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ORIGINAL ARTICLE

Controlling excessive pronation: a comparison of casted and non-casted orthoses

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SUMMARY Casted and plate orthoses were compared for their effectiveness in controlling excessive pronation and providing associated symptom relief. Two subject groups (n=30) matched for sex, age, sport involvement and injury type were prescribed either a casted or plate orthosis and were evaluated over a 3 month period. Pronation during treadmill running trials, with and without orthotic intervention, was determined by using two-dimentional video analysis. Symptom improvement was evaluated via questionnaire analysis. Two way analysis of variance demonstrated that both types of orthosis effectively reduced total pronation, maximum velocity of pronation, total calcaneal eversion and maximum velocity of calcaneal eversion ($P<0.05$), with no significant difference between orthotic types. Questionnaire analysis indicated that symptoms improved (to some extent) in 92% of all subjects after one month, with little difference between orthotic type. Considering the cost difference of the two types of orthotics (casted costing 2.5 times more), plate orthoses provide satisfactory treatment.

INTRODUCTION

Pronation is a normal and essential motion of the foot. It allows the foot to act as a mobile adapter over uneven ground, and helps attenuate the shock of ground contact.[1] Excessive or abnormal pronation occurs when the foot continues to pronate throughout gait (beyond midstance) at a period when supination should be occurring.[2] Excessive pronation, with associated excessive or prolonged internal tibial rotation, means that forces are applied to the lower limb in a potentially harmful fashion.[3]

During midstance the joints of the lower limb are held in their most stable alignment, when the foot is in its 'neutral' position.[4] This position occurs when the subtalar joint is neither pronated nor supinated. Moulded shoe insoles are designed to improve associated foot and leg mechanics by holding the foot in/around this neutral position.

Such orthoses may be manufactured specifically to individual requirements. Casts are taken of the patients' feet, the orthotic material is heat moulded to the casts and the degree of desired control (by way of rear/forefoot wedging) is manually machined into the orthosis. Such orthoses are termed 'casted' and, due to the nature of their design, are expensive and time-consuming to produce.

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Non-casted orthoses are based on a simple insole design, therefore, removing the need to cast the feet. An arch profile is preformed into the insole and the degree of desired control is achieved by adding, as required, preformed Ethyl Vinyl Acetate (EVA) wedges. These are termed 'plate' orthoses.

Many subjective studies (by way of questionnaire analysis) have been undertaken to show the success rate of casted vs non-casted orthoses in providing associated symptom relief.[5,6] Such studies have reported that the two types compare well. Objective studies have typically used video analysis to assess the effectiveness of orthoses in controlling excessive pronation. Such studies have typically compared rear-foot dynamics with and without the presence of an in-shoe orthosis; and there are many that report the effectiveness of casted orthoses in controlling pronation.[7–9] However, there has been very little objective research comparing pronation control between the two orthotic types. Therefore, the aim of this study was to compare the effectiveness of casted EVA orthotics and plate EVA orthotics in controlling subtalar joint pronation during running, and in providing patient satisfaction.

METHODS

Subjects

Sixty subjects, all of whom attended a routine podiatry clinic following referral from a consultant orthopaedic surgeon, their own GP or a physiotherapist, volunteered to participate in the study. All were recommended orthoses for the treatment of sports-related symptoms.

Selection criteria included a thorough biomechanical examination[10] during which lower limb joint range of motion was recorded. Those deemed to be excessive pronators, having no associated systemic conditions or previous surgical intervention were categorized as suitable for inclusion in the study. All were physically active with normal running gait apart from the excessive pronation.

