DESIGN OF NECK BRACE FOR BURN REHABILITATION BASED ON PARAMETRIC INVERSE MODELING

1Liu Zhihui, Doctor, Senior lab technician, Master Tutor

[1]Zhu Ying, Class 228, School of Mechanical Engineering, 1st year of Master

[1]Xu Yinling, Master

Donghua University

ShangHai

1 Introduction

The neck is an area rich in blood vessels, nerves and lymphatic vessels[1], and deep burns tend to lead to scar hyperplasia and scar contracture after healing[2], thus affecting the appearance and function[3]. Current treatment methods include compression therapy, brace fixation and medication[4], among which compression therapy is widely used for its convenience, low cost, effectiveness and simplicity[5]. Among them, neck orthoses and braces are a relatively simple and effective treatment method in compression therapy, but there are problems such as easy insecurity [6], no compression on the contracture scar of the jaw and neck, complicated manufacturing process, high cost, and poor patient comfort during the manufacturing process. Therefore, how to improve the shortcomings of neck orthoses and braces, improve the efficiency of personalization and patient comfort in wearing them has become the focus of attention.

This paper uses a 3D printed neck brace digital design method based on parametric inverse modeling and improves the shortcomings of existing neck orthoses and braces, aiming to assist orthopedists to achieve rapid and accurate modeling of neck braces and improve the efficiency of personalization and patient wearing comfort.

2 Acquiring and processing data

A scanner was used to scan and generate digital models of the jaw and neck of 10 subjects with widely varying body shapes. In order to collect the data without interruption, the subjects were scanned while sitting upright on a rotating table and rotated clockwise for one week. Each subject was scanned twice, and the two point clouds were later stitched together and exported in ply format.

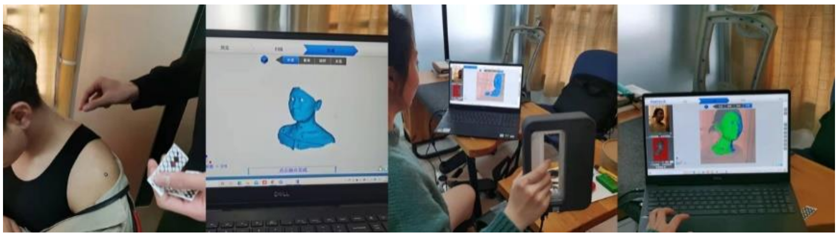

Fig. 1 Neck Scanning Procedure

Two females and two males were selected as typical samples from 10 subjects and their jaw and neck models were preprocessed. The point cloud data were first imported and redundant data were removed, then meshed and holes were filled, the surfaces were simplified using the smoothing tool, and finally cropped and exported in STL format as shown in Figure 2.

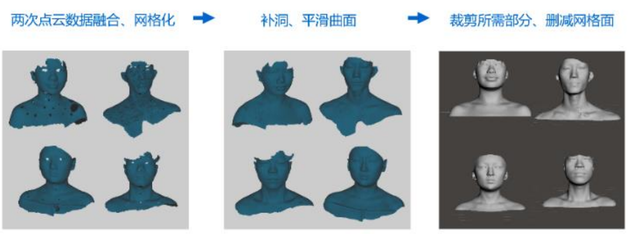

Fig. 2 Preliminary data processing

3 Description of the seven-stage process

(1) Extracting Eigenvalue Points. First, import the digital base model of the jaw and neck into Rhino, draw tangent lines and equipartition according to the range of the neck brace coverage, then extract the personalized feature contour line of the model, set up the intersection point and connect the d equipartition points to generate the equipartition line, extrude the equipartition surface, and establish the cross-section line where the equipartition surface intersects with the model is the personalized feature contour line of the jaw and neck, as shown in Figure 3. Finally, the personalized shape feature type value points are extracted. The digital model of the jaw and neck is a complex surface, and the extracted personalized feature contour line consists of numerous folds. To ensure the quality of the model surface, the equipartition point obtained from the equipartition feature contour line is the personalized shape feature value point of the jaw and neck, as shown in Figure 4.

