

Universal Conceptual Design Solution for Built-in Orthopaedic Rocker-Bar Device

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Abstract. Gout is an acute inflammatory joint disorder (Arthritis) caused by deposition of monosodium urate monohydrate crystals around joints, tendons, and other tissues. According to data from the Survey [1] of Taiwanese Epidemiology in 1999, residents have a 0.4% chance of developing gout disease with a rise of about 7.5% every year in Taiwan. In the UK, Gout affects about 1 in 200 adults. Men are more commonly affected than women and first attack of gout typically develops in middle age and there is a family history of gout in about 1 in 5 cases. In spite of being unacceptable in style, rocker-bar is always an effective treatment, this research is, therefore, focused on a universal design concept and fitting assessment in relation to the design of orthopaedic rocker-bar with new universal hidden built-in construction, which provides the best way to improve the appearance, comfort and strength, it is suitable not only for gout disorders, but also for those patients with standing, walking or shoe-fitting corrective requirements.

Keywords: Universal concept, Orthopaedics, Rocker-bar.

1 Introduction

Gout disorder has been discovered for a long time, but nowadays, it still exists too many known factors in its full field of symptom [2]. Gout is a heterogeneous collection of genetic and acquired diseases characterized by elevated levels of uric acid in the blood (hyper-uricemia) and recurrent arthritic attacks. These arthritic attacks result from the deposition of uric acid crystals in connective tissue and joints. Systemic manifestations consist of recurrent arthritic attacks, chronic tophaceous arthritis, tophi in soft tissue, and gouty nephropathy.

Based on recent Taiwanese medical statistical data, it shows that almost 99% of gout patients are male. It also presents that nearly 73% of these serious gout patients is at their ages between 41 and 60 in the rate of gender. This serious problem of gout disorder needs to be solved immediately.

This research focuses on the design and development of orthopaedic rocker-bar. Rocker-bar is a medical device, which is also an out-sole mechanical construction with a firm supportive sole, always used in the treatment of various foot conditions such as arthritis or inflammation of the foot bones and its associated joints, ligaments, muscles and tendons. In spite of being unacceptable in appearance and style, the

rocker-bar shoe is always an effective treatment used in various foot problems at bones and joints.

As we can imagine, the appearance of fashion shoe style is the first consideration when buying or wearing shoes. Without any alternative, most of the patients with foot disorders have to wear their shoes with orthopaedic assistive devices to prevent themselves from foot pains and post-injury.

In the case of the patient with gout foot disorder, it is obviously that the main purpose of a orthopaedic rocker-bar is to give a shoe-sole its rigid and fixed surface, and also provide a fitted toe-spring to perform the foot of its expected gait. However, it is impossible for the rocker-bar to have an exquisite shape as normal high street shoe does. This research is, therefore, aimed at concepts both in universal design and fitting assessment in relation to the design and development of orthopaedic rocker-bar construction and its footwear.

2 Related Work

SATRA Footwear Technology Centre has been doing research in shoe, last and foot assessment for several years. A number of experiments and reports have been published recently. However, under the conditions of their conservative and confidential principles, it is quite difficult to get the information, which is related to research work in this field.

Many groups have worked on the surface shaping of orthopaedic foot and last (Tuckman et al, 1992) [3]. Lord and Foulston (1991) reported and concentrated on the technical evaluation of a commercial shoe CAD system, which is already widely used in the volume shoe trade, to access its ability for orthopaedic shoe upper design. It is the first time that the commercial CAD is encouraging for its potential use with orthopaedic shoes and lasts successfully [4]. Also an interactive computer graphics system for the design of molded and orthopaedic shoe lasts was introduced by McAllister et al in 1991 [5]. Other commercial developments are noted but no publications reported.

An international research project "SELECT (EUREKA, EU-661)", in the Department of Medical Engineering and Physics, King's College London, which is purposed into feasibility and definition of integrated measurement, data-bases and computer-aided design for orthopaedic footwear. Although that is the first time that brings together medical researchers, specialists and orthopaedic footwear companies between the United Kingdom and the Netherlands [6], it was still focused on the shoe-uppers and last shapes. From the point of view of shoe-sole technology, there is no information enough, which is related to research work in this field too.

