

FABRICATION OF CUSTOMIZED SHOE LAST FOR DEFORMED FOOT USING PLASTER OF PARIS: AN APPROACH TO ENHANCE FOOT COMFORT

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Abstract- A last is the most important element for the footwear manufacturing process. A patient with defective feet needs customized footwear which also requires customized lasts. This study was to develop customized last for defective feet in the shortest possible time and at lower cost. In this study, two asymmetric feet of a patient were wrapped with Plaster of Paris cloth to make mold and a pair of lasts was developed by pouring molten plastic. A pair of shoes was made by using these custom lasts and the shoes were worn by the patient for two weeks. The patient felt no pain in any area of his feet during walking and the lasts were developed by only 6 USD and it took only 11 hours to complete last manufacturing process. So, this method may be helpful to all small-scale orthopaedic footwear manufacturers to develop custom footwear for the deformed feet.

Keywords: Deformed Feet, Plaster Of Paris, Customized Last and Footwear

1. INTRODUCTION

A last is a mold on which the material of footwear upper is shaped to its required size and fitting. It retains the 3D shape of the shoe upper as well as attaching insole & sole with upper. Last is not the exact replica of the foot but it provides approximate shape and several anatomical information of the human foot. The shoe fitting depends greatly on the different parameters of shoe last.[1] A more accurate last provides a more perfect fitted shoe which ensures foot comfort and health. On the other hand, ill-fitted shoes may cause the foot deformations or foot related injuries and illness. Common example of these problems are hallux rigidus, hallux valgus, blisters, corns etc.[2] Commercial shoes are not suitable for the person who is affected by one or a combination of the mentioned foot disorders and, therefore, customized shoes are mandatory to use for them.[3]

The customized shoes are produced on customized shoe lasts. A lot of methods have been developed and used for the production of customized lasts. Researchers are still working to develop the most convenient way of customized last production. Few researchers used 3D foot scanner to get the perfect shape of a foot that helps to develop a custom shoe last.[4] A study proposed to use the dissimilarities of colour code mismatch between human foot and shoe last to justify the shoe fit to choose a 'best-fitting' last from a group of available lasts.[5] However, the details of the method were not given in that study and there is no specific standard to define what the 'best fitting' is. Another study showed a shoe last

customization method based on a distance map and an amendment map.[6] However, the amendment map is the hard to be built and no local deformation was allowed in that method. Furthermore, all of these methods require so many sophisticated machinery which are not affordable for a small-scale orthopedic footwear industry.

Trial-and-error method is another widely used method which is a kind of the manual crafting process to develop shoe lasts for defective feet.[7] But it is very time consuming process to get accurate shoe fitting. In another study, a hollow mold for foot was possible to make by using saturated Plaster of Paris cloth and casting of soft, flexible plastic material into it to produce temporary last in which toe extension was added by further modification of last.[8] This method required so many mechanical operations for adding toe extension and feather edge to the molded last which were also very time consuming processes.

In this study, the hollow molds were developed directly from the deformed feet by using saturated plaster of Paris cloth to get accurate shape of the foot and the lasts were developed by pouring molten plastic on the mold. The developed last had well defined feather edge and toe area which did not require any post mechanical operations and finally shoes were made on the lasts. This study is mainly for those patients who have diabetic feet, ill-fitted feet, asymmetric feet or different types of deformed feet. In addition, the corks of plastic bottles (HDPE) were used to make customized lasts which can be recycled further.

The main purposes of this study was to develop custom made last for better shoe fitting for the deformed feet and to obtain the custom last in a shortest possible time & at lower cost.

2. EXPERIMENTAL PROCEDURE

2.1 Deformed feet selection

A 65 years old male patient around weight of 80 kg and height of 5 feet 10 inch was selected for this study who had asymmetric feet. Length of two feet was dissimilar where right foot was larger than left foot. Moreover, the girths of the feet were also dissimilar especially ankle girth of right foot was wider than left foot. After being paralyzed he couldn't place his feet straight to ground. As a result, outside of right foot bore the weight of his body where pressure sores were found.

2.2 Bottom preparation

A white pattern paper was taken on a plane surface and the foot was kept on the paper and the bottom shape of the foot had been taken by pencil. A smooth toe shape was found by providing 14 mm toe extension in front of toe which was drawn by pencil. The pattern paper was then cut along the edge. Five layers of pattern paper of similar shape had been attached to avoid the deformation of bottom shape during wrapping the plaster of Paris cloth and to get well defined feather edge. Cork sheet had been cut according to the shape of toe extension and height of the toe depth of the foot. The cut piece of cork sheet was attached to the bottom pattern at the toe extension area by the tape which is shown in figure 2.1.



