P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : https://tci-thaijo.org/index.php/SciTechAsia
Science & Technology Asia
Vol. 23 No.3 July - September 2018
Page: [28-34]
Original research article

A Direct Casting Method for the Fabrication of a Custom Scotchcast™ UCBL Foot Orthosis: A Case Study

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Received 18 January 2018; Received in revised form 18 May 2018
Accepted 18 June 2018; Available online 25 September 2018

ABSTRACT

The UCBL orthosis is a useful intervention for correction of foot pronation. An alternative fabrication method which utilized the 3M™ Scotchcast™ materials was evaluated in a single patient. A twenty-three-year-old patient with 10° of correctable calcaneus valgus was provided a UCBL made from 4mm polypropylene as well as a Scotchcast UCBL. Degree of valgus correction permitted by the Scotchcast was evaluated through goniometry by using the Rearfoot Angle (RFA) and tensile and compression force testing was performed to evaluate durability of both types of devices. The Scotchcast UCBL permitted acceptable valgus correction of the calcaneus. Tensile and compression testing revealed observable differences in hardness between the two orthosis. Use of Scotchcast as a direct cast to fabrication UCBL provided adequate correction for this patient. The Scotchcast UCBL is an inherently harder orthosis, yet it is less than half the price of a polypropylene UCBL. The unique use of this material has potential in resource limited environments as a method of reducing cost and fabrication time.

Keywords: UCBL; Rigid foot orthosis; Scotchcast; Foot pronation; Fabrication

1. Introduction

In Thailand the number of disabled persons rose to nearly 1.5 million persons according to the last census with foot problems being a prevalent clinical presentation in major Thai hospitals [1,2]. The late T.J Engen once described the orthosis as an 'analog of the ligaments', aiding musculoskeletal function and mitigating biomechanical deficits of an individual [3]. In a similar vein, the foot orthosis that is commonly prescribed to

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treat problems such as excessive foot pronation, can provide important functional improvements for the patient [4]. Typically, the pronated foot is as a result of a lowered medial longitudinal height which has a marked effect on the walking ability of the individual [5,6]. More specifically, the unique relationship between the rear foot and axial rotation of the tibia and the knee have been studied, evidencing the effect of calcaneus eversion and talus internal rotation on knee motion [7] and the ensuing reduced internal tibial rotation [8]. This effect of foot orthosis to alter angular kinematics up the chain [9], and reduce foot pronation [10] can improve arch alignment significantly [11]. In addition, electromyography activity while wearing a foot orthosis results in decreased lateral hamstring activity and increased activity in the tibialis anterior muscles throughout early stance phase running as compared to non-orthosis conditions [12]. These inherent benefits seen with foot orthoses have cemented the foot orthosis into modern orthotic practice.

The UCBL (University of California Biomechanics Laboratory Orthosis) was first developed in the Berkeley laboratory out of a need to provide corrective forces to the foot and maintain the calcaneus in a neutral position without the need for extensive custom shoe work [13]. Typically the device is fabricated using polypropylene, a thermoplastic polymer. The advantages of this material are its relatively lightweight, durability and user acceptance [3]. In order to fabricate the polypropylene UCBL a three-step process must occur; casting of the foot, creation of a positive foot model and finally fabrication of the UCBL through thermoforming of the material over the positive model. This process is commonplace as a standard of fabrication for a UCBL. Yet the fabrication time and amount of materials required to fabricate this device can at times be resource heavy, especially in clinics with a high volume of patients such as the foot clinic in our institution. Furthermore, often times patients reside in rural communities and must travel long distances to attend our foot clinic.

Therefore, a viable alternative which could mitigate the aforementioned issues of cost and fabrication time would be helpful within the context of Thailand. Previous researchers have used the 3M™ Scotchcast™ (3M Health Care, St. Paul, MN, USA) material for fabrication of prosthetic and orthotic devices [14,15]. We designed and evaluated a UCBL created with Scotchcast (Fig. 1.), in a single participant case study and sought out to explore foot correction ability along with durability testing of mechanical compression and tensile forces.

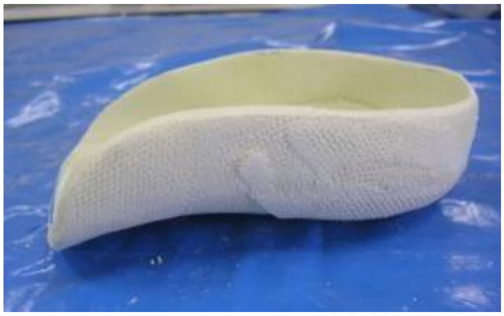

Fig. 1. Scotchcast UCBL.

