Feb. 17, 1948. L. DIAMOND ET AL 2,436,164

ORTHOPEDIC APPLIANCE AND METHOD OF MAKING THE SAME

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Fig. 1

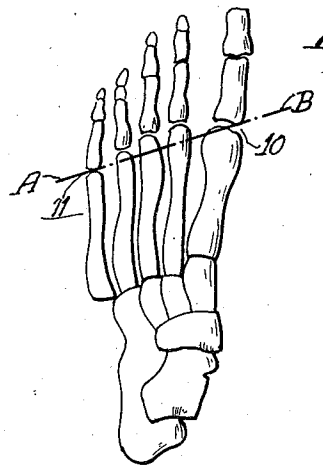


Fig. 2

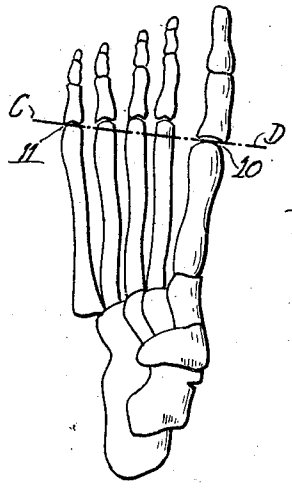
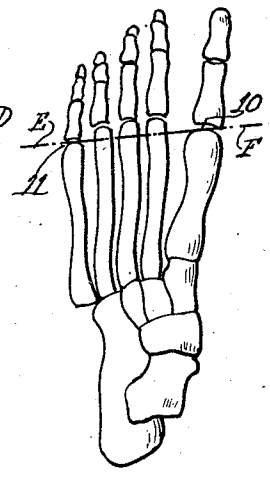