Fig. 2.1: Bottom preparation

2.3 Mold making

The foot was placed over the bottom pattern accurately. Then the foot along with bottom pattern was inserted into the sock carefully. The sock was covered by polyethylene paper which was mainly used to protect the sock not to attach with dried plaster of Paris cloth which is presented in figure 2.2. A greasy substance was smeared over the polyethylene paper and the plaster of Paris cloth saturated with water was wrapped tightly over the foot. After drying for 30 minutes the center back of the mould was cut carefully by a sharp knife to remove the foot from the mold. The greasy substance helped to remove the foot easily from the mold and the cut portion was joined with cotton & saturated plaster of Paris cloth. Then the mold was kept for drying and finally, the mold was developed which is shown in figure 2.3



Fig. 2.2: Wrapping the foot with Plaster of Paris



Fig. 2.3: Prepared mold for last making

2.4 Last making

To develop the customized lasts, around 5 kg plastic cork of bottle which was mainly polyethylene were collected from local market. The molten plastic was poured into the mold which was surrounded by the sand which is depicted in figure 2.4. The mold was filled up with molten plastic and the mold with the last was cooled around 5.5 hours. A sharp knife was used to cut the mold and last was then removed from the mold. Pile was used for removing unevenness of the top surface and bottom part of the last. Emery paper was used for smoothening and final finishing purpose to obtain more accurate shape of the customized last. Wedge cut was given by using band saw machine. Split pin and pin hole were mainly used to hold the wedge on the last. Drilling was carried out in several locations of last to facilitate lasting and delasting operation during shoe manufacturing.



Fig. 2.4: Pouring molten plastic into the mold

2.5 Custom shoe making

Patterns were developed for monk shoe for each last separately as two lasts were not similar in size and shape. Shoe upper pieces were cut from leather according to the shape of patterns. The pieces were skived, folded along the edges where required and then the uppers parts were assembled. Finally, the uppers were lasted & soles were attached to the uppers and finishing was carried out. The developed customized last and shoe according to the shape of deformed left foot are shown in figure 2.5.



Fig. 2.5: Developed customized last and shoe

2.6 Fitting test

Fitting test was done by wearing the shoes by the patient for checking the fit of shoes on feet. To get more accurate results of fitting, a comparison was made among both feet, customized lasts and commercial lasts at different important points. As the patient used to wear the shoes of Paris point 41 size though he felt pain in his feet, the comparison was made with that size. The measurement of feet, customized lasts and commercial last were based on foot length, heel to ball length (both inside and outside), measurement of girth for toe, ball, waist, instep, short and long heel, measurement of width for toe, ball, waist and heel.

2.7 Wear trials

The fitting of shoes was also observed by wearing the custom shoes by the patient for two hours every day up to two weeks which is represented in figure 2.6 and comfort level by wearing these shoes was measured by pain score numerical rating scale. This scale contains 11 numerical ratings (0-10). Here 0 for no pain, 5 for moderate pain and 10 for worse possible pain.[9] The patient gave ratings every day and by average of these ratings approximate results were found.



Fig. 2.6: Wear trials

3. RESULTS AND DISCUSSION

3.1 Fitting test

Comparison among both feet, commercial lasts & customized lasts were done to get the accurate fitting measurement which is shown in table 1. In most of the cases the measurement of different locations of feet and customized lasts were almost similar except several points where the difference between foot and last is always required which indicates that the customized lasts were developed to the shape of deformed feet. On the other hand, there were large differences found in different locations between the feet as well as customized lasts and commercial lasts which represent that the shoes made on commercial lasts are not suitable to use for the the patient of defective feet. Stick length was found larger for customized lasts than the commercial lasts for both feet which indicates that the defective feet can not be easily inserted into the shoes that are produced by commercial lasts.

Table 1: Comparison among deformed feet, customized lasts and commercial last in different locations (mm)

Measure- ment Locations	Left		Left or Right	Right	
	Foot	Customized Last	Commercial Last	Foot	Customized Last
Stick length	276	290	283	281	295
Heel to ball length (outside)	179	179	162	160	160
Heel to ball length (inside)	180	180	185	183	183
Toe girth	234	240	231	219	225
Toe width	99	99	87	96	96
Ball girth	241	247	243	242	248
Ball width	104	104	93	96	96
Waist girth	251	257	250	259	265
Waist width	66	66	60	65	65
Instep girth	274	280	260	282	288
Short heel girth	345	350	345	347	352
Long heel girth	355	360	357	355	360
Heel width	66	66	60	62	52

Similarly, ball girths were wider for both customized lasts than that of commercial lasts but similar to the girths of feet which represents that the commercial shoes are not suitable for the deformed feet and foot insertion of the patient becomes easier in case of custom footwear. In other locations the values for both feet were almost similar to the values of customized last whereas, there was a large variation found in values for deformed feet and commercial lasts. Figure 3.1 shows the comparison among customized lasts and commercial last. In all cases, the deviation was found among customized lasts for both feet and commercial last. So, the patient will face loose fitting or tight fitting in his feet in different locations of his feet if he wears conventional shoes that are developed by the conventional lasts.

