Evaluation of a weightbearing neutral position casting device

Abstract

This study compared neutral position weightbearing casts of the foot using the Foot Alignment System (FAS) to traditional non-weightbearing casts. Using inexperienced undergraduate podiatry students the FAS was shown to have good repeatability and less variability. The arch profile of the FAS and nonweightbearing casts were different, but when a forefoot alignment curve was used with the FAS, the arch profiles were similar. The FAS system has a number of theoretical advantages over other weightbearing methods of modelling the foot compared to the traditional non-weightbearing casting.

Introduction

Foot orthoses are widely used to treat a range of lower limb pathologies. Outcome studies have shown that foot orthoses are successful in treating a large number of pathologies (Landorf & Keenan, 1998), but the mechanisms by which they achieve these outcomes is unclear (Payne & Chuter, 2001).

Foot orthoses are usually made from negative casts of the foot taken in a non-weightbearing position (McPoil et al, 1989; Losito, 1996; Root et al, 1971; Valmassy, 1979). There is no evidence as to whether the use of weightbearing or non-weightbearing casts are the most suitable for the manufacture of foot orthoses or related to patient outcomes. The assumed advantage of weightbearing casts are the ease of putting the foot in its defined subtalar joint neutral position, the midtarsal joint in its assumed maximally pronated position and the osseous segments in what is assumed to be their better functional alignment. The main disadvantage of a weightbearing cast is that this is the 'compensated' position of the foot, however the rearfoot can still be placed in its defined subtalar joint neutral position. The advantage of a weightbearing cast is that this is assumed to be more representative of the position that the clinician wants the foot to function in if it is placed in its defined subtalar joint neutral position. In a weightbearing position, expansion of the soft tissues around the heel are assumed to allow for a better fit of the final orthoses (this is accounted for by additional plaster modifications around the heel of the positive mould made from a non-weightbearing cast). The assumed major disadvantage of weightbearing casts is the difficulty in placing the forefoot in its assumed maximally pronated position and keeping the first ray in its assumed correct alignment. A

weightbearing position tends to dorsiflex the first ray and invert the forefoot about the rearfoot. This is assumed to be a functionally poor position for the foot, as the orthoses made of this cast would tend to prevent first ray plantarflexion. The prevention of first ray plantarflexion would inhibit first metatarsophalangeal dorsiflexion and establishment of the windlass mechanism (Roukis et al, 1996). There have been reported differences in the forefoot to rearfoot relationship of plaster casts of the foot taken in weightbearing and non-weightbearing positions (McPoil et al, 1989; Cox et al, 1999), with only the above theoretical constructs being used to suggest which is the more appropriate alignment.

An accurate model of the foot is widely assumed to be necessary for the manufacture of appropriate foot orthoses. We have previously reported (Chuter et al, 2001) that there is a wide variability in the forefoot to rearfoot relationships in the casts taken of the same foot by both experienced and inexperienced clinicians. As all these casts were taken non-weightbearing, it is not known if this variability can be reduced if the casts were taken weightbearing. The finding of the subtalar joint neutral position has been shown to be highly variable between clinicians (Pierrynowski et al, 1996). Despite this variability of non-weightbearing casting, foot orthoses made on the casts have been shown by outcome studies to be successful (Landorf and Keenan, 1998)

The Foot Alignment System[*] [1] (FAS) has recently been developed to take a cast of the foot in a weightbearing subtalar joint neutral position (fig one). The system is adjustable so that the subject can be placed in their angle and base of gait. The patient stands on a firm contoured foam footplate that is adjustable under the rearfoot by

[*] Patent Pending, Vertical Orthotic Pty Ltd, Sydney, Australia
[1] The authors have no fiduciary interest in the FAS

levers so that the subtalar joint can be placed and held in its defined neutral position. The patient stands relaxed without any muscular effort to hold the foot in the required position. An additional tool, the forefoot alignment curve, then allows for the anterior part of the footplate to be aligned for the desired forefoot to rearfoot relationship to be obtained and to prevent the first ray being dorsiflexed during the weightbearing casting process. Casting a patient with the FAS takes no longer than would a normal cast.

