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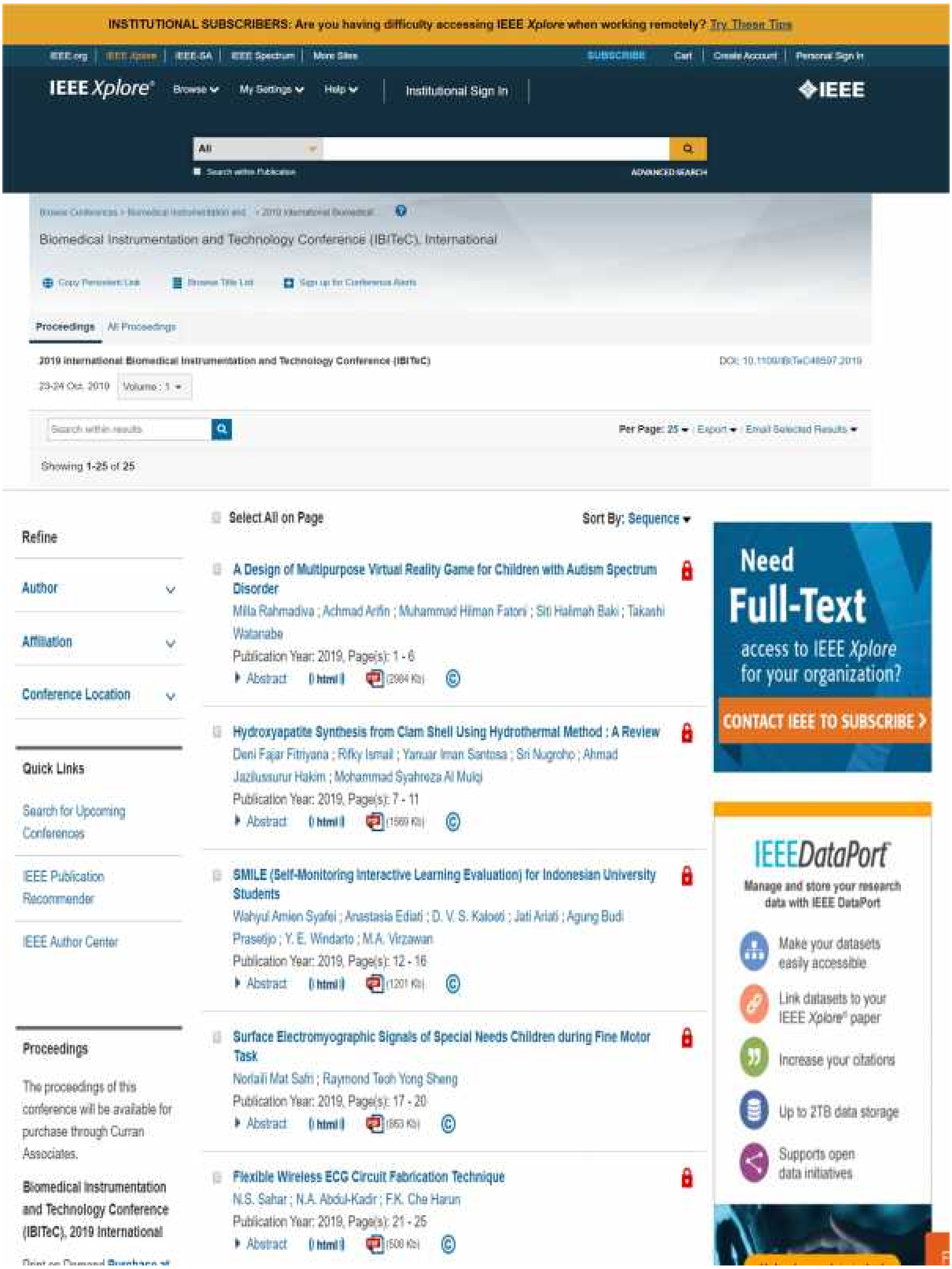