2. Methods

Patient Assessment

One healthy able-bodied client, age 23 years with 10° of correctable calcaneus valgus, no prior foot problems nor any underlying disease or disabilities was casted for the UCBL. The client was first asked to lie down in a prone position on a casting table with the distal segments of both limbs being permitted to hang off the table. Four locations of the foot were palpated and marked using an indelible pencil; (1) the base of calcaneus, (2) Achilles tendon attachment; (3) the center of the Achilles tendon at the height of the medial malleoli; (4) the center of the posterior aspect of the calf. For measuring the Rearfoot Angle RFA, a goniometer was used while the client stood still in a double stance position. The arms of the goniometer were aligned with the corresponding marks (1) and (2) and the moving arm was aligned with the other corresponding marks (3) and (4).

Fabrication

The individual laid back in a prone position for casting [16], and the skin was first protected by wrapping the foot with plastic wrap with an inlayed cut strip placed along the dorsal aspect of the foot, as shown in Fig. 2. Bony prominences and joint spaces of the first and fifth metatarsal heads were marked. A four-layer Scotchcast (rigid cast size 4 inches) slab was created which matched the shape of the plantar surface of the foot with rounded edges to encompass the heel.

Fig. 2. Casting procedure for the Scotchcast UCBL.

Two slabs for creation of the mediolateral shell were also made by folding the slab in half to create a four-layer slab. Slab length was measured from the big toe to the little toe and encompassed the heel. The casting procedure began by first wetting the plantar surface slab, applying and contouring around the foot and then applying the mediolateral slab with a 2 cm overhang onto the plantar slab. A final circumferential wrap of Scotchcast was applied to insure proper binding throughout the cast. The subtalar joint was manipulated to neutral by the orthotist fixating the midtarsal joint into a locked position. This was performed by placing the thumb and index finger along the sustentaculum tali and medial tubercle of the talus to manipulate the foot into a subtalar neutral position, while dorsiflexion and adduction of the forefoot was performed using the opposite thumb distal to metatarsal heads. Upon the complete setting of the cast, a cutting tool was used to safely remove the cast from the participant foot. The cast was gripped along the proximal borders and lightly pulled downwards to remove the cast without any deformation. Finally, the desirable trimlines of the UCBL were delineated by the orthotist. The lateral trimline was lower than the medial trimline and was high enough to maintain adequate control of the foot. Smoothing was performed using a pair of scissors and a grinder. Weight and thickness of the participant - fit UCBL were also recorded. A total of three Scotchcast UCBLs were created from the single participant. Additionally, two 4mm polypropylene UCBL and three Scotchcast UCBLs were fabricated from a single positive mold of the client's foot. These orthoses were tested for compression and tensile properties. A single orthotist evaluated, casted and fabricated all devices.

Rearfoot Angle (RFA)

The client was initially evaluated during barefoot standing for the angle of calcaneus valgus using a goniometer by a single orthotist. The participant stood on a flat level surface wearing the Scotchcast UCBL and was evaluated using the RFA technique. This procedure occurred three times to insure accurate measurement and the same procedure was performed while the participant was fit with three Scotchcast UCBL.

Tensile and compression force testing

Compression testing was performed using a1000/500 kN motorized compression testing machine (ELE International, Bedfordshire, UK). The machine was calibrated by a trained co-investigator prior to all measurements. Both the polypropylene and Scotchcast UCBL were placed in the load frame of the machine in a manner which permitted the two compression platens to contact the widest width of the UCBL (Fig. 3.).

Fig. 3. Image depicting compression testing of the Scotchcast UCBL.

The self-aligning upper platen permitted easily administered compression testing. A single force was applied to the devices in a ramping manner until device failure. Tensile testing was performed using a SATEC Mark III (Instron, Norwood, MA, USA). The machine was calibrated by a trained co-investigator prior to data collection. Two 10 d steel nails with a width of 3.75 mm were screwed into the middle section of the UCBL. These two nails served as anchor points for the tensile testing machine's pulling apparatus (Fig. 4). Each device was tested with a single maximum tensile force of 120 kgF applied in a ramping manner. This method was chosen as 120 kg is well over the maximum body mass of the typical patient seen in the foot orthoses clinic.

Fig. 4. Image depicting tensile testing of the Scotchcast and polypropylene UCBL.

3. Results

The participant exhibited initial calcaneal valgus of 10°. Overall, each Scotchcast UCBL was capable of reducing the degree of participant valgus. Two UCBLs reduced valgus to 3° and one UCBL reduced valgus to a neutral position (0°) (Fig. 5).