As no information is available on the repeatability and validity of the FAS, the aim of this preliminary project was to determine the variability and repeatability of casts taken of the same subject by different inexperienced clinicians using the FAS device and to compare casts taken of different subjects using the FAS device and a standard non-weightbearing cast by the same experienced clinician.

Methods

To evaluate the FAS device, three projects were undertaken. The first project investigated the variability of casting using inexperienced subjects. The second project compared neutral subtalar joint weightbearing FAS casts without the forefoot alignment curve with the traditional non-weightbearing casts. The third project compared weightbearing FAS casts with the forefoot alignment curve with the traditional non-weightbearing casts. Ethics approval was given by the Faculty of Health Sciences Human Ethics committee and informed consent was given by all participants prior to participation.

For the first project, using the instructions provided by the developer of the FAS, six inexperienced podiatry students in the second year of their course (4 male, 2 female, mean age 20.5±2.1) each took two casts of the right foot of the same subject on the same day. The subject was a 22 year old male with a severely pronated, but currently asymptomatic, foot. The negative casts were filled and the positive casts used for the evaluation. The casts were subsequently evaluated by methods previously described (Chuter et al, 2001). Two researchers examined each cast together to agree on a vertical posterior calcaneal bisection line. This was done by placing an EVA wedge under the medial or lateral forefoot until it was agreed that a bisection of the calcaneus was in a vertical position. A set square was then used to mark the bisection with ink. An inclinometer was used to measure the posterior bisection of the calcaneus as either inverted, everted or perpendicular when the cast was resting on a flat surface. The angle measured reflects the frontal plane forefoot to rearfoot relationship in the cast. The forefoot to rearfoot relationship of the casts was determined independently on two occasions by two experienced clinicians, with the mean value of the two being used for the analysis. Intraclass correlation coefficients (ICC's) were used to determine the reliability of the two clinicians to determine this. A Wilcoxon signed rank test was used to assess the difference in the forefoot to rearfoot relationship of the first cast and the second cast taken by each student.

For the second project, using instructions provided by the developer of the FAS, one experienced clinician (20 years of clinical practice) took casts of the right foot of nine subjects (undergraduate podiatry students) on the FAS without the use of the forefoot alignment curve. The subjects were five females and four males with a mean age of 22.6 (±4.3) years and had a range of foot types from mildly supinated to severely

pronated. All were symptomatic at the time of casting. A non-weightbearing neutral position cast of the foot was also taken of same foot of each subject using traditional methods (Root et al, 1971). The negative casts were filled and the positive casts used for the evaluation. The casts were subsequently evaluated by two experienced clinicians. To evaluate differences in arch morphology between the weightbearing FAS cast and the nonweightbearing cast, a mark was placed on the plantar surface of the heel area, 2 cm from the most posterior aspect of the cast on a line that bisected the centre of the heel. A second mark was then placed in the centre of the first metatarsal head. A steel ruler was then place on the two marks. The height of the arch, using the steel ruler as the base was measured with digital callipers at 25%, 50% and 75% of the distance from the heel mark to the first metatarsal head mark. The mean of the two clinicians was used for the analysis and the ICC was calculated to determine the reliability between the two clinicians. The differences in the arch morphology between the two casts were determined with the use of the Wilcoxon matched pairs test.

For the third part of the project, using instructions provided by the developer of the FAS, one experienced clinician took casts of the right foot of eleven subjects on the FAS with the use of the forefoot alignment curve to place the forefoot in its assumed maximally pronated position at the midtarsal joint while the subtalar joint was maintained in its defined subtalar joint neutral position. A non-weightbearing neutral position cast of the same foot was also taken of each subject using traditional methods (Root et al, 1971). The subjects were five females and six males with a mean age of 21.2 ($\pm$2.3) years and had a range of foot types from mildly supinated to severely pronated. All were currently asymptomatic. The negative casts were filled and the

positive casts used for the evaluation. The casts were evaluated the same as described above for the second part of the project with the same statistical tests used for the reliability of the clinicians evaluating the cast and differences between weightbearing and nonweightbearing.