Intervention

Subjects were split into two groups matched for age, sex, sport involvement and history of previous injury. One group was fitted with a pair of casted orthoses, the other was fitted with plate orthoses. For casted orthoses, a standard procedure[11] of casting the feet, obtaining positive casts, then moulding the orthotic material to the cast and machining to the desired shape/degree of control was followed. For the purpose of this study, high density EVA was used for the orthotic shell with the desired degree of wedging machined into the rear/forefoot. For plate orthotics, shoe sized templates of 1.5 mm EVA were used, with an arch profile preformed and filled with plastazote (to give extra arch strength). A preformed EVA wedge (5°) was added to the rearfoot and the plantar surface of the plate covered with 1.5 mm thickness poron (to provide a continuous base to the insole).

In the present study, EVA was used as the base material in both types of orthoses. It was decided that since the study was dealing solely with sports-related symptoms, EVA was the best option since it gave a degree of flexibility and shock absorption and did not require an extended familiarization period. EVA is also the material most readily available for the majority of clinical podiatrists as well as being the most economical choice.

Questionnaire

The improved questionnaire posed questions relating to presenting symptoms (i.e. injury type), type and extent of sport involvement, other treatment received, symptom relief and patient satisfaction following orthotic intervention. It was completed by all 60 subjects at one and 3 months.

Film analysis procedure

Thirty subjects (15 matched pairs) were chosen for film analysis. The group consisted of 14 males aged 17–42 (mean 31±9) and 16 females aged 16–50 (mean 26±9). The analysis took place when the orthoses were fitted approximately 2 weeks after initial assessment. Each subject wore their own running shoes. In accordance with the recommendations of Edington et al.[12] four markers (per leg) were placed on the subject: two to define the lower leg segment and two placed on the rear of the subject's running shoe, the calcaneal bisection (Fig. 1A).

A Panasonic F15 video camera was set on a tripod 10 m away from the rear of a Powerjog G100 treadmill. The camera was zoomed in to maximize the field of view of the four markers. Subjects were familiarized with treadmill running and after a short rest were asked to run under two experimental conditions: shoes only and shoes with orthoses. Following the guidelines of Edington et al.,[12] female subjects ran at 3.3–3.7 $m.s.^{-1}$ and male subjects at 3.6–4.0 $m.s.^{-1}$ Once a natural gait pattern was observed, subjects were filmed for approximately 20 footfalls, allowed to rest for 5 min, then filmed under the other test condition at the same speed. The video was played back (at 50 Hz) and, using the freeze frame facility, was transferred via a moving image capture board (resolution 640/512) to an Acorn Archimedes 440 computer. From five frames before heel contact to five frames after heel lift, each frame was manually digitized by locating each of the four lower limb markers. Data from three footfalls were then averaged, with right and left limbs treated separately. Averaged data were smoothed using a Butterworth digital filter with a cut off frequency of 5.5 Hz.

The resulting coordinate data were used to determine the following two angles: pronation angle (the angle between the line joining the two leg markers and the line joining the two shoe markers) and calcaneal angle (the angle between the line joining the two shoe markers and the horizontal) Fig. 1B.

The dependent variables (total pronation, maximum velocity of pronation, total calcaneal eversion, maximum velocity of calcaneal eversion and calcaneal touch down angle) were determined for each data set. Total pronation was taken as the degree of pronation from heel contact to the point of maximum pronation; similarly total calcaneal eversion was

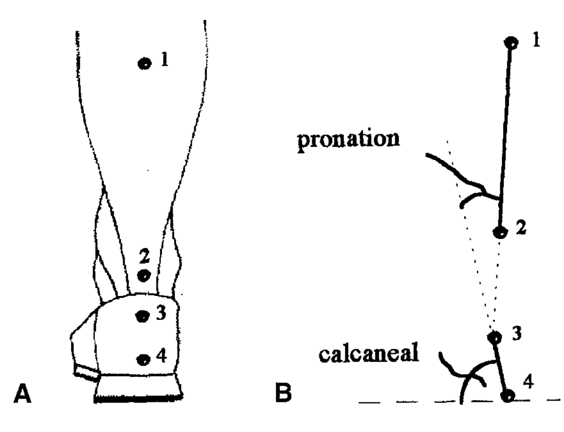

Fig. 1—(A) Marker placement (a line joining markers 1 and 2 defined the lower leg segment and a line joining markers 3 and 4 defined the foot segment). (B) How pronation and calcaneal angles were defined.