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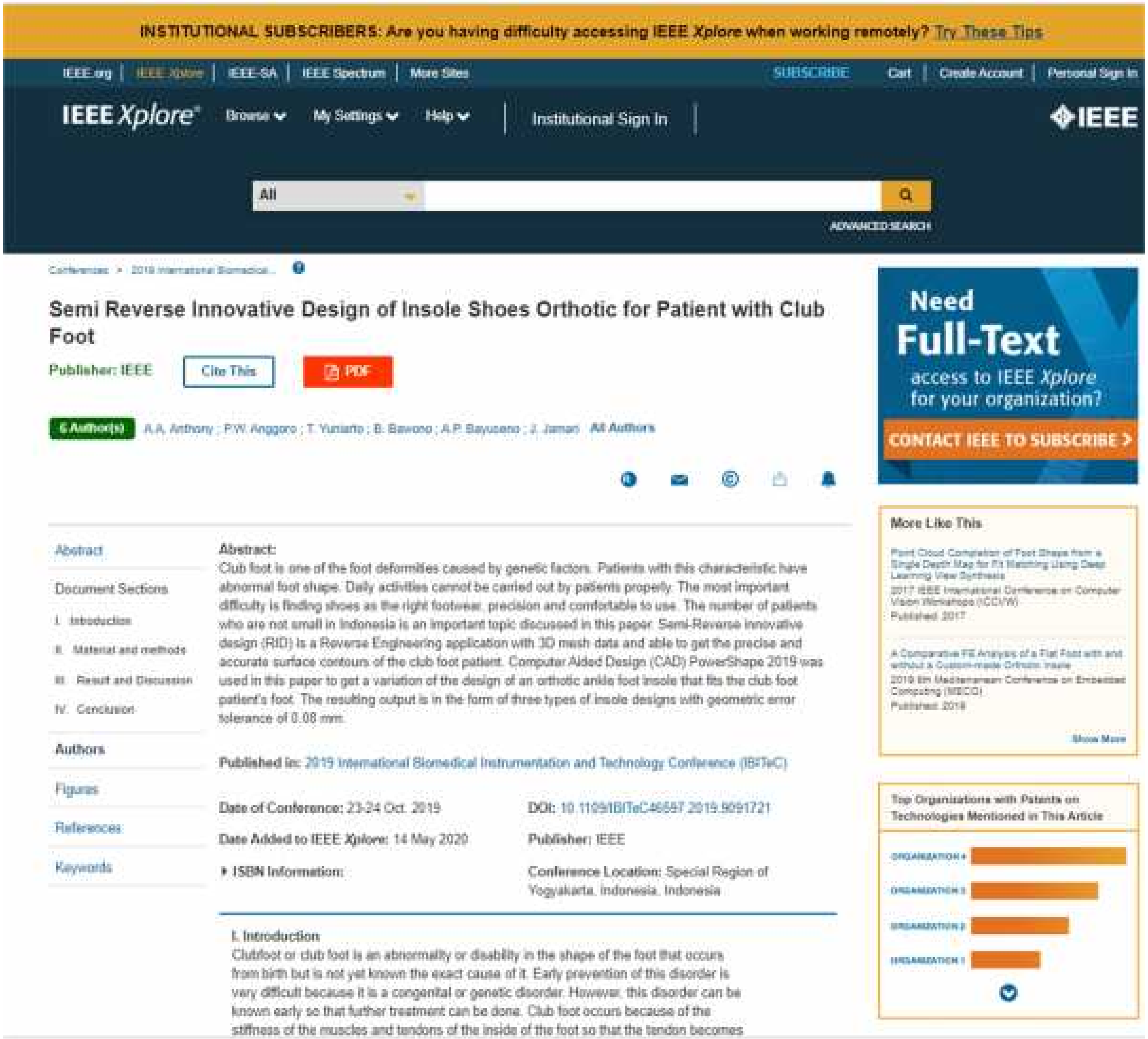

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Abstract

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Abstract:
Club foot is one of the foot deformities caused by genetic factors. Patients with this characteristic have abnormal foot shape. Daily activities cannot be carried out by patients properly. The most important difficulty is finding shoes as the right footwear, precision and comfortable to use. The number of patients who are not small in Indonesia is an important topic discussed in this paper. Semi-Reverse innovative design (RID) is a Reverse Engineering application with 3D mesh data and able to get the precise and accurate surface contours of the club foot patient. Computer Aided Design (CAD) PowerShape 2019 was used in this paper to get a variation of the design of an orthotic ankle foot insole that fits the club foot patient's foot. The resulting output is in the form of three types of insole designs with geometric error tolerance of 0.08 mm.

