A Pilot study for Usefulness of Customized Wrist Splint By Thermoforming Manufacturing process Using 3D printing : Focusing on Comparative Study with 3D scanning Manufacturing process

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ABSTRACT

The occupational therapist can manufacture of the upper limb splint according to the shape of the body, taking into account the client's performance patterns and predictable risks, and can help them adjust to their activities of daily living by training them with management methods and precautions. Manufacture of the upper limb splint is an activity that uses special materials of plastic to make it suitable for individuals through manufacturing, including design plan.

The splint is a device for preventing and correcting physical deformities and improving their movements. Sometimes it is necessary for rehabilitation for a while, but it is essential for occupational aspect and community activities, and it is a necessary factor for the daily life of people with disabilities. the splint uses the principle of three-point pressure, the principle of compression and the principle of shearing force to align and support the body and to protect the body part. Depending on the area of body, it can be classified as upper limb, lower limb, or spine. Especially, it is mainly used for upper limb such as hands and arms.

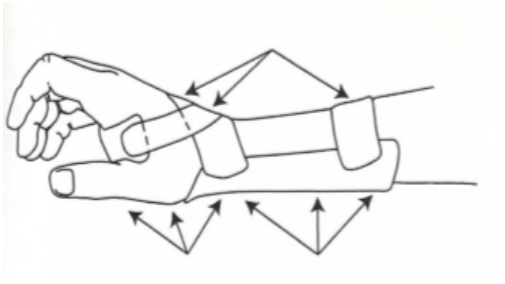


Figure 1: Principle of splint

A cock-up splint is a wrist resting and extension splint that is associated with the wrist pain syndrome. This splint fixes from the bottom of the forearm to the palm of the hand. The wrist is keep in the extended position to maintain the functional posture of the hand, but the resin joint can move relatively freely. Typical diagnoses requiring a cock-up splint are tendonitis, sprained wrists, nerve paralysis, simple wrist fractures, and other diagnoses. Modern people use computers and smart phones for a long time, and the number of occupation groups related to Video Display Terminal is increasing every year, so the frequency of musculoskeletal diseases on the wrist is increasing, and as a result, the cock-up splint is increasingly prescribed.

Figure 2: Cock-up splint

However, the cock-up splint is heavy and air circulation is not possible, so it is difficult to wear for a long time due to skin hygiene problems and itching due to sweating, which causes poor compliance of the splint. In addition, since the plastic thermoplastic board is cut by scissors in clinic, there is a lot of power and a safety risk. And expensive materials are wasted, and the cut edge is not clean.

In order to overcome these problems, researches has emerged on the manufacturing of splint using 3D printing, which is widely recognized as the latest manufacturing technology. 3D printing is a technology that manufacture of layer by layer processing

information from 3D scanning or 3D modeling, and it is now highly interesting and studied in a various fields. 3D printing technology shows a system specialized in small quantity production system of various types and contributes to the coming of customized manufacturing industry reflecting personal tendency. Therefore, 3D printing possible to make the splint as an optimized product according to the body, and occupational therapists will contribute to the manufacturing of splint by using 3D printing technology because they understand the anatomical body structure and movement function of the patient.

As a result of reviewing the application of 3D printing technology to the upper limb splint, using a 3D scanner to shoot the upper limb and 3D modeling the photographed data and proceed 3D printing. To introduce simplify the 3D scanning manufacture method based on 3D printing.

However, there is a problem to be solved in order to manufacture an splint by the 3D scanning manufacture method in actual clinic. First, 3D scanning requires maintaining a static posture for a certain period of time, which is difficult due to pain, tremors, stiffness, and relaxation. Second, the shape obtained by 3D scanning has an error rate, and since an error rate is higher for an inexpensive scanner, an expensive scanner is required to manufacture a customized product. Third, the splint manufactured using 3D scanning is difficult to modify. Therefore, if you do not fit your body with the error rate according to the equipment performance, you have to go through a troublesome process and waste time and materials.

So I have devised a new process that does not use 3D scanning based on 3D printing, which replaces some of the splint manufacturing processes in the clinical field, and complementary relationships. The process is as follows.