Fig. 3



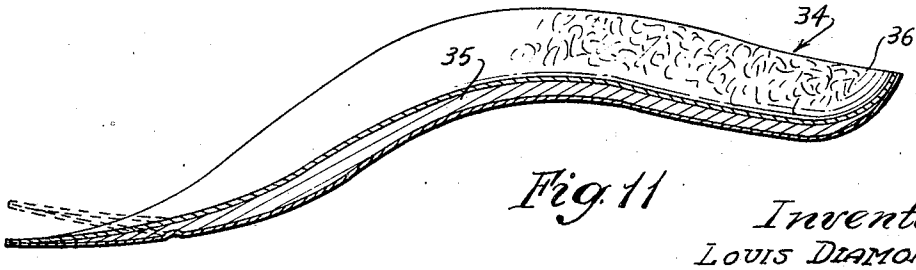


Fig. 11

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Fig. 4

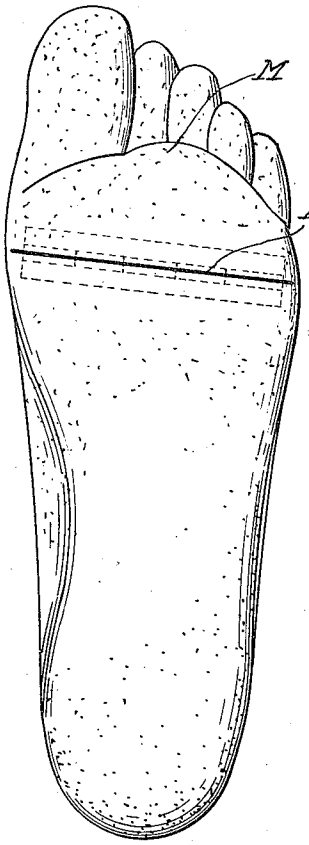


Fig. 5

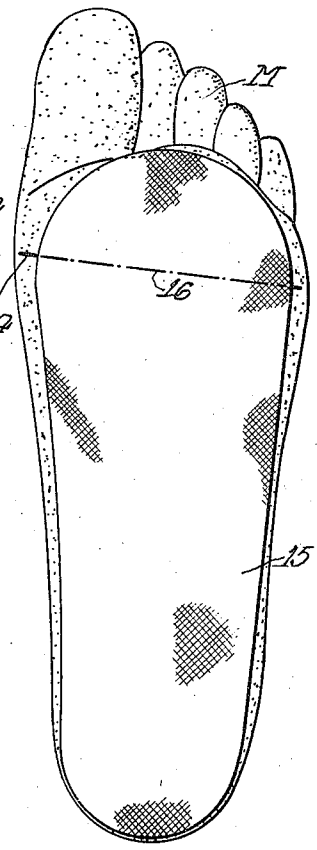


Fig. 6

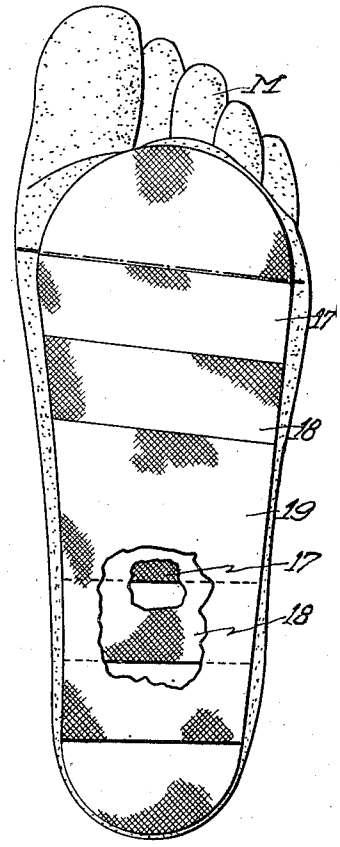
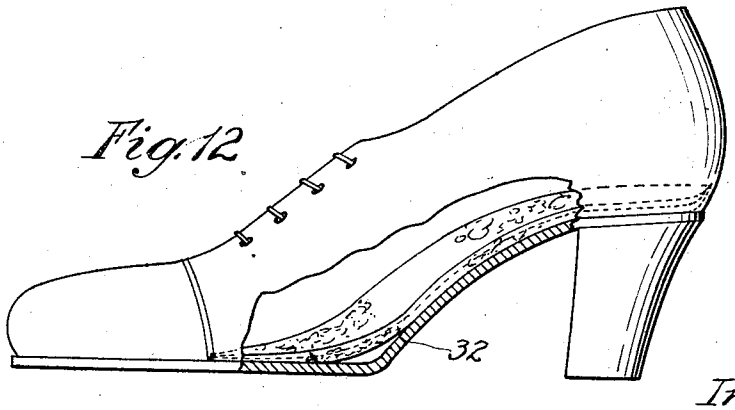