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I. Introduction

Clubfoot or club foot is an abnormality or disability in the shape of the foot that occurs from birth but is not yet known the exact cause of it. Early prevention of this disorder is very difficult because it is a congenital or genetic disorder. However, this disorder can be known early so that further treatment can be done. Club foot occurs because of the stiffness of the muscles and tendons of the inside of the foot so that the tendon becomes

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Semi Reverse Innovative Design of Insole Shoes Orthotic for Patient with Club Foot

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Abstract— **Club foot is one of the foot deformities caused by genetic factors. Patients with this characteristic have abnormal foot shape. Daily activities cannot be carried out by patients properly. The most important difficulty is finding shoes as the right footwear, precision and comfortable to use. The number of patients who are not small in Indonesia is an important topic discussed in this paper. Semi-Reverse innovative design (RID) is a Reverse Engineering application with 3D mesh data and able to get the precise and accurate surface contours of the club foot patient. Computer Aided Design (CAD) PowerShape 2019 was used in this paper to get a variation of the design of an orthotic ankle foot insole that fits the club foot patient's foot. The resulting output is in the form of three types of insole designs with geometric error tolerance of 0.08 mm.**

Keywords—club foot, deformity foot, semi reverse engineering, CAD, insole ankle foot orthotik

I. Introduction

Clubfoot or club foot is an abnormality or disability in the shape of the foot that occurs from birth but is not yet known the exact cause of it. Early prevention of this disorder is very difficult because it is a congenital or genetic disorder. However, this disorder can be known early so that further treatment can be done. Club foot occurs because of the stiffness of the muscles and tendons of the inside of the foot so that the tendon becomes short and pulls the foot inward. Someone who has the shape of a foot like this will feel discomfort when doing daily activities so that every work or activity carried out runs poorly and not optimally [1]. The development of the existing shoe industry is indeed running very fast and rapidly both in terms of design and fabrication offered [2-4]. However, this can not be enjoyed by some people who have deformity foot like a club foot that can be displayed in figure 1. This happens because the shape of the foot that is owned is not in accordance with the form of footwear that is mass-fabricated and spread on the market . The shape of the foot like this if forced to use mass fabricated footwear will eliminate the feeling of comfort and it will actually injure the foot. Shoes consist of insole, shoe last, upper shoe and outsole. Insole is the inside of the shoe which will come in direct contact with the foot [5]. Outsole is the bottom of the shoe that is in direct contact with the ground when people are on the move. Upper shoe is a blanket part of the shoe that covers the back of the foot, while shoe last is the core that forms the shoe that determines the final shape and is an important factor in determining the quality of shoes. The shoe last design and manufacturing process can be done in two methods, namely the manual process and using CARESystem as in the journal reported by [5, 7] In general, the shoe fabrication process is largely determined by the form of shoe last, this is reported by [5, 8-9] However, one of the factors supporting the comfort of footwear lies in the insole that is in direct contact with the sole of the foot. This condition has been reported by [2-4, 7] in his paper stating that one of the factors in the comfort of footwear when used for daily activities lies in insoles that are designed and manufactured according to the shape and size of the soles of the feet. The process of making insoles with designs that fit the shape and size of the soles of the feet needs to be used Reverse Engineering (RE) technology on a CAD, CAE, and CNC / RP basis that is reliable and this is often referred to as a Computer Aided Reverse Engineering System (CARESystem) as success reported by [7, 10-14]

Figure 1. The shape of the club foot patient's foot

Reverse Engineering (RE) can be explored to design or modify the design of an existing product into a new product with better function values. Nowadays there have been many studies on RE in the field of product design as has been done by [10, 15-17]. However, only a few studies have focused on developing innovative designs for orthotic shoe soles. The RID research was first conducted by [10] to design an orthotic shoe sole. Based on three RE strategy scenarios that have been presented in the journal

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reported [10] two of them are automatic freeform surface modeling and featured-based parametric solid modeling that cannot be applied because they cannot form a solid 3D according to the scanning of the foot contour. The Curve Base Surface Modeling (CBC_Modeling) strategy was chosen and applied in this RID implementation in this paper. CBS_Modeling modeling was chosen because the foot contour curve can cover parts of curves, curve boundaries, and roomate so that it can give an advantage to the curve editing process that is formed and finally can produce a perfect shoe insole surface, as successfully done [5, 7, 8, 14] but the patients the researchers worked on were patients [2-4, 7, 16] and normal people were not patients with deformity, especially the club foot as in this paper. The editing process of the curve with the creation of an oblique feature in Autodesk PowerShape 2019 also accelerated the design time of orthotic shoes and this was very beneficial for CAD engineers. This paper will develop a stage of the insole design concept and shoe last shoe orthotics based on the use of semi-modern technology using the Handyscan 700TM scanning tool.