3 Aims and Objectives

The aim of this study is to develop a universal orthopaedic rocker-bar device, which is used for making special orthopaedic footwear for fitting the foot of gout patients. This research will provide a special built-in construction with well-fixed rocker-bar factors, which are toe-spring angle and heel-strike cut.

The specific objectives of this trial are:

- 1) to develop, design and make a series of trial shoes/sandals with different angles of toe-spring and adjustable heel-strike bars;
- 2) to measure the length of the foot at the weight-on position, i.e. standing position;
- 3) to assess fit from different graded toe-spring and heel-strike;
- 4) to identify tolerable allowance at forepart and back-part of the foot during gait assessment;
- 5) to provide recommendations for acceptable ranges of the toe-spring angle and heel-strike cut for new built-in orthopaedic rocker-bar design and manufacturing.

4 Trial Protocol

In this experiment, a number of techniques are required i.e. foot measurement, fit assessment skills and special trial shoes/sandals making with different ranged construction at their forepart and back-part of the bottom region. Seven different RBAs with their toe-springs ranged from 5mm to 35mm (within 5mm intervals) of the same men's notional size of 8G and five different HSCs ranged from 0mm to 20mm (within 5mm intervals) of heel-strike cut were developed according to British Standard Institution (BS-5943, 1980) [7]. Then these were trialed on a number of normal subjects of this notional shoe size. During experiment, the biomechanical studies, including fitting assessment, plantar pressure measurement and gait analysis, are also performed.

The stages in this trial can be identified as:

- 1) Orthopaedic rocker-bar trial shoes/sandals making (see figure 1).
 - a. Different ranged RBA (rocker-bar angle also called toe-spring angle) making, modification and checking.
 - b. Different ranged HSC (heel-strike cut) making, modification and checking.
- 2) Subjects selection and foot measurement.
- 3) Fitting trial (see figure 2)



Fig. 1. Orthopaedic rocker-bar trial shoes/sandals



Fig. 2. Fitting trial shoes/sandals

5 Foot Measurement System and Observer Tests

A foot measurement system was adopted based on the orthopaedic standard BS-5943 and Clarks (C&J Clarks International Ltd.) system commonly used in fitting trials. In order to assess operator consistency, a trial was conducted involving the experienced author and his assistant who would subsequently take the measures and has received formal training offered to those staff from Taiwan Footwear Research Institute, an international research centre of footwear technology in Taiwan. Intra-observer tests were conducted by the assistant, who took measurements on a single subject three times over the course of a day. Inter-observer tests were done by both the author and the assistant, who took measurements on the same subject without reference to each other and then compared the results.

Before the trial was assessed, the reference points of foot ball joint (i.e. the 1st and the 5th Metatarsal-head), instep joint (i.e. dorsal medial cuneiform-head), short heel (i.e. talo-navicular) joint and back-heel height (i.e. back-top of calcaneum bone) were all determined and marked on those subjects' feet in order to ensure the same location for the measurements.

6 Subjects Selection

Based on recent Taiwanese medical statistical data, it shows that almost 99% of gout patients are male. National Yunlin University of Science and Technology, Graduate School of Design provided 20 usual fitting trial volunteers subjects. Their feet were measured by methods similar to those used in the volume shoe manufacture and orthopaedic trade including length, girth (width), and height measurements of the feet. The volunteers are all known to represent a good average of a given size, in this case of size 8G.

7 Trial Shoes (sandals) Making

In this study, due to the gout patient's foot is always rigidus in the foot bone and joint regions and it causes seriously hurt while moving and walking even at the position of standing. Therefore, a hard mechanical construction to support its out-sole firmly is necessary in making this trial shoes/sandals. In order to evaluate the shoed factors (RBA and HSC) of satisfaction, all the designed prototypes of trial shoes are well assembled with various heights and angles at the out-sole region. In figure 3, the RBA factor was taken from the toe-end of the trial sandal to the tread-line (at the bottom of 1st metatarsal-head point) of the sole. The toe-springs and heel strike cuts of trial shoes both were measured upright from the floor surface with 5mm increments. Two different materials (i.e. wood for hardness and cork for softness) of heel top-lift were used at the back-part of those trial sandals for getting better understanding.