First, fix the upper limb on the A3 paper and draw a line of upper limb using a ball-point pen.

Figure 3: Upper limb measurement

Second, the cock-up splint design drawing on the outline of the upper limb drawn on A3 paper, and 2D scanning for save as a JPG file.

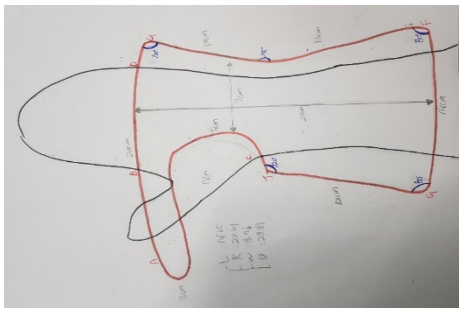


Figure 4: Drawing a Cock-up splint design

Third, the JPG file is loaded into the cad software and 3D modeling is performed by drawing lines along the cock-up splint design, and the pattern for weight reduction and air circulation.

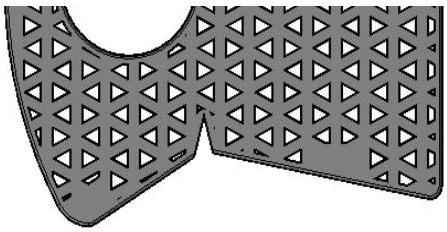


Figure 5: 3D Modeling

Fourth, transmit the saved 3D modeling file to 3D printer and 3D printing.

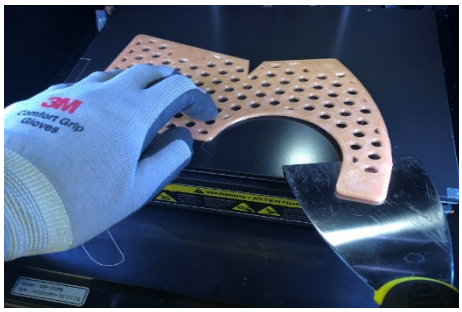


Figure 6: 3D Printing

Fifthly, the output cock-up splint is surface-processed using sand paper [Fig. 7].

Figure 7: Finishing

Sixth, put the cock-up splint in a water temperature control tank, soften it, wipe the water, check the temperature, and thermoforming on the upper limb.

Figure 8: Thermoforming

Seventh, attach the strap.

. Figure 9: Attach the strap

Eighth, educate the subjects and their caregivers about precautions and management methods, and provide them with written instructions.

. Figure 10: User education

Therefore, in this study manufacturing of cock-up splint by thermoforming method and 3D scanning method based on 3D printing technology applied to the actual wrist pain patient. And compared to satisfaction and effectiveness.

DESIGN

Research procedure

In this study, two occupational therapists who had experience manufactured of splint, and 3D scanner, 3D printer, and 3D modeling were contacted. the two subjects who complained of wrist pain were manufactured of cock-up splint in different manufacture method process. Both processes use 3D printing to create a cock-up splint, but there is a difference in the way 3D modeling data is obtained. Therefore, we divided the method into two ways of obtaining 3D data by using 3D scanning and 3D modeling by upper limb measurement without 3D scanner. The subsequent finishing, attach the strap, user education continues in the same way. We will have compared the total manufactured time by measuring the time step by step during the process and compare the product satisfaction and service satisfaction using K-QUEST 2.0(Quebec User Evaluation of Satisfaction Assistive Technology 2.0) to check which process is more effective. The research procedure is summarized as Figure 10.