Fig. 12



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ORTHOPEDIC APPLIANCE AND METHOD OF MAKING THE SAME

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Fig. 7

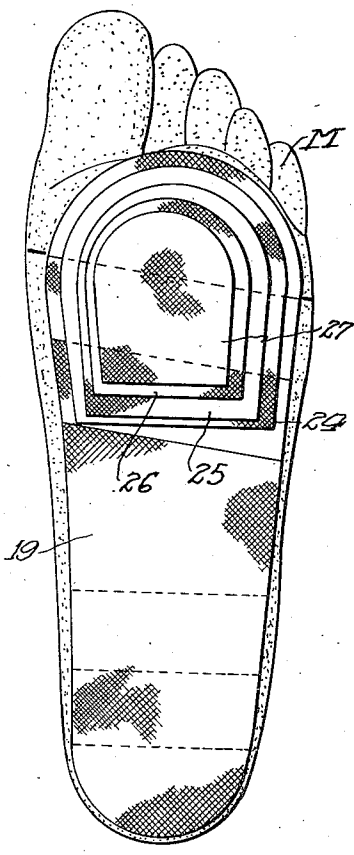


Fig. 8

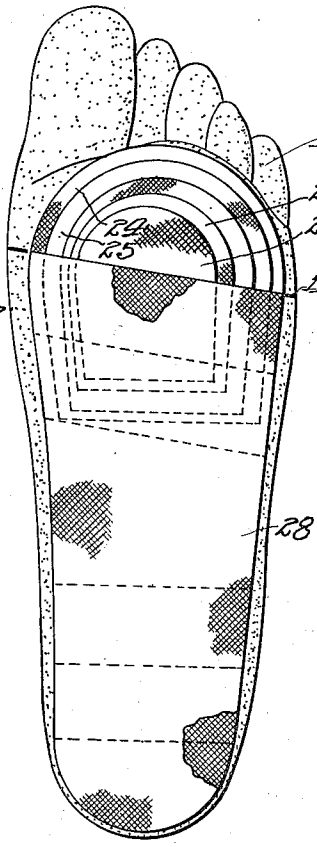
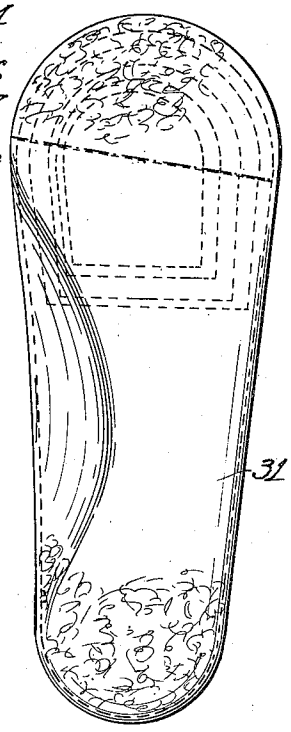


Fig. 9



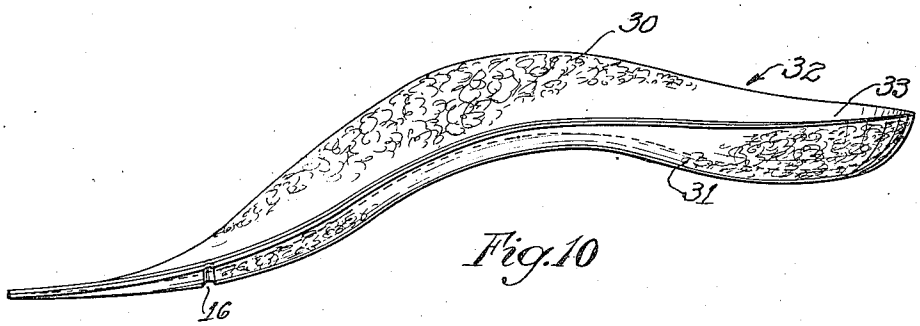


Fig. 10

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UNITED STATES PATENT OFFICE

2,436,164

ORTHOPEDIC APPLIANCE AND METHOD OF MAKING THE SAME

Louis Diamond and Maurice R. Udell,
Chicago, Ill.

Application December 24, 1943, Serial No. 515,510

3 Claims. (Cl. 128—80)

1

The invention relates to corrective foot appliances and especially to those adapted to restore normal functions and the method of making the same.

In pathological conditions of the foot such as pronation, abduction, eversion and weakness of the foot, a mere palliative device is objectionable because it lacks therapeutic value and only a device capable of restoring structural alignment and promoting the normal function of the foot both as to static and dynamic aspects has curative or corrective value.

In providing an orthepedic corrective device the foot structure and balance from a physiological must be considered, and fundamentally the position and function of the calcaneum (os calcis) and its relation to the skeletal segments of the foot is of prime importance.

Any rotation of the calcaneum will alter the relative angulation of the articulations and the general osseous alignment of the foot proper. This basic fact is frequently overlooked in view of the more manifest and complicated malalignments apparent upon examination and consequently more attention has been paid to rectifying symptoms instead of causes.

In the evolution development of men, the human foot began to acquire its present character and form; the calcaneum was compelled to assume changes in formation and even in its internal structure to help maintain alignment of the foot structure as a whole.