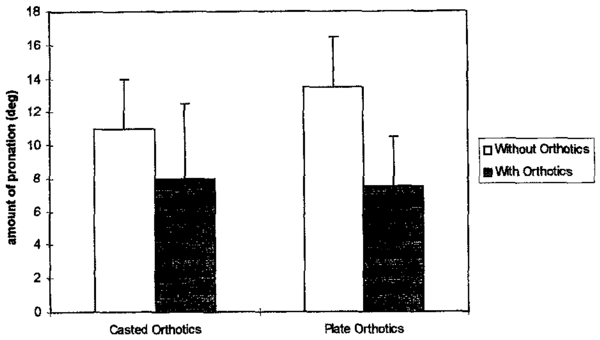

Fig. 2—Amount of pronation with and without (A) casted orthotics and (B) plate orthoses. (T) indicates standard deviation.

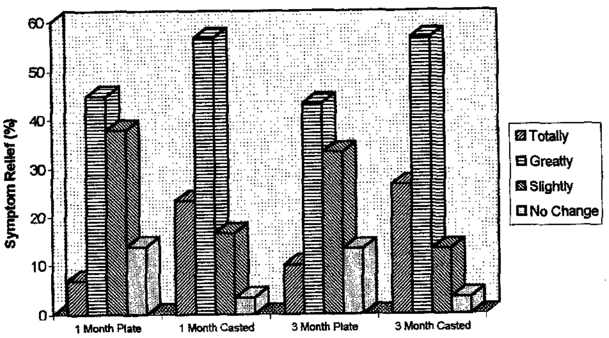

Fig. 3—Symptom relief after one and 3 months: (patient questionnaire response). After using orthoses for one month, 97% of subjects using casted and 87% of subjects using plates, showed some degree of improvement (symptom relief).

taken as the degree of eversion from heel contact to the point of maximum eversion. Calcaneal touch-down angle was the angle of the calcaneum to the horizontal at heel contact.

Data analysis

Digitizing repeatability was assessed by digitizing one footfall 10 times. After smoothing these data, the variability (residual mean square within subjects [Sw]) in determining maximum pronation angle and maximum pronation velocity was evaluated using analysis of variance (ANOVA). The 95% limits of agreement were then determined as ±2 Sw.[13] Statistical procedures for parametric data were followed; using a matched-pairs, repeated-measures design.

Two-way ANOVA was used to determine the effects of two independent variables; orthotic type and condition (i.e. with or without orthosis) on each of the five dependent variables and the interaction between the independent variables, on the given dependent (determined) variable. Post hoc Scheffe testing was used to assess any difference in effects between the two types of orthotics.

A critical alpha of $P<0.05$ was adopted to evaluate statistical significance. Analyses were performed with the CSS Statistica (Statsoft Ltd) software package.

Questionnaire results were analysed by tallying responses and comparing frequency percentages.

RESULTS

Statistical analysis (ANOVA) indicated that the repeatability in determining maximum pronation angle and maximum pronation velocity, within 95% limits of agreement, was ±2° and ± 1.04 rad^{-1} respectively. These low values indicate the film analysis procedure was a repeatable and thus reliable method of determining the measured parameters.

Film analysis results

The results showed that both types of orthosis had a significant ($P<0.05$) effect on four of the five measured variables (total pronation, maximum velocity of pronation, total calcaneal eversion and maximum velocity of calcaneal eversion) and no effect on calcaneal angle at heel contact.

The effects of orthotic intervention on the total amount of pronation is highlighted in Fig. 2. It also reflects the effect of orthotic intervention on the other four variables.