II. Material and Methods

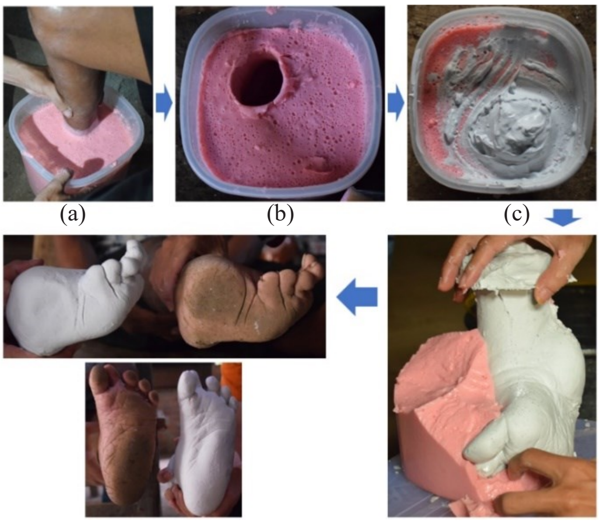
In this paper, patients with club foot type abnormalities were determined (Figure 1); 65 years old and has suffered a leg disorder from birth. The condition of the patient's right foot as shown in Figure 2. looks twisted inside where the patient's foot is no longer a foothold when walking. While the patient's left leg changes bone structure (Figure 2) due to being the patient's main foundation when standing. And this becomes a patient's difficulty in carrying out daily activities, such as: walking, running, and using shoes or footwear. The results of manual shoes that have been done by shoe craftsmen and shoe last in Yogyakarta according to patients there are still shortcomings (Figure 3).

Figure 2. Patient *club foot* shape

(a) (b)

Figure 3. The initial form of club foot patient shoes: (a) sandals with a patchwork patch that is thickly sewn as an insole; (b) closed shoes with outside models are in accordance with the shape of the feet, but the shape of the insole is still flat

In this paper, the SemiRID method that has been done by [5, 13] is done and begins with the process of forming 3D replica legs using gypsum which is a physical model of the foot ready to be processed digitally with a scanning tool. This process is done because the geographical location of the patient is not able to be reached by the researcher when scanning. The 3D implant technique is performed on the patient by printing the foot with white and blue gypsum material into the box (foam box shoe method). The 3D foam box stages form the physical model of the club foot patient foot (Figure 4) which will be further processed in the scanning tool.



(a) (b) (c) (e) (d)

Figure 4. The traditional method of foam boxes: (a) Foot printing using powder molding in a box; (b) Powder Molding output; (c) The process of casting Gibs material into foot prints; (d) The process of peeling mold; (e) prototype of club foot patient feet

The current research begins with the 3D process of the patient's foot implant using gypsum material. These results are used as objects to carry out the scanning process using HandySCAN700. The scanning process in Figure 5a and Figure 5b is needed to virtualize the patient's profile into a digital form so that it can be processed on a CAD PowerSHape 2019i device. The resulting output is a 3D CAD insole model and shoe last for club foot patients and presented in Figure 5 (c).

(a) (b) (c)

Figure 5. The scanning process of the club foot foot prototype: (a) Attaching the hologram point scanning to the prototype; (b) The process of scanning protorypes with HandySCAN700; (c) The results of scanning in 3D mesh with the image of the .stl file

CBS-modeling that was successfully applied [5, 7] in this paper is also used to obtain insole output and shoe last on club patients in the form of 3D CAD models as shown in Figure 6. This 3D model is then carried out by design variations by doing scale enlargement foot geometry based on geometric tolerance as has been done by [14]. The stages of CBS-insole modeling in club foot patients are presented in Figure 6.

Flow chart methodology SemiRID orthotic shoe insole in club foot patients is presented in Figure 7. The final result of this paper is a 3D CAD insole design model (Figure 8) and the geometry variation of the two products based on the tolerance set in the direction of sb X and Y (Table 1) . Verifying the size comparison between the patient's legs, 3D replica legs with CAD results are presented in Table 2.