The heel became more massive in size because of environmental changes that were taking place and by reason of the upright posture in standing and walking, with less body supports by the hands and arms.

The foot of modern human beings gradually changed from a flexible flat structure to a firm, stable, arched organ, capable of balance, weight-bearing and locomotion, sustaining the entire body weight, and yet able to adapt itself to all environmental changes encountered in active daily life.

In the modern foot the subtalar joint forms an almost horizontal plane across, resulting in body weight being transferred to the outer segment of the foot as a weight-bearing structure.

The bones of the foot are so formed and the arrangement of the foot skeleton is so firmly associated by a ligamentous network, that the foot could maintain its form under weight-bearing to a large extent, without the aid of the muscles which provide resiliency and stabilization of the body structure, and not for carrying or supporting body-weight except in an auxiliary capacity such as maintaining the arch of the foot when the body is in action.

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In primitive feet the abduction of the great toe was an added factor in maintaining foot balance; therefore the skeletal structure maintained its alignment more readily. In the modern rigid human foot this assistance is not always possible. When a reversion to primitive type does manifest itself and the great toe starts to become abducted, shoes and stockings are apt to produce a hallux valgus. Where the footwear does not interfere with this reversion to type, we find that incomplete reversion of the structure as a whole, tends to produce the distortion of the first metatarsal phalangear articulation. To explain this we can say that while some of the structures of the foot are attempting to assume a changed position, others tend to remain normal in their relationship to the modern foot, and do not allow for this change. The unbalanced pull which they produce tends again to bring this toe into alignment with the foot structure, causing an angulation at the great toe joint. An adduction of the phalanges with an abduction of the first metatarsal shaft takes place. This in the acquired hallux valgus is encouraged by the rotation and angulation of the calcaneum which throws the foot out of balance. It is found in the treatment of early stages of hallux valgus, that the maintenance of the alignment of the calcaneum materially aids correction.

It is, therefore, of utmost importance that maintenance of the heel shall be the first consideration before a correction can be made in the general alignment of the foot proper.

The foot must be considered from the standpoint of weight-bearing and locomotion or propulsion (dynamics). The calcaneum, cuboid and astragalus are the bones involved in weight-bearing. The other bones of the foot enter into its locomotive, stabilizing and propulsive action. Weight first falls on the heel in walking and is immediately transmitted by momentum forward until the posterior leg muscles come into play. At this point the heel commences to elevate and the propulsive action of the forefoot begins. The leverage action is produced by the first metatarsal in cooperation with the second and third. The metatarsals (4 and 5) of the outer segment act as a guide in this forward movement. If the position of the outer segment is altered so that it cannot effectively guide the inner segment of the foot in this propulsive action, the

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first metatarsal is forced away from its fulcrum into a position of abduction, causing the foot to pronate. The burden of leverage must then be assumed by the second and third metatarsals, thus creating an unnatural weight-stress and fulcrum point at the head of the second metatarsal bone. X-ray examination in pronated feet with metatarsal contractions show this distinctly.

In providing normal stabilization for the foot it is necessary that the outer segment be maintained in alignment and the heel held from rotating outward and upward. If this outer structure is maintained the inner segment will be more easily strengthened and normal weight-bearing will result.

It is, therefore, repeated that it is due to the distortion of the calcaneum and the outer segment, that a collapse of the inner segment develops, with subsequently more pressure on the head of the second metatarsal.

It is reasonable to assume, that the inner segment which is superimposed upon the outer segment when it is collapsed, will produce a greater amount of weight-stress bearing, at the first, second, and third metatarsal heads.

The first metatarsal, being unable to act as a lever and stabilizing factor in the pronating and collapsing foot due to mechanical and physical restrictions, throws an added weight-bearing function on the second metatarsal head. This produces general shifting of weight-bearing on the inner segment of the foot with an enlarged and traumatized second metatarsal head.