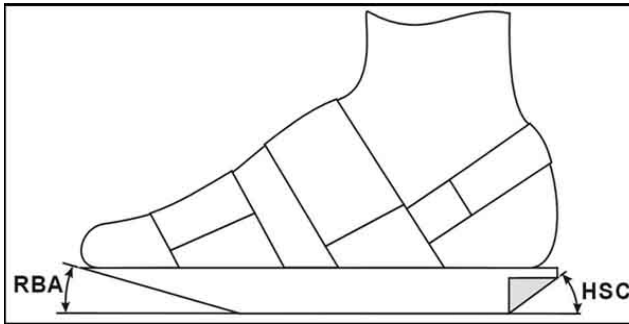


Fig. 3. Orthopaedic rocker-bar trial shoes/sandals making

8 Results and Discussions

The figure 4, 5 and 6 presented the detailed results of the suitability of fitting assessment on rocker-bar toe-spring (RBA) and heel-strike cut (HSC) factors. Figure 4 explains the relationship between the fitting assessments. It also indicates that the well-fit (acceptable) zone was found between 20mm and 30mm RBA (with the best-fit on 25mm RBA). Based on the best-fit of 25mm RBA, the HSC factor was assessed in both rigid (wood) and soft (cork) materials. The heel regions of those trial sandals were also designed to be replaceable (adjustable).

The figure 5 shows the suitability of HSC fitting assessment by using cork heel-lift; it indicates that the well-fit (acceptable) zone was found between 0mm and 15mm HSC with the best-fit on 5mm HSC. Figure 6 shows the suitability of HSC fitting assessment by using wooden heel-lift; it also indicates that the well-fit (acceptable) zone was found between 0mm and 15mm HSC with the best-fit on 5mm HSC. Although its well-fit (acceptable) zone is not so smooth as that in figure 5, the best-fit of 5mm HSC can be pointed out very clearly.

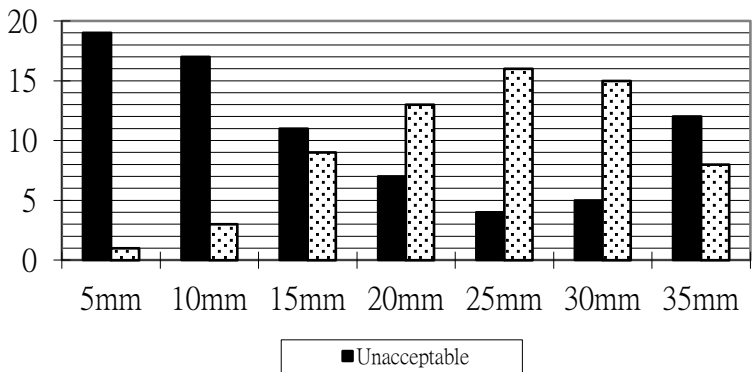


Fig. 4. The suitability of RBA fitting assessment

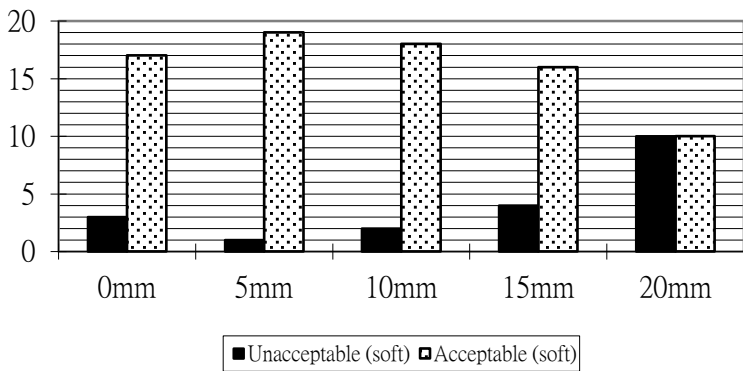


Fig. 5. The suitability of HSC fitting assessment by using cork heel-lift. (Based on the best-fit of 25mm RBA).