Results

For the first project, the twelve casts taken by the six inexperienced students of the one subject, the mean forefoot to rearfoot relationship was 5.5° (±1.10) inverted, with a range of 3.7° to 7.5°. The ICC (2,1) intratester reliability for the first clinician evaluating the cast was 0.97 (95% CI 0.90-0.99) and for the second clinician it was 0.97 (95% CI 0.89-0.99). The ICC for intertester reliability was 0.88 (95% CI 0.72-0.96). The Wilcoxon signed rank test showed no differences in the forefoot to rearfoot relationship between the first and second cast taken by the inexperienced students (p=0.32).

For the second project, the nine casts taken in a non-weightbearing position, the mean (SD) height of the arch at 25% from the heel mark was 9.31mm (±2.96); at 50% it was 14.88mm (±3.43); and at 75% it was 6.59mm (±2.28). For casts taken of the same subject using the FAS without the forefoot alignment curve the mean (SD) height of the arch at 25% was 7.79mm (±1.95); at 50% it was 9.39mm (±2.61); and at 75% it was 2.61mm (±0.65) (fig two). Using the Wilcoxon matched pairs test, the height of the arch was lower at all three points using the weightbearing FAS with the significance (*p*) of the differences at 25% being 0.031; at 50% being 0.008; and at 75% it was 0.011 (table one). The ICC (2,1) for intertester reliability of the two

experienced clinician measuring the height of the arch at all three points was 0.85 (95% CI 0.77-0.95).

For the third project, the eleven casts taken of different subjects in a non-weightbearing position, the mean (SD) height of the arch at 25% was 9.86mm (±3.21); at 50% it was 13.46mm (±3.12); and at 75% it was 6.89mm (±2.43). For casts taken of the same subject using the FAS with the forefoot alignment curve the mean (SD) height of the arch at 25% was 8.49mm (±1.91); at 50% it was 12.3 mm (±2.97); and at 75% it was 5.32mm (±1.64) (fig three). Using the Wilcoxon matched pairs test, the height of the arch was not different between the FAS with the forefoot alignment curve and nonweightbearing casts at all three points, with the significance (*p*) of the differences at 25% being 0.042; at 50% being 0.183; and at 75% it was 0.24 (table one). The ICC (2,1) for intertester reliability of the two experienced clinicians measuring the height of the arch at all three points was 0.89 (95% CI 0.79-0.98).

Discussion

This preliminary study has evaluated the variability of neutral position weightbearing casting using the recently developed Foot Alignment System, as well as the differences between using this system and the traditional non-weightbearing neutral position cast of the foot. In order to evaluate the casts taken by the use of this system, there needs to be a high degree of reliability between the clinicians who are using the methods described to evaluate the casts. We used two clinicians to independently take measurements of the positive casts that were made from the negative casts. The reliability of the two clinicians doing these measurements was high (ICC's varied

from varied from 0.88 to 0.97), so the mean value obtained from these measurements was suitable for further analysis.

We have previously reported substantial variability between clinicians taking the traditional neutral position casts (Chuter et al, 2001) with the standard deviation of the forefoot to rearfoot relationship of 20 experienced clinicians taking one cast of the same foot being $\pm$3.3° and a range of 10° (from 7.3° everted to 3.7° inverted). The study reported here using inexperienced undergraduate Podiatry students and the FAS showed a standard deviation of $\pm$1.1° and a range of 3.8° (from 3.7° inverted to 7.5° inverted). Although both studies used a different single subject that all casts were taken on, the variability and consistency of taking a cast of the foot appears to be considerable more repeatable using the FAS when compared to the traditional non-weightbearing method, especially considering that we used inexperienced undergraduate students for the FAS and very experienced clinicians for the previous non-weightbearing cast study.

One of the major theoretical concerns with the use of a weightbearing position of the foot for casting is the potential for the first ray to be placed in an artificially dorsiflexed position, especially if the neutral position of the first ray is a plantarflexed position. The outcome of this could be that foot orthoses made on a cast taken like this is that the device will hold the first ray/metatarsal in an artificially dorsiflexed position. Plantarflexion of the first ray is needed for normal first metatarsophalangeal joint dorsiflexion (Roukis et al, 1996) and to enable establishment of the windlass mechanism (Aquino & Payne, 1999). Casts that are traditionally taken in a non-weightbearing position are usually further modified by the use of plaster additions in

the anterior aspect of the medial longitudinal arch to further facilitate plantarflexion of the first ray. The use of weightbearing casting or modelling systems such as the FAS, foam boxes and some computer aided devices increases the probability for the construction of foot orthoses that may inhibit this normal motion.