In modern footwear where the shoe is a factor in maintaining the alignment of the foot, the flare and the general construction very often defeat the best intentions of orthopedic skill.

Shoes and their relation to foot health must be considered. This particularly is true in respect to the flare of the shoe which should coincide with the flare of the foot.

To overcome the deficiency in modern shoe construction, which is very often the factor in producing a foot abnormality, a principle of flare determination has been devised which provides a scientific determination across the five metatarsal heads of an axis which is the hinging structure of the foot in locomotion and at which point the normal hinging of the shoe should also occur if it is to correspond synchronously to the natural hinging of the foot at this point.

The principle of determining the normal flare of the normal foot is very simple and can be ascertained from the position of the metatarsal heads. The position or the angle of transverse axis at this point establishes the correct flare of the foot. The combined action of the metatarsal heads at this transverse axis creates a unified, synchronous joint action. If the shod foot is to remain in normal balance, the shoe must co-ordinate with this function of the foot at the metatarsal phalangeal transverse axis.

To determine the normal flare of the abnormal foot it is necessary to measure the amount of contraction of the metatarsal bones and the amount of elevation of the phalanges above their normal longitudinal alignment with the metatarsal bones.

In a normal foot the phalanges form a continuation or extension of the metatarsal bone. If the phalanges are out of longitudinal alignment with the metatarsal bones then the bending axis is not in proper position for the hinge axis

across the metatarsal heads and the elevation of the phalanges and the depression of the metatarsal bones cause a shifting of the hinge axis and are indicative of the degree of displacement of the hinge axis resulting in abnormal foot binding at this point. The extent of the elevation determines the distance between the abnormal axis and the normal axis shifted anteriorly.

In modern shoe construction, nearly all shoes are made on an in-flare last. We therefore find, that the shoes worn by most people break across the metatarsal heads on a transverse angle of from 20 to 30 degrees. The feet of most humans, however, are found by our typing method to be at a much straighter transverse angle. By this failure of the foot and shoe to properly coincide, a contraction of the dorsal ligaments and tendons is produced, depressing and rotating the fourth and fifth metatarsals, thereby upsetting the stabilization of the entire outer segment of the foot.

The foundation stabilizer has been created and successfully employed to correct this deficiency.

To properly determine the flare of the foot, it is necessary to draw a straight line from the great toe joint across to the metatarsal phalangeal joint of the fifth toe. If the line is at an extreme angle from the center of the articulation of the great toe joint, as much as thirty degrees, then the foot would be classified as inflare. If it is at a lesser angle, the foot would then be typed as a straight flare. In instances where the fifth toe joint is almost directly opposite to, or even a degree or more ahead of the first metatarsophalangeal articulation the foot may be considered an outflare foot.

It is, therefore, an object of the invention to provide a foundation stabilizer capable of re-establishing the normal foundation for the bones of the foot, to shift the displaced bending axis to normal position and to maintain the entire structure in a balanced stabilized position both while standing and walking.

It is a further object to provide a corrective device which is molded to the contour of the foot, providing a cupped heel seat for the calcaneum to maintain it in its correct position.

A further object aims at providing a corrective device molded to the contour of the foot in its relaxed state when the contour of the plantar surface of the foot is at the highest normal point of elevation since no weight and muscular weakness manifest themselves in this condition.

Another object is to provide a stabilizer for the foot adapted to be placed in the shoe and to create a corrective influence on the foot compelling the foot to function normally regardless of proper construction of the shoe, the only requirement being that the shoe be long enough and wide enough for comfortable shodding.

A still further object is a novel method of producing an orthopedic corrective device.

Another object aims at providing a corrective device which extends from the heel up to and under the web of the toes.

It is still another object to provide a corrective device which has a semi-flexible front extension beyond the metatarsal heads to hold the outer segment in position as the foot is dorsiflexed during the propulsive action in walking, when the heel is elevated and weight is transmitted to the front part of the foot.