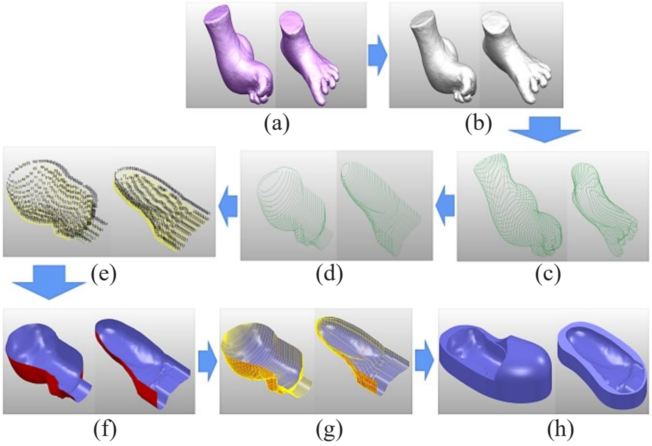


Figure 6. Stages of CBS-Modeling process in CAD PowerShape 201i: (a) Import 3D mesh as the initial process; (b) Results of a solid 3D foot model from the initial 3D mesh; (c) Wireframe feet; (d) Reconstruction of Wireframe; (e) Repoint wireframe curve; (f) Formation of surfaces; (g) Reconstruction of the curve on the surface; (h) Results of a 3D solid insole shoe orhotic for club foot patient feet

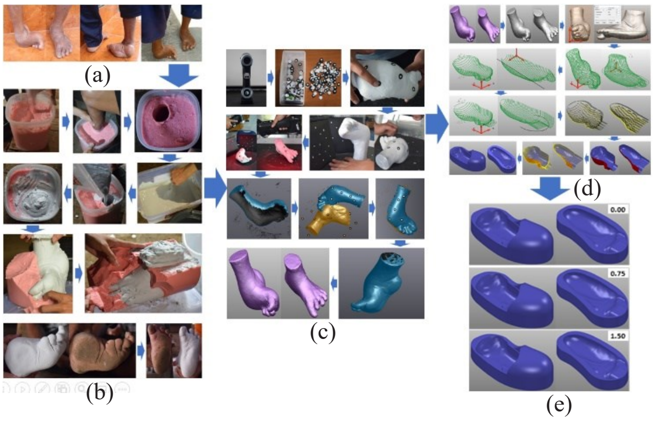
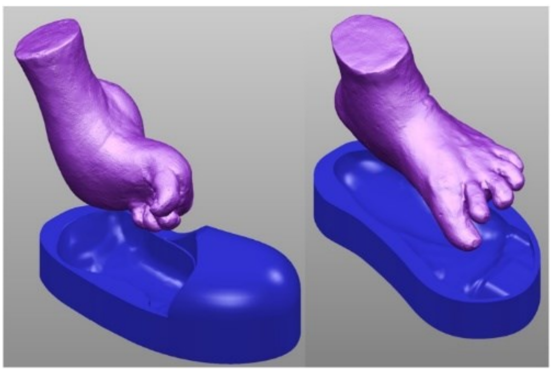


Figure 7. Flowchart methodology for SemiRID positions: (a) The feet of the patient with club foot; (b) 3D formation process physical model of club foot patients with foam box method; (c) The process of scanning the prototype of a club foot patient foot to obtain a 3D mesh in the form of an .STL file; (d) CBS_Modelling to design a club mesh patient insole from 3D mesh; (e) Variation of insole models: 0; 0.75; 1.5



(a) (b)

Figure 8. 3D solid insole shoes for patient's foot club foot: (a) right foot insole; (b) left foot insole

Tabel 1. Variation in geometric tolerance of orthotic shoe insoles for patient with club foot

Geometry Tolerance (mm)	Left Foot Patient Club Foot without Material Added			Right Foot Patient Club Foot without Material Added		
	Dimension (mm)			Dimension (mm)		
	Lenght of ISO (A)	Wide of ISO (B)	High of ISO (C)	Lenght of ISO (A)	Wide of ISO (B)	High of ISO (C)
0.00	224.6	104.30	35.03	179.4	101.00	42.42
0.75	226.0	105.77	35.03	180.9	102.50	42.42
2.00	227.5	107.26	35.03	182.4	104.00	42.42