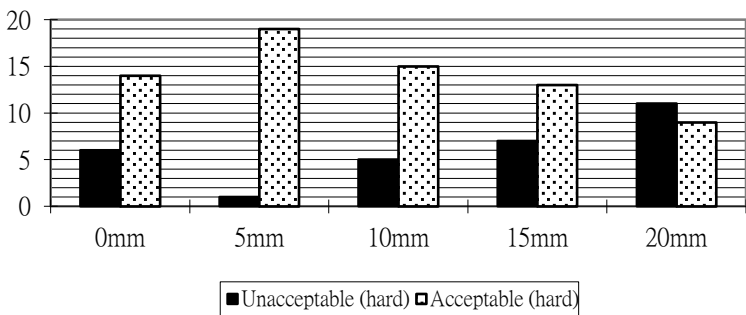


Fig. 6. The suitability of HSC fitting assessment by using wooden heel-lift. (Based on the best-fit of 25mm RBA).

Comparing with the 8mm of normal shoes in high street, to design and development the built-in constructed orthopaedic rocker-bar shoes for gout, the appropriate RBA is 25mm (ranged from 20mm to 30mm). It offers suitable toe-spring at forepart of shoe and makes the patient's problem foot feel comfort during walking, standing. This new built-in constructed rocker-bar with suitable RBA and HSC factors showed the best way to improve the appearance, comfort and strength of designing orthopaedic rocker-bar shoes for those gout patients with foot or joint disorders.

9 Conclusions

A special built-in orthopaedic rocker-bar construction was successfully developed for taking place of the old styled rocker-bar. It is the first time that the hidden rocker-bar construction has been developed. This new built-in constructed rocker-bar with suitable RBA (25mm) and HSC (5mm) factors showed the best way to improve the appearance, comfort and strength of designing orthopaedic rocker-bar shoes for those gout patients with foot or joint disorders. This universal orthopaedic technique can also be used to treat all the gout foot patients' not only physical order but also psychological rehabilitation.

In this study, all the designed prototypes of trial shoes are well assembled with various heights and angles at out-sole region. During experiment, the biomechanical studies, including fitting assessment, plantar pressure measurement and gait analysis, are also performed. For RBA factor, the acceptable (well-fit) range of toe-spring was found between 20mm and 30mm RBA with the best-fit toe-spring at 25mm RBA. For HSC factor, the well-fit (acceptable) zone was found between 0mm and 15mm HSC with the best-fit on 5mm HSC both in rigid and soft out-sole materials

References

1. Department of Health, Executive Yuan: in Annual Report of DOH, Taiwan (1999)
2. Emmerson, B.: The Management of Gout. *Clinical Biochemistry* 3(30), 253 (1997)
3. Tuckman, A.S., Werner, F.W., Fortino, M.D., Spadaro, J.A.: A Technique for Measuring Absolute Toe Pressures: Evaluation of Pressure-Sensitive Film Techniques. *Foot and Ankle* 13(14), 220–223 (1992)
4. Lord, M., Foulston, J.: Clinical Trial of A Computer Aided System for Orthopaedic Shoe Upper Design. *Prosthetics and Orthotics International* (15), 11–17 (1991)
5. McAllister, D.F., Carver, D., Devarajan, R., Harrison, L., Pietenpol, J.L., Yang, S.H.: An Interactive Computer Graphics System for the Design of Molded and Orthopaedic Shoe Lasts. *Journal of Rehabilitation Research and Development* 28(4), 39–46 (1991)
6. Chen, R.: An Investigation into Shoe Last Design in Relation to Foot Measurement and Shoe Fitting for Orthopaedic Footwear. Ph.D. thesis, King's College, University of London, UK (1993)
7. British Standard Institution: Methods for Measurement and Recording for Orthopaedic Footwear. BS-5943 (1980)