A still further object constitutes the provision of a corrective device which is laminated, the laminations being determined by the pathologi

conditions of the foot and the weight to be sustained.

With these and other important objects in view which will become apparent from a perusal of the invention, the latter comprises the novel steps of a method and the means for carrying it out as described in the following specification, particularly pointed out in the claims forming a part thereof, and illustrated in the accompanying drawings, in which:

Figs. 1 to 3 are plan views of the skeletal structure of the foot and its hinge axis.

Figs. 4 to 6 are bottom plan views of the model and disclosing various stages of construction of the corrective device constructed in accordance with the invention.

Figs. 7 and 8 are bottom plan views of the model showing further stages in the construction of the device.

Fig. 9 is a bottom plan view of the device.

Fig. 10 is a side view of the device.

Fig. 11 is a longitudinal section through a slight modification, and

Fig. 12 shows in elevational view the device applied to a shoe and particularly broken away to disclose the interior.

In constructing the orthopedic device the hinge axis of the device is first determined. From clinical examinations of thousands of feet, it has been established that the angle of the foot at the metatarsal heads varies from five to thirty degrees.

The angle is determined by drawing a straight line from the great toe joint **10** (Figs. 1 to 3) across to the metatarsal phalangeal joint **11** of the fifth toe.

The line A—B in Fig. 1 is at an extreme angle, such as thirty degrees from the joint axis of the straight foot as shown in Fig. 3 and is termed an "inflare."

The lesser angle of the line C—D in Fig. 2 is termed an "outflare," while the line E—F in Fig. 3 is termed a "straight."

The bend of the foot along any of the three lines shown in Figs. 1 to 3 determines the hinge axis of the device which is made up of a pattern not controlled by the dimension of the shoe but by the contour of the foot and is somewhat larger as will be hereinafter further explained.

In constructing the device a slipper cast is made from the relaxed foot and a positive model M is made from the negative slipper impression.

Thereafter a transverse line is drawn on the model M connecting the centers of the articulation of the first and fifth metatarsal phalangeal joints which line has the angularity of any of the lines shown in Figs. 1 and 3.

Thereafter a basic pattern **15** is cut (shown in Fig. 6) which extends from the heel of the foot to and under the web of the toes and of sufficient size to be molded or shaped to the contour of the foot when in relaxed state and forming a cup seat for the heel.

The basic pattern is made of fabricated cellulose acetate or other suitable material and is softened such as in butyl acetate before being applied to the model to extend anteriorly to the web of the toes and posteriorly encasing the plantar surface of the heel.

Then a line **16** preferably with an indelible pencil is drawn which coincides with the line **14** of the model.

The line **16** is the guide line for the further construction of the device.

Thereafter laminations or reinforcements are provided which are superposed on the pattern **15**. Three such laminations **17, 18, 19** are used which are made of the same material as the basic pattern and may be of equal size.

Reinforcements are also applied to the anterior portion of the device. The reinforcement **24** extends to the front line of the last lamination **19** as shown in Fig. 8. The second reinforcement **25**, being smaller, fits over and within the margin of the first one, the third reinforcement **26** fits over and within the second and the fourth reinforcement **27** is similarly arranged.

The number of reinforcements used is determined by:

1. The amount of contraction of the toes which correspondingly create a depression of the metatarsal heads.

2. The amount of extension of the toe which is correspondingly desired in producing the anterior stabilization.

It is important that the highest point in thickness of these reinforcements shall be directly under and across the hinge line. Thus it is possible to use several additional anterior reinforcements as would be indicated by the particular pathology in the foot.

The anterior laminations are so placed on the device that they will create a fulcrum which extend and lengthen the contractions of the metatarsal and phalangeal structure.

The reinforcements are then covered by the first covering layer **28** (Fig. 8) which extends from the hinge line to the heel, leaving exposed the portion anterior to the hinge line. A second cover **29** is superposed on the layer **28**.

