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Reliable casting of pes cavus to minimise errors in custom orthosis fabrication

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ABSTRACT

The neutral suspension casting technique is the most commonly used method for obtaining a foot impression. Reliable plaster casting aims to minimise error in orthosis fabrication and improve treatment success. The purpose of our study was to investigate the reliability of neutral suspension plaster casting in people with a painful pes cavus foot deformity. Ten participants, mean age 44.1 (SD, 10.1) years, volunteered for the study. Two plaster casts from the left foot of each participant were scanned using a 3D non-contact laser to measure six parameters relevant to orthosis fabrication. Reliability of casting was excellent for all parameters. Intraclass correlation coefficients were high (ICC 3, 1 = 0.81 to 0.99), measurement error was low and there were no significant differences between the two plaster casts of the left foot (P<0.05). The neutral suspension casting technique is a reliable method to obtain an impression of the pes cavus foot prior to the fabrication of custom foot orthoses.

INTRODUCTION

Many different methods exist for obtaining an impression of the foot prior to the fabrication of custom moulded foot orthoses.1 The purpose of taking an impression is to accurately replicate the plantar surface of the patient’s foot, ie arch height, forefoot to rearfoot alignment and general foot morphology. While foam box, vacuum casting and laser scanning are occasionally used, neutral plaster casting previously described by Root et al is the most commonly used technique for obtaining a foot impression in Australia and New Zealand.1,2

Pes cavus is seen in approximately ten percent of the population, and foot pain in these patients is particularly challenging to treat with orthotic therapy due to the extent of the foot deformity.4,5 Therefore, the ability of the clinician to accurately and reliably cast a patient with pes cavus is paramount when that cast is used to manufacture custom foot orthoses. In the absence of reliable casting, a foot orthosis cannot be termed ‘custom’ and could introduce considerable error in fabrication and potential failure in treatment. There have been several studies comparing various impression techniques of the foot, however the reliability of the neutral plaster casting technique has only briefly been investigated in the literature.6-10 Chuter et al reported wide variability of frontal plane, forefoot-to-rearfoot alignment in ten casts taken by an experienced clinician.10 However, this study was limited in that the casts were taken using a ‘preferred method’ from a single subject only and reliability coefficients were not reported. In a larger study of 15 young asymptomatic participants, Laughton et al reported excellent reliability for forefoot to rearfoot alignment, rearfoot width and forefoot width (ICC2, 1 = 0.83 to 0.92), but only fair reliability for medial arch height (ICC2, 1 = 0.67). However, the generalisability of this study may be limited because only the prone casting technique (direct pressure) was examined: a technique less favoured than casting the patient in a supine position (suspension).2

In light of these limitations, the aim of our study was to investigate the reliability of the neutral suspension casting technique in people with a painful pes cavus foot deformity.

METHOD

Participants

Ten participants (nine women and one man), mean age 44.1 (SD, 10.1) years with a mean body mass index (BMI) of 27.3 (SD, 6.7) kg/m2, volunteered for this study and gave informed consent in accordance with the requirements of the University of Sydney Human Ethics Committee before testing commenced. All participants were experiencing musculoskeletal foot pain of a chronic nature [Foot Health Status Questionnaire pain score 48.6 (SD, 19.0) ], and were identified as having a pes cavus foot type [mean Foot Posture Index -3.2 (SD, 1.4)].11,12 All participants were part of a larger study investigating the effect of custom orthoses on foot pain and plantar pressure in pes cavus.

Procedure

The standardised neutral suspension casting technique was performed by a podiatrist with eight years’ clinical experience (JB). The participant was positioned long sitting with hips flexed and knees extended on an examination table. Each cast was taken in...
a subtalar neutral position while applying a dorsiflexory force to the ankle joint using a single strip of extra-fast plaster bandage (Specialist®, Johnson and Johnson). The midtarsal joint was fully locked by a force applied through the thumb placed in the plantar sulcus of the fourth and fifth digits to dorsiflex and abduct the forefoot.15 Two casts were taken from the left foot of each participant (Figure 1), to satisfy the independence requirement for statistical analysis.15 The casts were then allowed to dry according to the manufacturer’s specification and the top half of each cast was trimmed using a band-saw to leave an impression of the plantar surface of the foot. Using a 3D non-contact laser scanner (Virtual Orthotics, Australia), a scan was taken of the inside of the negative cast using approximately 10,000 x, y & z co-ordinates (dependent on foot size). The scanning data of the individual feet were exported to computer aided design-computer aided manufacture (CAD-CAM) software for data analysis (Virtual Orthotics, Australia). The primary advantage of the CAD-CAM system relate to speed and accuracy. According to manufacturer specifications, the 3D laser optical system scans a cast in 0.6 seconds to an accuracy of 0.5mm or to within 1/100th of a degree.

**Data analysis**

Using the CAD-CAM analysis software, six cast parameters were measured that were considered relevant to orthosis fabrication and for comparison to previous research (Figure 2). These included medial arch height (mm), lateral arch height (mm), forefoot to rearfoot alignment (degrees), rearfoot width (mm), forefoot width (mm) and cast length (mm). The medial and lateral arch heights were measured at 31% of foot length to approximate the talonavicular and calcaneocuboid joint line (midtarsal joint), measured in a previous report.16 The forefoot-to-rearfoot alignment was determined by measuring the frontal plane angle between the forefoot (first and fifth metatarsal heads) relative to the vertical bisection of the heel. The rearfoot width was measured at the widest location of the rearfoot in the first 31 per cent of foot length at 10mm above the supporting surface to avoid the curvature of the plantar surface of the foot. The forefoot width was measured at the bisection of the first and fifth metatarsophalangeal joints, again 10mm above the supporting surface. Cast length was measured between the posterior aspect of the heel and the longest digit.