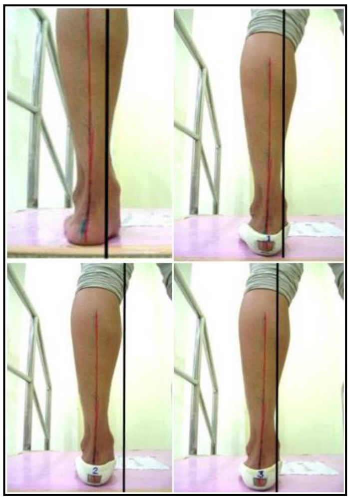

Fig. 5. Observed calcaneus valgus without orthosis and with three Scotchcast UCBL

Compression testing to the maximum load permitted by the machine resulted in the deformation of the polypropylene UCBL and failure of the Scotchcast UCBL. Tensile strength testing to 120 kgF elicited extension in both types of UCBL. Both UCBL types were extended in the machine until 5 cm was achieved. Maximal forces of 94 kgF were observed for the polypropylene UCBL and 112 kgF in Scotchcast UCBL (Fig. 6)

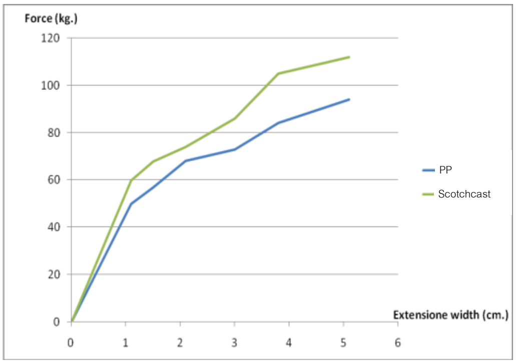

Fig. 6. Tensile extension testing of the Scotchcast and polypropylene (PP) UCBL

4. Discussion

Correction of participant calcaneus valgus in each of the Scotchcast UCBLs was acceptable with less than 3° difference in correction from neutral between all UCBLs. The Scotchcast UCBL foot orthosis was capable of manipulating the participant's foot into a better biomechanically sound position. The RFA of ≥ 5° valgus represents a pronated foot type, 4° valgus to 4° varus a neutral foot and ≥ 5° varus a supinated foot. The compression testing and tensile testing were an opportunity to display the hardness of each type of UCBL. The Scotchcast UCBL is a harder material and therefore was the first to fail in compression testing. In contrast, the polypropylene UCBL reached 5 cm of extension at a lower tensile force. These data represent two important findings about the Scotchcast material, the material is a durable alternative to polypropylene and is effective at correcting calcaneus valgus. Moreover, when costs comparisons are made between the two materials, the combined materials and fabrication costs of the Scotchcast UCBL is 1,200 Baht ($35 USD) and polypropylene UCBL is 2,500 Baht ($73.35 USD). The weight and thickness of the Scotchcast UCBL are slightly higher, 96 g to 66 g and .380 cm to .335 cm. This difference is not likely to have any consequences for the patient. This preliminary investigation is not without a number of limitations. The first being the small participant sample recruited. Future investigations should recruit a larger sample size with flexible pes planus. Furthermore, the addition of outcomes such as Foot Posture Index (FPI) or radiographic imaging, as well as patient compliance should be included in future evaluations. The number of practitioners performing this device fabrication should be increased to increase reliability of fabrication. However, as the Scotchcast is already a commonly used material it should be a relatively easy casting procedure. Protecting the patient's skin from the sometimes rough texture of the material is important. We recommend using an aliplast lining or sock to protect patient skin because of the possible rough surface of the Scotchcast. Our compression and tensile testing providing us with a basic and single outcome measure, future testing should consider performing ISO cyclic and static testing protocols as this is the current global standard for prosthetic and orthotic device testing [17]. Finally, the effects of walking participants in shoes and possibly providing a heel post to the UCBL were not explored but should be as this has been shown to have an effect on rear foot pronation [18]. Continued research exploring kinematic and kinetic data while wearing the orthosis should be explored as previous scholarship has observed differences in orthosis user GRF at the early phases of gait [19]. However, despite these limitations, our study provides preliminary evidence that the Scotchcast UCBL is a viable alternative to the polypropylene made UCBL.

5. Conclusion

Ultimately the orthotist and pedorthotist practicing in SE Asia requires devices that are affordable and effective, the UCBL made from Scotchcast has great potential at meeting the needs of practitioners. The availability of the material, decreased unit cost and its ability to facilitate valgus correction of calcaneus, make the Scotchcast UCBL a formidable foot orthosis.

Acknowledgements

The authors would like to thank Assoc.Prof. Dr. Nisarat Opartkiattikul, all essential staff and study participant for their assistance throughout the duration of the project.

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