While the device thus far described is still in the moist state, all margins and edges are pressed down or burnished smoothly to eliminate rough and sharp edges.

The device is placed on the model and held thereon under pressure to dry for about twenty-four hours and thereafter allowed to dry without any pressure for about forty-eight hours and removed from the model.

During the second drying period it is placed, however, on the model several times for a period of one to two hours to avoid deviation or shrinkage of the material.

After being thoroughly dried, a top cover **30** of thin leather is cemented to the device and the edges are beveled with a file or rasp, or grinding wheel.

Thereafter a cover **31** of split leather is cemented to the bottom, thus completing the foundation stabilizer, **32**.

As indicated in Fig. 12 the device is inserted in a shoe and its posterior part **33** forms a cup seat for the heel while the anterior portion extends to and under the web of the toes. The hinge line **16** shown in Fig. 10 is slightly exaggerated.

The modification shown in Fig. 11 differs from the previously described embodiment, therein, that the device generally designated by **34** has an integral body portion **35** instead of being laminated and provides the hinge axis and the cup shaped seat **36** identically as previously described.

The orthopedic device herein described is instrumental in guiding, steering, balancing and stabilizing the foot in all its functional activities, and creates for the foot a normal environmental factor which by reason of its re-generated normal function strengthens and develops weakened and deformed foot structures.

While the drawings show two embodiments of

the invention various changes may be made without departing from the purview of the invention, nor is the method of making the device limited to the sequence of steps in carrying out the method. We, therefore, include all revisions, alterations, re-arrangements and modifications which come within the scope of the invention, as defined in the appended claims.

We claim:

1. The method of constructing an orthopedic appliance, comprising the steps of casting a model of the foot, drawing a line on the model connecting the first and fifth metatarsal phalangeal joints, placing on the model a softened moist layer of fabricated cellulose acetate to cover the plantar surface of the model from the heel to a point under the web portion of the toes, drawing a line on said layer coincident to the normal hinge line which is spaced anteriorly from the model line a distance equal to the deviation of the phalanges from their longitudinal alignment with the metatarsal bones, placing moistened laminations on said layer extending posteriorly from said lines, and maintaining said layer and said laminations under pressure on said model until hardened to obtain rigidity of said layer from the heel to said line.

2. The method of constructing an orthopedic appliance, comprising the steps of casting a model of the foot, placing on the model a moist layer of fabricated cellulose acetate to cover the plantar surface from the heel to and under the web portion of the toes and providing a cup seat at the heel, drawing a line on said layer which coincides with the normal hinge line and is spaced from a line connecting the first and fifth metatarsal phalangeal joints, a distance equal to the deviation of the phalanges from the longitudinal alignment with the metatarsal bones, placing moistened laminations of predetermined length on said layer extending posteriorly from said layer line, and maintaining said layer and said laminations under pressure on said model until hardened to obtain rigidity of said layer from the heel to said line.

3. The method of constructing an orthopedic appliance comprising the steps of casting a model of the foot, placing on the model a layer of material to cover the plantar surface from the heel to and under the web portion of the toes and provide a cup seat at the heel, drawing a line on said layer connecting the first and fifth metatarsal phalangeal joints, placing moistened laminations of predetermined length on said layer extending posteriorly from said line, placing a plurality of laminations in superposed relation on the anterior portion of the layer with the thickest part thereof in vertical registry with said line, and maintaining said layer and said laminations under pressure on said model until compacted to obtain rigidity of said layer from the heel to said line.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
975,576	Sexton	Nov. 15, 1910
1,191,122	Brown	July 11, 1916
1,210,066	Hara	Dec. 26, 1916
1,370,799	Egerton	Mar. 8, 1921
1,914,049	Smith	June 13, 1933
2,177,304	Murray	Oct. 24, 1939

FOREIGN PATENTS

Number	Country	Date
190,709	Switzerland	May 15, 1937
192,694	Switzerland	Nov. 16, 1937
700,265	Germany	Dec. 17, 1940