In this study we have shown that the height of the arch was lower at all three points that we measured when comparing the weightbearing FAS (without forefoot alignment curve) and the traditional cast. (table one). The lowering of the height of the arch was greater in the anterior part of the arch, which is consistent with the first ray being dorsiflexed with weightbearing casting. However, when we repeated the study and measurements using the forefoot alignment curve with the FAS (figure one) which is used to place the forefoot in an assumed postion of pronation about the midtarsal joint while the subtalar joint is maintained in its defined neutral position, we found no significant differences in the arch profile between the FAS casts and the traditional non-weightbearing casts (table one). The most notable change between the casts taken with the FAS with and without the use of the forefoot alignment curve was the change in the height of the anterior aspect of the arch, with the casts taken with the forefoot alignment curve being similar to the non-weightbearing cast. The assumption from this is that foot orthoses made from the FAS using the forefoot alignment curve may be better able to facilitate the normal first ray plantarflexion which other weightbearing systems (eg foam boxes and computer aided devices) may not be able to do without substantial modifications made to the positive model prior to manufacture of the device.

This preliminary study is somewhat limited with the relatively small sample sizes used, but the results are still of significance. The subjects used in the study were healthy undergraduate university students who were asymptomatic at the time of the casting. The foot types that they had varied from mildly supinated to severely pronated. The system is still to be evaluated on symptomatic subjects and on more feet at the extremes of foot types.

Other features of the FAS which were not evaluated in this study included the advantage of the system being adjustable so the subjects can stand in their natural angle and base of gait. Another advantage could be the need for less modifications needed to the positive cast prior to manufacture for reasons outlined above related to the position of the first ray. Casts taken in a weightbearing position will need less additions (if any) to the positive model to account for expansion of the fat pad under the heel that occurs during weightbearing. The amount the fat pad 'bulges' during weightbearing can be substantial and vary significantly from subject to subject (Fuller & Hogge, 1988). It is not possible to tell from a non-weightbearing cast, how much plaster to add to the positive model to allow for this expansion, thus a weightbearing cast would be an advantage compared to non-weightbearing cast. Also not evaluated in this study is the effect of muscle action on casting position. One of the assumed greatest flaws of nonweightbearing casting is the patient contracting muscles during the casting, which can alter osseous alignment. The most notable is the contraction of the anterior tibial muscle which would dorsiflex the first ray and invert the forefoot, potentially creating a cast that has a forefoot to rearfoot relationship in the cast that may not exist in the subject. A potential advantage of the FAS is to avoid this possibly common error in casting. The FAS maintains the foot in its defined subtalar joint

neutral position while the patient weightbears on a firm contoured foam by a system of levers. The forefoot is maintained in the appropriate alignment with the forefoot alignment curve, so it is less likely that the patient will contract muscles to alter alignment. Clinically, if the repeatability or less variability in taking casts is considered important, then the FAS offer an advantage over the traditional non-weightbearing casting methods. It is not known if this variability is of clinical significance, especially given the outcome studies showing the clinical success of a wide variety of foot orthoses, both casted and non-casted.

Conclusion

This preliminary study has shown that the Foot Alignment System (FAS) for neutral position weightbearing casting of the foot has less variability and more repeatability than the traditional non-weightbearing method for doing this. The disadvantages normally associated with weightbearing casting, such as an inappropriate dorsiflexion of the first ray, appear not to occur when the forefoot alignment curve is used with the FAS. This has a number of theoretical advantages in the manufacture of foot orthoses designed to facilitate function of the foot.

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Fig One – The forefoot alignment curve being adjusted on the Foot Alignment System.

Table one

Measurement of the mean (±SD) height (mm) of the arch of positive casts at 25%, 50% and 75% of the distance from the centre of the heel to the centre of the first metatarsal head.