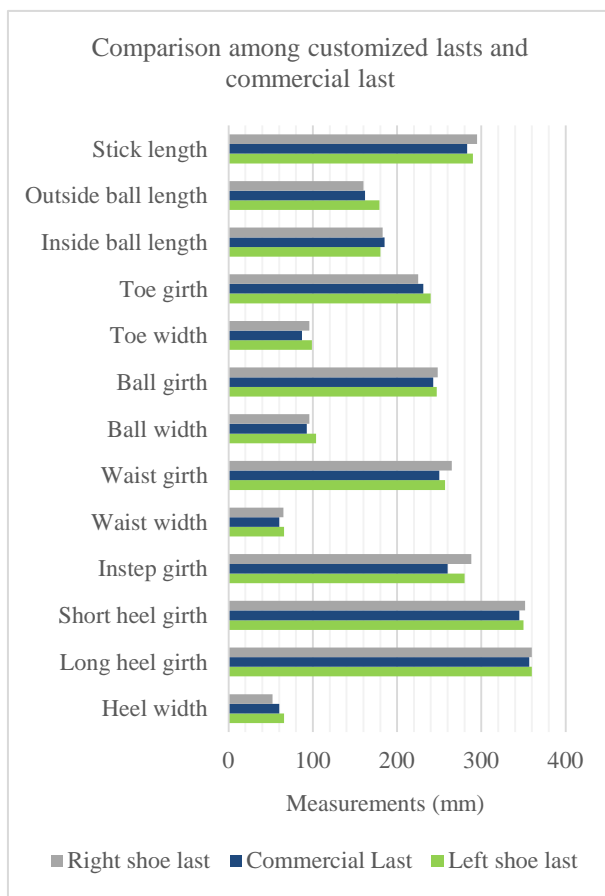


Fig. 3.1: Comparison among customized lasts & commercial last

3.2 Wear trials

Pain score rating for 14 days was given by the patient after wearing shoes two hours every day which is given in table 2. In first six days pain score was 2 and from seventh day pain score had been decreased to 1 up to fourteenth day. That may be because of shoes need time to take the shape of the foot. On average, the value had been found 1.43 which means that the patient felt almost no pain during his wearing period. It also indicates that the customized lasts as well as the shoes were made to the exact requirement of the feet and that's why the patient did not feel any pain in his feet during wearing period.

Table 2: Pain score rating of the patient by wearing customized shoes

Days	Daily pain score rating by wearing shoes
1-6	2
7-14	1
Average rating for 14 days	1.43

3.3 Cost of last making

The price of 5 kg plastic was 3 USD which was the maximum costly material in this process and the 4 pieces of Plaster of Paris clothes were required which cost was 2 USD. The cost of pattern paper & socks which were used in the experiment was 0.5 USD in total that are enlisted in table 3. Other materials such as tape, polyethylene etc were of almost 0.5 USD. Total material cost to develop a pair of lasts was 6 USD which was much less than that of commercial custom lasts. Moreover, sophisticated machinery was not required to make the lasts.

Table 3: Materials cost for customized last making

Materials	Cost (USD)
Pattern paper & socks	0.5
Plaster of Paris cloth	2.0
Plastic cork of bottle	3.0
Others	0.5
Total	6.0

3.4 Duration of last making

Bottom preparation, mold making and plastic melting took altogether almost 2 hours. About half an hour was needed for pouring molten plastic and for cooling plastic it required 5.5 hours. Last removal, smoothing and drilling took almost 3 hours all of which are shown in table 4. The whole process took 11 hours which was far less time than that of conventional wooden customized last manufacturing process.

Table 4: Duration for customized last making

Process	Time (hour)
Bottom preparation	2
Mould making	
Plastic melting	
Pouring molten plastic	0.5
Cooling plastic	5.5
Last removal, smoothing and drilling	3
Total	11

4. CONCLUSION

This study allows the last developer to develop the custom shoe last of plastic material by pouring it in molten condition into a mold which can be made by wrapping the deformed foot with plaster of Paris. As the shoes were made on the customized lasts which ensured accurate fitting to deformed feet that was justified by different fitting measurements and wear trial for two weeks. This method may be helpful to all the small-scale footwear manufacturers who develop custom footwear for the patients with deformed feet. Besides, the lasts were developed by the cork of waste plastic bottle which was mainly HDPE plastic material that can be recycled further time. Moreover, the lasts were developed in the shortest possible time with a minimum material cost which can be more beneficial to the small-scale customized last and shoe manufacturers.

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