Two way ANOVA showed that both orthotic types significantly ($P<0.05$) reduced total pronation (from 11.0±3° to 8.0±3°: casted and from 13.0±5° to 7.5±3°: plate). Similarly, maximum velocity of pronation was significantly reduced (from 220°. sec^{-1}± 103 to 170° sec^{-1}±58: casted and from 250° sec^{-1} ± 78 to 110°.sec^{-1}±41: plate); as was total calcaneal eversion (from 9 ± 3° to 7 ± 3°: casted and from 11± 5° to 6 ± 3°; plate); and maximum velocity of calcaneal eversion (from 180°.sec^{-1} ± 61 to 140°.sec^{-1} ± 50: casted and from 200°.sec^{-1} ± 76 to 100°.sec^{-1} ± 41: plate). Post hoc Scheffe testing showed no significant difference between orthotic types, in terms of their ability to change rearfoot kinematics.

Questionnaire results

The subjects response in terms of symptom relief at one and 3 month are summarized in Figure 3.

After using the orthoses for one month 97% of subjects using casted and 87% of subjects using plates, showed some degree of improvement (symptom relief). Eighty percent of subjects using casted orthoses and 50% of subjects using plate orthotics, indicated that symptoms were greatly or totally relieved. At 3 months there was no notable change in these values, indicating that both orthotic types appeared to offer a rapid improvement in regard to symptom relief. In 84% of cases subjects reported improvement in symptoms was due to the use of orthoses.

Anterior knee pain was the most commonly reported symptom (43%), followed by plantar fasciitis (12%), shin splints (10%), Achilles tendinitis (9%) and lower back pain (8%). Running was the most popular sport participated in (50%) with all other sports involving some degree of running. Eighty-eight percent of subjects had experienced symptoms for at least 3 months, and 66% for at least 6 months.

DISCUSSION

The purpose of this study was to compare the effectiveness of casted EVA orthoses and plate EVA orthoses in controlling excessive rearfoot pronation during running. The results indicate that both types of orthosis reduced total pronation, maximum velocity of pronation, total calcaneal eversion and maximum velocity of calcaneal eversion ($P<0.05$), with no significant difference between orthotic types.

The reduction in total pronation when using orthoses is in agreement with other authors,[7,14] as are the results for reduced maximum velocity of pronation.[15] In this study, we determined both pronation angle (the angular displacement between the lower leg and the calcaneus in the frontal plane) and calcaneal eversion angle (the angle of the calcaneus to the horizontal in the frontal plane) (Fig. 1). Calcaneal eversion angle was determined since it is this angle that is most often observed in clinical practice. The results showed that there was little difference between the change in magnitude of these two angles, i.e. the determined change in eversion angle and angular velocity matched the magnitude of the change in pronation angle and angular velocity. The lack of difference suggests that the common clinical practice of observing eversion angles when evaluating rearfoot dynamics is an acceptable one.

A number of studies have suggested a link between excessive pronation and injuries to the lower limb.[16–18] It is thought that excessive (or prolonged) pronation results in increased stress on the structures of the lower leg and foot as they attempt to stabilize the foot during stance. With excessive pronation there is also associated increased or prolonged internal tibial rotation which also places increased stress on the lower leg, particularly the structures of the knee. Although the 'cause and effect' relationship between excessive pronation and overuse injuries is still not fully understood, excessive pronation has been shown to be a good predictor of various overuse injuries of runners.[19]

In this study, questionnaire analysis of injury type indicated that, of the 60 patients who attended the podiatric clinic (and took part in the study), anterior knee pain was the most commonly reported symptom (43%), followed by plantar fasciitis (17%) and shin splints (10%). This is in agreement with other studies.[20–22] After using orthoses for one month, 97% of subjects with casted and 87% of subjects with plates showed some degree of improvement. This very high success rate is in agreement with McCourt[5] who showed that 96% of subjects using casted and non-casted orthoses reported some improvement. Considering that the majority of subjects (66%) had their symptoms for longer than 6 months prior to orthotic intervention, the success rate for symptom control is very impressive. An earlier Health Authority survey[23] gave similarly high success rates; 84% reported improvement and 97% of these put this down to orthotic use. In the present study, 84% of subjects put improvement down to orthotic use, which again is in general agreement with other studies.[24]