Table 1: Information of Subject

	Subject A	Subject B
Age	17	26
Sex	male	female
Diagnosis	DeQuervain Syndrome	Carpal tunnel Syndrome
Job	Student	Employee
Damaged side	Lift	Right
ADL	Independent	Independent
Cognition	Normal	Normal

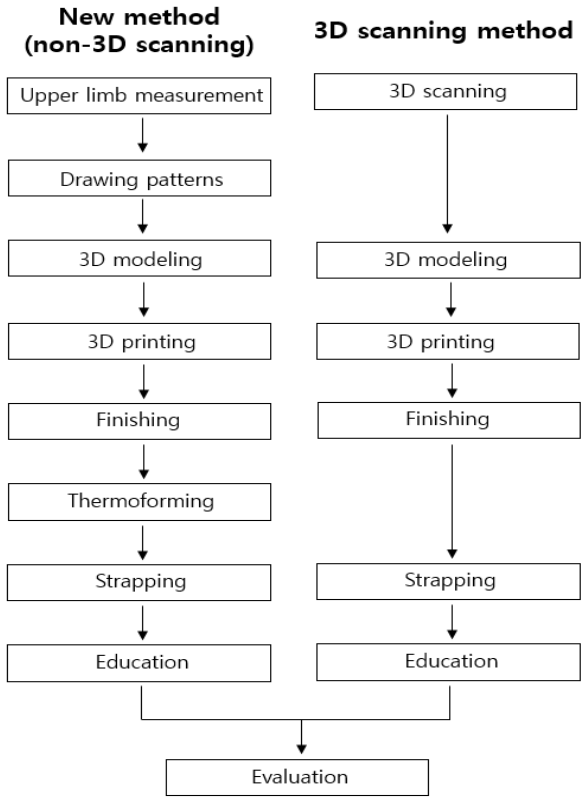


Figure 11: Research procedure

Analysis method

In this study, the average of the product satisfaction, service satisfaction, and manufactured time were calculated to compare the two ways manufacturing methods based on 3D printing. no statistical techniques were used Because of the small number of subjects.

RESULT

Completed Cock-up splint

Subject A was worn on the right and Subject B was worn on the left.

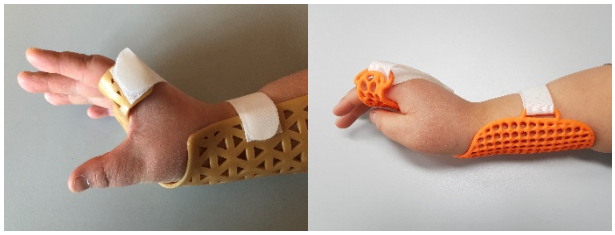


Figure 12: Subject A
(Left: Wrist splint by Thermoforming,
Right: Wrist splint by 3D scanning)

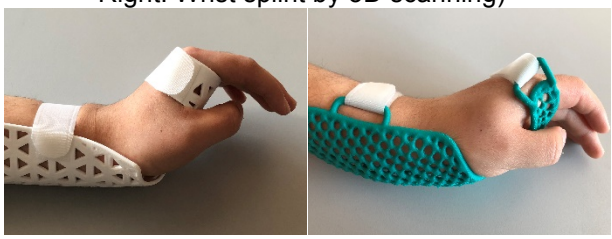


Figure 13: Subject B
(Left: Wrist splint by Thermoforming,
Right: Wrist splint by 3D scanning)

Production satisfaction

The results of the comparison of the product satisfaction in wrist splint by two ways manufactureing process methods. There was more than One-point difference in the standard at safety, durability, comfort, and effectiveness. Overall, the thermoforming process was more satisfying than the 3D scanning process.

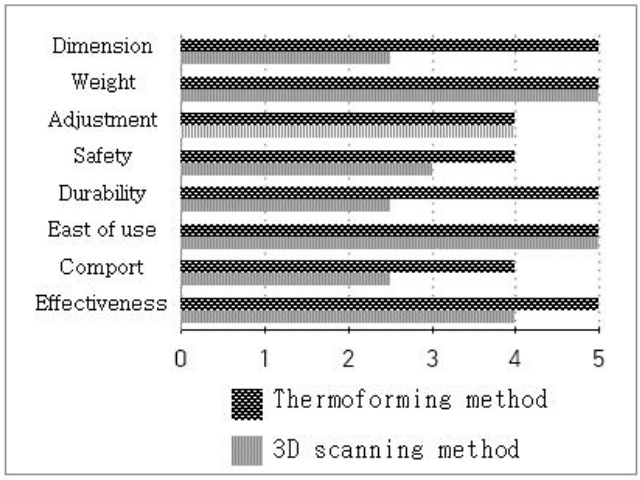


Figure 14: Production satisfaction

Service satisfaction

Service satisfaction is composed of four items, but only three items were evaluated except follow-up service items. The service delivery score of the thermoforming process method was higher than that of the 3D scanning process method, and the scores of the other two items were the same.