Project 2:	**25% from heel**	**50% from heel**	**75% from heel**
Non-weightbearing cast (n=9)	9.31 (±2.96)	14.88 (±3.43)	6.59 (±2.28)
FAS without forefoot curve (n=9)	7.79 (±1.95)	9.39 (±9.39)	2.61 (±0.65)
p* for difference	0.031	0.008	0.011
Project 3:			
Non-weightbearing cast (n=11)	9.86 (±3.21)	13.46 (±3.12)	6.89 (±2.43)
FAS with forefoot curve (n=11)	8.49 (±1.91)	12.30 (±2.97)	5.32 (±1.64)
p* for difference	0.042	0.183	0.24

* Wilcoxon sign rank test

Figure two – Project two - Height of the arch at 25%, 50% and 75% of the distance from the centre of the heel to the first metatarsal head for the Foot Alignment system without the forefoot alignment curve (*clear*) compared to the traditional non-weight bearing cast (*shaded*)

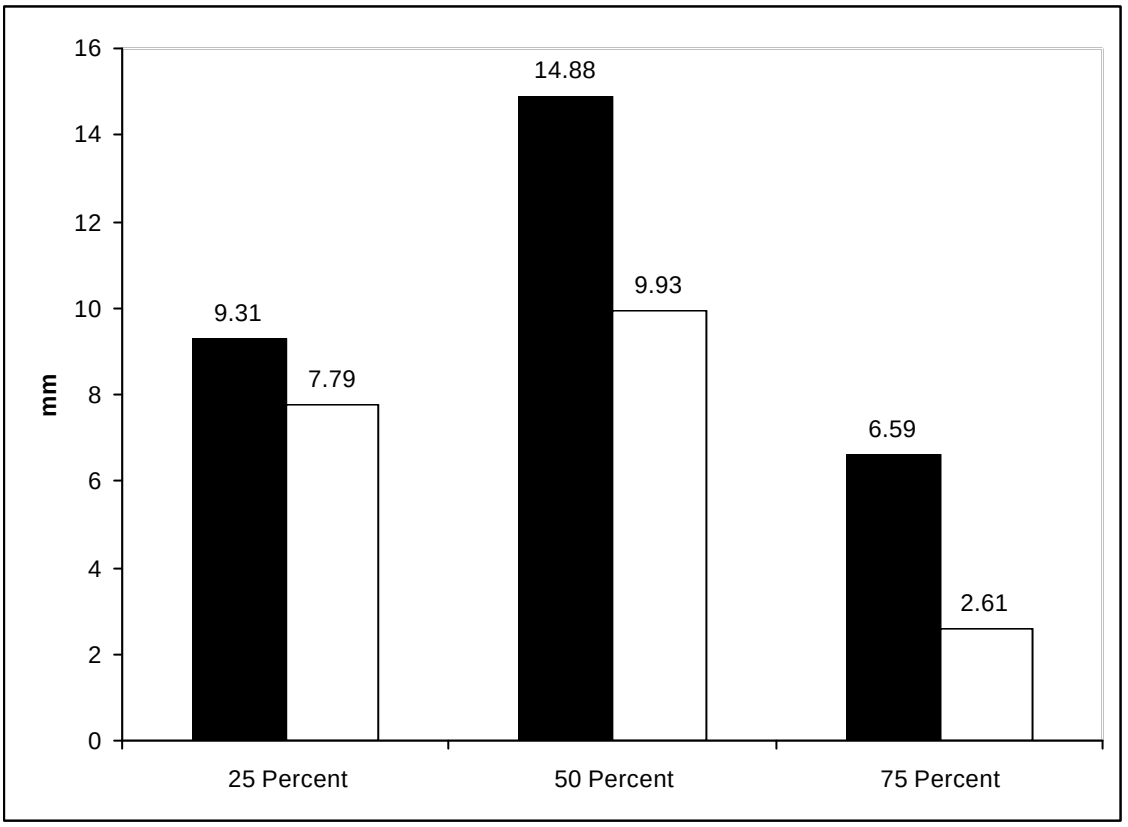

Fig three – Project 3 - Height of the arch at 25%, 50% and 75% of the distance from the centre of the heel to the first metatarsal head for the Foot Alignment system with the forefoot alignment curve (*clear*) compared to the traditional non-weight bearing cast (*shaded*)