, affecting patient acceptance (Clark et al., 2006). Therefore, the therapeutic efficacies of custom molded insoles with a metatarsal support vary widely with their designs and materials for the rheumatoid foot with metatarsalgia (Conrad et al., 1996; MacSween et al., 1999; Novak et al., 2009).

A Plastazote foam is generally used in neuropathic foot because of the excellent self-molding properties and therapeutic effectiveness, but it has a very short life due to high compressibility (Bertram and Hsu, 1997). The Plastazote combined with less compressible foam Aliplast has been reported to relatively increase its longevity, but it still limits the effective use within a few months (Bertram and Hsu, 1997). Furthermore, an insufficient toe-box space of shoes would have restricted the initial thickness for sufficient pressure reduction. We designed a simple and effective method that a dynamic impression insole was made by sequential padding of foams with different compressibility under successive dynamic impression in daily walking. Very few studies have provided the plantar pressure analysis in the accommodative insole for the RA subjects with metatarsalgia. The purposes of this study were to investigate the biomechanics of dynamic impression insole in plantar pressure reduction, as well as to compare with custom molded insole among seventeen RA adults with metatarsal pain.

2. Methods

2.1. Participants

Nineteen consecutive RA patients with metatarsal pain, who were diagnosed by rheumatologists according to American College of Rheumatology criteria (Arnett et al., 1988) were recruited from the podiatry outpatient clinic of Taipei Veteran General Hospital. Seventeen participants (15 females and 2 males, 16 bilateral feet and 1 unilateral foot involvements) completed this study without interruption of using dynamic impression insoles. One of the dropouts was due to an insufficient toe-box space for the severely deformed forefoot with the Plastazote in walking, and the other was due to difficulty following the schedules required by this study. The participants were active in walking without any aids. There were no flexible flat feet in all participants. The demographic characteristics of subjects are given in Table 1. The locations (% morbidity) of metatarsal pain were the first MTH (8.8%), the second MTH (76.5%), the third MTH (70.6%), the fourth MTH (20.6%), and the fifth MTH (2.9%). The metatarsal pain was complicated with toe deformities including hallux valgus (76.5%) and claw/hammer toes (58.8%). All subjects were instructed to wear extra-width and extra-depth shoes that could accommodate deformed forefoot and minimal 10-mm thick insole. This study was approved by the Ethics Committee of the Taipei Veterans General Hospital, and informed consent was obtained from all participants.

2.2. Dynamic impression insole

The procedures of fabricating the dynamic impression insole were divided into four steps in four visits to the podiatry clinic.

1) A 9-mm thick Plastazote (15 Shore A hardness, Schein orthopädie service KG. Remscheid, Germany) was inserted into wide extra-depth shoes in each RA participant. The Plastazote in the MTH region would be compressed more than one half of the original

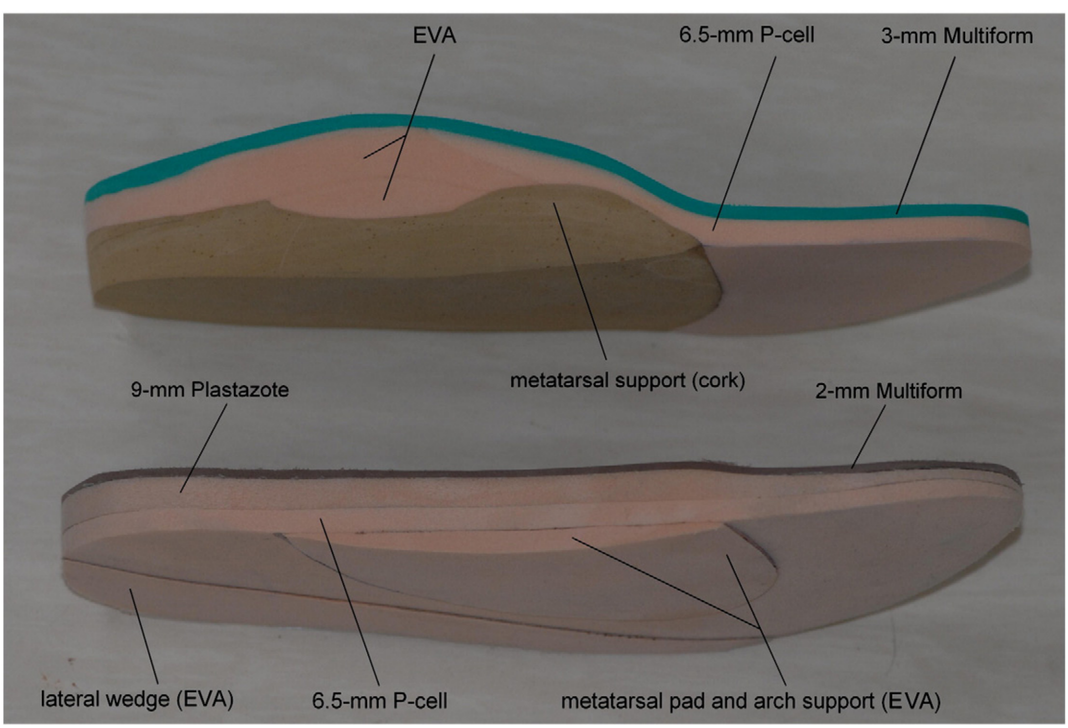

Fig. 1. In the custom molded insole (upper), the bottom layer is the cork with a metatarsal support 5-mm proximal to MTH, and the middle layer is incorporated with a P-cell in forefoot region. The dynamic impression insole (lower) has a more flattened arch contour than the custom molded insole.