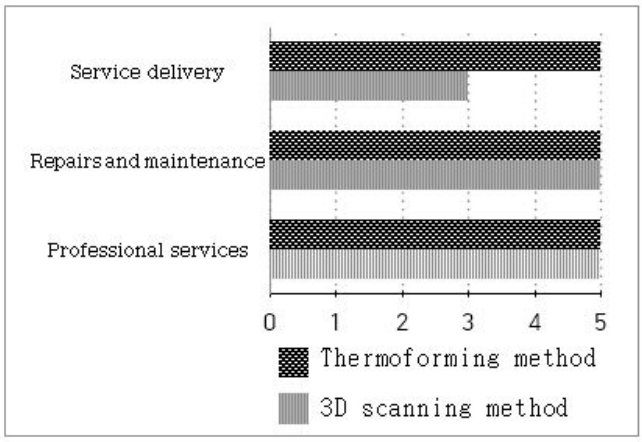


Figure 15: Service satisfaction

Manufactured time

We measured the step-by-step the times of the two ways manufacturing methods. And each step time was calculated for mean value. We did not measure the step like finishing, attach the strap, user education which are commonly included to compare pure turnaround times between the two ways manufacturing methods.

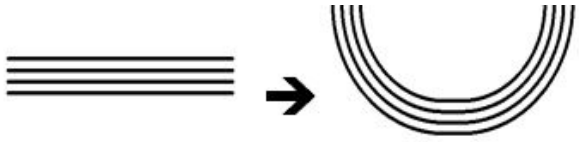
Table 2: Comparing the time of two ways manufacturing method

Thermoforming method (min)		3D Scanning method (min)	
Upper limd measurement	3	3D Scanning	28
Drawing a splint design	6		
3D Modeling	11	3D Modeling	17
3D Printing	185	3D Printing	484
Thermoforming	18		
Total	223	Total	529

CONCLUSION & DISCUSSION

Comparing the score of product satisfaction, the score of the thermoforming method was higher than that of the 3D scanner in the five items (Dimension, safety, durability, comfort, effectiveness). It is thought that this is the result that the cock-up splint by 3D scanning method is outputted in the form of free curve according to the shape of upper limb.

3D printing is stacked as the heating bed is lowered in the Z-axis direction, so that the wrist and forearm circumference like the free curve portion are laminated more weakly than the bottom portion supporting the wrist. So, it is considered that the durability, safety, comfort item score in 3D Scanning method lower than the thermoforming method.



(a) Lamination layer of Thermoforming method

(b) Lamination layer of 3D scanning method

Figure 16: Comparing the lamination layer

As a result of comparing service satisfaction scores, the 3D scanning method was evaluated to be lower than the thermoforming method in the service delivery item among the three items. Because of the lost tracking due to difficulty maintaining static posture, Therefore, the subject repeatedly shot 3D scanning. it is considered complaints have appeared.

Next, the comparing manufactured time by the two ways method. The 3D scanning method took more than two times longer than the thermoforming method. 3D modeling took a similar amount of time between the two ways method, but 3D scanning method took more time than the thermoforming method because of repeated shot the 3D scanning performed to obtain the data of the damaged upper limb. In addition, 3D printing time of the 3D scanning method was about 2.5 times longer than the

thermoforming method, because the height of the cock-up splint by thermoforming method is 2.5mm, while the 3D scanning method cock-up splint The maximum height was 7.5cm, so it took a long time to laminate and more time was required as additional support for free curve like wrist and forearm circumference.

However, this study involved only two subjects, so there are limitations to the generalisation of the results. In future research is considered necessary to select large number of subject and to evaluate the clinical effectiveness. Also, the 3D scanning method should not be disparaged. However, in order to using 3D scanning method to be applied in the clinic field, it is necessary to consider how to perform 3D scanning for actual patients.

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