The results presented here indicate that both plate and casted orthoses were effective in reducing excessive pronation and in providing associated symptom relief. In other words, if either is prescribed, each will be as effective. Given that many practising podiatrists work within tight financial limits, cost implications are also an important factor for consideration in orthotic prescription. If the orthosis which costs less to produce and takes less time to manufacture is as effective as the alternative, this must be the most economically viable option. When both time and material costs are considered, then the casted orthoses used in the present study were approximately 2.5 times more expensive to produce than the plate orthoses. From their survey of in-shoe orthoses provision, McCourt et al.[6] reported fabrication time for casted orthoses was 3 times that of non-casted. This suggests our cost estimation is in agreement with typical clinical practice. The life span of the two orthotic types was not investigated. Thus, although the cost of producing casted orthoses was estimated to be 2.5 times greater, if they last 3 times as long as plates, then it would not be 'false economy' to prescribe them. This point was also highlighted by McCourt et al.[6] and warrants further investigation.

The plate orthoses used in the present study were administered in an attempt to control excessive subtalar joint pronation. In general podiatric practice, many symptoms are treated which are not necessarily linked to excessive pronation (i.e. other pathologies may be linked to excessive supination, lack of pronation or abnormal pressure distribution, etc). And by their very design, prescription of plate orthoses may not be suitable in the treatment of such feet and the use of a casted orthosis may be the only viable alternative.

Two-dimensional (2-D) analysis techniques were used in the present study. Such an approach has a number of limitations when compared to three-dimensional (3-D) techniques. Segmental kinematics are obtained by filming from a posterior view in the frontal plane, and as such, angles measured are influenced by segment rotation about other axes. Parallax error is a recognized limitation[25-27] whereby the angle being measured rotates out of the plane of motion.

Cornwall and McPoil[25] presented a technique aimed at reducing 2-D rearfoot motion measurement variability. They found that measurements taken after heel lift were those most susceptible to error related to

3-D axial rotations (out of the plane motion). This was also highlighted by Areblad et al.[27] who stated that results of 2-D rearfoot angles correspond well with 3-D results during the period of stance when the camera is aligned with the long axis of the foot. This part of stance occurs up to heel lift, since at heel lift the foot starts to progressively adduct out of the frontal plane of motion. Thus in order to minimize the measurement errors relating to 2-D analysis, the present study only reported rearfoot pronation angle between heel contact and heel lift.

In a recent study reporting 3-D rearfoot kinematics, Mosely et al.[28] looked at the relationship between each of the individual 3-D movement components; namely, eversion/inversion, abduction/adduction and dorsi/plantar flexion. Their results challenge the conventional descriptions of the composite movements of pronation and supination. Thus, although this study found both orthotic types were effective in reducing relative calcaneal eversion and eversion velocity (measured in the frontal plane), we cannot assume that orthotic use had the same effect on the other components of pronation. Future research using 3-D techniques should look at how casted and plate orthoses affect each of the components of pronation/supination.

CONCLUSIONS

The present study has shown that both casted and non-casted orthoses effectively control excessive subtalar joint pronation during running to a similar degree. Questionnaire analysis revealed there was little difference between the two orthotic types in providing a degree of symptom relief after one and 3 months. As casted orthoses were estimated to cost 2.5 times the amount of plate, these results suggest that plate orthoses are the most economically viable choice.

The study was limited in that it only considered pathologies relating to excessive pronation. In general podiatry, plate orthoses would not be suitable for all patient groups. Future research is necessary to investigate the use of plate orthoses for the treatment of other foot types and to compare the life span of the different orthotic types.

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