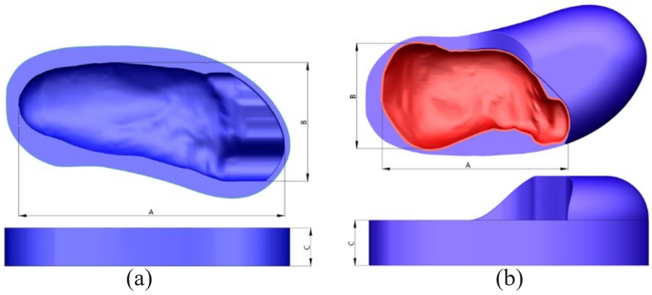


Figure 9. Geometry of insole dimension

Tabel 2. Measurment foot of patient with club foot

Number of Measure	The Measure of Actual Foot from Patient with Club Foot		The Measure of 3D Replika Foot from Patient Club Foot		Error	
	Right Foot (mm)	Left Foot (mm)	Right Foot (mm)	Left Foot (mm)	Right Foot (mm)	Left Foot (mm)
1	179.50	224.70	179.40	224.60	0.06	0.09
2	134.50	160.10	134.50	160.00	0.08	0.08
3	155.90	104.40	155.80	104.30	0.07	0.08
4	89.52	81.06	89.45	80.99	0.07	0.07
5	101.10	196.70	101.00	196.60	0.05	0.08
6	84.23	87.47	84.15	87.41	0.08	0.06

III. Result and Discussion

This paper demonstrates very well a new method for designing orthotic shoe insoles in patients with club foot type deformities based on 3D mesh data with the .STL format from the scanning process with 3D scanning tools. The scanning process is carried out for approximately 30 minutes using HandySCAN700TM. The scanning process in this paper is different from the process carried out by [7] where the physical model to be scanned is not the actual patient's foot but in the form of a replica 3D prototype of the patient's foot. This prototype is manufactured using foam box technology (Figure 4).

Club foot as shown in Figure 1 is a congenital disease or disability of the foot whose cause is not known with certainty. In this patient there is stiffness of the muscles and tendons of the inside of the foot so that the tendon becomes short and pulls the foot inward. Actually this type of disease can be detected early during pregnancy with the help of ultrasound ultrasound) during the Ante Natal Care period by obstetricians [1] but in general patients do not take further care because of their limitations. This is exactly the same as the patient done in this paper.

The club foot patient in Figure 2 has an abnormal shape on both legs. The right leg is bent inward and the left leg changes its bone structure as a result of the burden received greater than the load received by the right foot. This disorder makes the patient unable to walk normally. These abnormalities cause discomfort and tend to be painful. To be able to carry out daily activities so far, patients have modified their shoes themselves by adding some sewn cloth to thick to be placed on the right foot, before using shoes that have also been modified by the patient themselves as shown in Figure 2. This type of shoe then developed by shoe craftsmen in the Bantul area, Yogyakarta became semi orthotic shoes that approached the patient's foot shape. But in fact this type of shoe is still an obstacle for patients to walk, especially during the rainy season, where patients often slip due to the shape of the insole that is still designed flat (not according to the shape of the patient's foot) by craftsmen. This condition makes the patient uncomfortable when using these shoes (Figure 2). The comfort of the shoe shape according to [7, 18, 21] in addition to the geometric aspects and the strength of the footrest, is also determined by the shape and geometry of shoe insole. The precise and accurate shape of the insole according to the foot shape of the foot will cause the patient to feel safe and comfortable while on the move. The occurrence of slip when the foot is stepped on using an initial type of shoe (Figure 3) when the rainy season can be reduced by the formation of an insole surface such as the sole of the foot. Here the surface of the protruding insole functions as a foot holder and cushion so that no slip occurs due to the appearance of a large friction force. Figure 3, shows three types of shoes that have been made and used by patients for daily activities.