**Statistical analysis**

In the statistical analysis package SPSS 12.0 (SPSS Inc, Chicago, USA), descriptive statistics were used to characterise the study sample. Reliability of the neutral suspension casting technique was determined using the intraclass correlation coefficient (ICC, 1) and 95% confidence intervals (CI).14 Paired t-tests were also performed to test for any systematic differences between casts, and the standard error of measurement (SEM) and 95% confidence intervals of the SEM were calculated to determine the absolute variability between casts.16 Benchmarks suggested by Fleiss were used to interpret ICC values (>0.75, excellent reliability; 0.40 to 0.75, fair to good reliability; and <0.40, poor reliability).17

**RESULTS**

Reliability of the neutral suspension casting technique was acceptable (Table 1). The ICCs were excellent for all cast parameters (ICC 3, 1 = 0.81 to 0.99). Rearfoot width and cast length were the most reliable casting parameters (ICC 3, 1 = 0.99) and forefoot to rearfoot alignment was the least reliable (ICC 3, 1 = 0.81). There were no statistical significant differences between cast one and two (P<0.05), and the measurement errors were small for all of the parameters, indicating that the plantar surface dimensions of the foot could be expected to vary little between subsequent casts of the same participant.

**DISCUSSION**

The six cast parameters were chosen because they are considered by the authors of this paper to have a large impact on the specifi-
cations of custom foot orthoses. The inability to reliably capture these parameters may lead to an uncomfortable and poor fitting orthosis, footwear fitting problems or possibly treatment failure.

**Medial and lateral arch height**

A reliable impression of the height of the medial and lateral longitudinal arches are two of the most important aspects of successful casting and significantly affect the fit and comfort of the orthosis, particularly in patients with pes cavus where arch height is excessive. The reliability of capturing the medial arch height when plaster casting healthy participants in a prone position has been reported as only fair in a previous study, however we found excellent reliability and small error in capturing medial and lateral arch height when casting pes cavus participants using the more common suspension technique. The reliable impression of arch height may be important if custom foot orthoses are to have an effect on providing mechanical control, redistributing plantar pressures, optimising muscle activity or giving proprioceptive feedback. One study recently found that foot orthoses fabricated from a semi-weightbearing impression using dental plaster offered greatest pressure reduction in six participants with diabetes mellitus, compared to full-weightbearing and non-weightbearing impressions. Further research is needed to understand the effect of different impression techniques on custom foot orthoses efficacy.

**Forefoot to rearfoot alignment**

Pes cavus commonly features a plantarflexed position of the first ray or valgus deformity of the forefoot. Therefore, reliable casting of the forefoot to rearfoot alignment in these patients is advantageous in an effort to balance the forefoot with a customised foot orthosis. In agreement with Laughton et al who also measured cast parameters with a laser scanner, we found excellent reliability between casts and little variation of this angle. In contrast, a study by Chuter et al reported wide variability and large error for forefoot to rearfoot alignment, suggesting errors may easily occur for this cast parameter. However, their method of cast evaluation (inclinometer and measuring calipers) may explain the wide variability reported, since the potential for human error associated with this manual procedure may be greater than laser scanning.

**Rearfoot and forefoot width**

Reliably capturing rearfoot and forefoot width in a cast may be an important factor for the fabrication of custom foot orthoses, with error possibly resulting in irritation and/or callousities at the heel and footwear fitting problems at the forefoot. Our method of neutral suspension casting was highly reliable in capturing rearfoot and forefoot width with little error between casts, a finding consistent with prone casting.

**Cast length**

Unintentional dorsiflexion or plantarflexion of the digits and pronation or supination of the foot during the casting procedure may impact negatively on the length of the overall cast, and subsequently on the length of the orthotic device. This is the first study to report the reliability of cast length. We found that an experienced clinician could very closely repeat overall cast length using the suspension casting technique in a group of participants with painful pes cavus.

**Limitations**

Our study was limited in that we recruited only ten participants, all with a pes cavus foot structure. A larger sample size with a variety of foot types would have allowed our results to be more generalised. However, pes cavus is rare, plaster bandage is expensive and neutral plaster casting is time consuming and fatigueing. Constructing a large sample is therefore difficult. Furthermore, we regarded pes cavus as a challenging foot type to cast because it is a multiplanar deformity featuring an excessively high medial longitudinal arch, varus calcanæus, plantarflexed first metatarsal, adducted forefoot and clawed digits. Therefore, we expect reliable casting of this sample would translate to reliable casting for other foot types. Nonetheless, further research investigating accurate foot positioning while casting a variety of foot types is warranted.

**CONCLUSION**

Based on the results of our study, the neutral suspension casting technique is a reliable method to obtain an impression of the pes cavus foot. While the neutral suspension casting technique is commonly used, further investigation of the efficacy of foot orthoses made from different impression techniques is an area worthy of future research.

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