The solution to answering the challenges in this paper is to get 3D CAD orthotic shoe insoles that are precise, accurate and in accordance with the shape of club foot patients using CARESystem technology. This technology requires every engineer in the product design process to be based on reverse engineering (RE) using tools. scanning (Figure 5). To obtain optimal design geometry variations by [10] the RID method was introduced and proved successful by [17] This paper does not discuss in detail the application of RID as successfully carried out by [20] diabetic patients but only up to the stage of orthotic shoe insole design for patient club foot so it is called semi reverse innovative design (SemiRID). This method is also based on RE in the process of designing insole and oitsole in club foot patients. The semiRID output in this paper was obtained by the researcher by applying the curve base surface modeling method (CBS-modeling) as shown in Figure 6. The resulting output is a 3D model image of the patient's orthotic foot and shoe insole (Figure 6h; Figure 7e; and Figure 8). The stages of developing the latest semiRID method in orthotic shoe insole designs for deformity foot patients are demonstrated in detail and in detail in Figure 7. This stage can be used as a general standard for engineers or other orthotic experts who want to study the design process and manufacturing of orthotic shoes.

Kaki according to [10] is an organic part component that the 3D modeling design process starts from wireframe to surface and solid modeling. This type of component can also be easily processed from the RE results in the .stl format, but it takes CAD that is able to do a good surface editing process so that the RE results are truly perfect. According to researchers, CAD PowerShape 2019i software is one of CAD software that is able to solve design solutions on organic part components and this was successfully carried out by [7].

CBS_Modeling (figure 6) is used to make insole based on the results of foot scanning in 3D mesh. Feet in the form of 3D mesh, converted into solid 3D form, before being used as a basis for making insoles. Figure 6 illustrates that the solid 3D results are used to obtain a complete wireframe model. Based on this wireframe, the surface can be formed according to the shape of the foot of the scan, so that the obtained form is appropriate and precise. The surface produced in the process, then refined by reconstructing the curve arising from the results of surface formation. The results of this reconstruction are then made in full insole in accordance with the shape of the patient's foot, and according to the needs to get the same form of shoes in general.

Measuring the geometric dimensions of club foot patients in this paper was done by measuring the two types of patients' feet. Determination of foot measurments in this paper is based on [19 - 20]. Six foot measurments, namely: foot length, arch length, heel to fifth toe, foot width, bimalleolar width, and height at 50% foot length selected as baselines in club foot patient foot measurements. The measurement results with mitutojo caliper dial with a tolerance of 0.02mm are presented in table 1. Whereas the comparison of the measuring dimensions of each foot measurment is presented in Table 2 with accuracy of 0.068 mm for the left foot and 0.077 mm for the right foot. These results indicate the accuracy of the exact tolerance of less than 0.1 mm and greater than 0.08 mm (66%) compared to research carried out by [7]. But this result can be used as a reference for insole manufacturing, shoe last and orthotic shoes in the shoe industry.

Based on the results of the design variations in Figure 7.e and Table 1, the design manufacturing process was carried out in type 0.75 mm according to the results of research conducted by [7]. In this type, the best conditions for the best insole products were obtained with machining parameters (toolpath, spindle speed, step over, depth of cut) which were also carried out by previous researchers [5, 7, 20] and produced ankle foot orthotic insole products (AFO insole)) specifically for club foot patients as shown in Figure 10.

Gambar 10. insole ankle foot orthotik

In the future, this research will continue with the manufacturing process of shoe lasts for club foot patients using CNC machines.This shoe last was made as a master mold in the manufacture of orthotic ankle foot shoes (AFO shoes) type of boots. Shoe fabrication is carried out in the shoe industry. Testing the standard of industry feasibility and comfort in the use of AFO Shoes for patients will be carried out by researchers after AFO shoes are obtained.

IV. Conclusion

SemiRID applied in this paper has been proven to provide maximum results in an effort to help the problems faced by club foot patients to obtain orthotic shoe insole in accordance with the patient's foot shape and also to form general shoes based on the insole made.

Visually and the results of the confirmation of measurements between the patient's feet and the protoype have been obtained the average geometry accuracy for each measurement foot is 0.08 mm for the patient's feet. The modern CARESystem technology with the semi RID method is expected to be able to answer the challenges faced by deformity foot patients, orthotic and prosthetic specialists, orthotic laboratories in the process of design and manufacturing shoes that are precise, accurate and in accordance with the patient's foot shape and prove that this technology is truly presented for human welfare.

In the future, Semi RID with CARESystem can be used to design custom shoe orthotics for the feet of disabled patients (flat feet, high-heel syndrome, Morton's neuroma syndrome, metatarsalgia, and other foot deformities) and fabricated of AFO shoes. This system is expected to resolve the design and manufacturing problems faced by sandal and shoe industries for developing customized AFO shoes products.

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