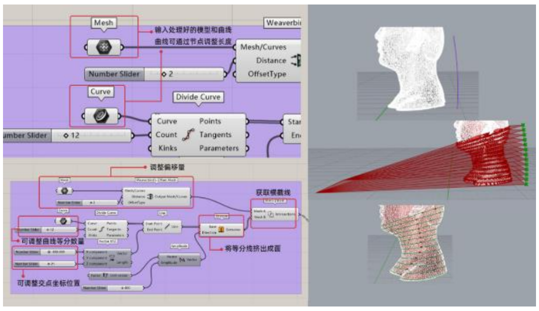

Fig. 3 Extracting feature contours

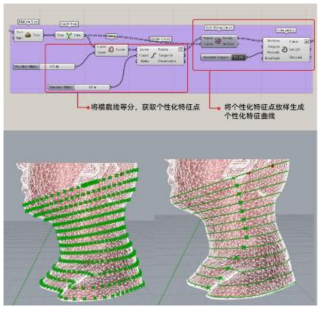

Fig. 4 Extracting Eigenvalue Points

(2) Building surfaces. According to the extracted personalized shape eigenvalue points, the sorted points are reordered according to their centers, and the curves are generated by the release and outward offset parameters to generate the basic coverage of the neck brace for burns, as shown in Figure 5.

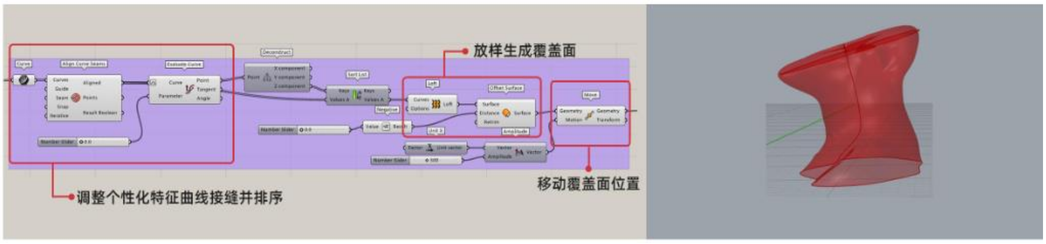

Fig. 5 Building surfaces

(3) Cutting surface. First, input two tangent curves and extrude to generate the tangent surface, then the tangent surface intersects with the basic covering surface x of the neck brace to get the cross-section line, and use it to divide the covering surface and remove the excess parts. For the convenience of wearing, the neck brace is cut into front and back parts in the same way, as shown in Figure 6.

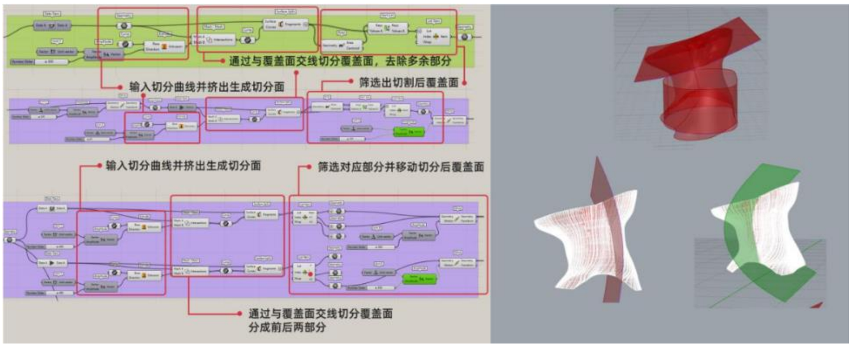

Fig. 6 Cutting surface

(4) Smoothing model edges. To avoid too sharp edges of the neck brace for burns, a rounding treatment operator component was designed, as shown in Figure 7, which extracts the upper and lower edge lines of the covering surface of the neck brace to generate a rounded tube.

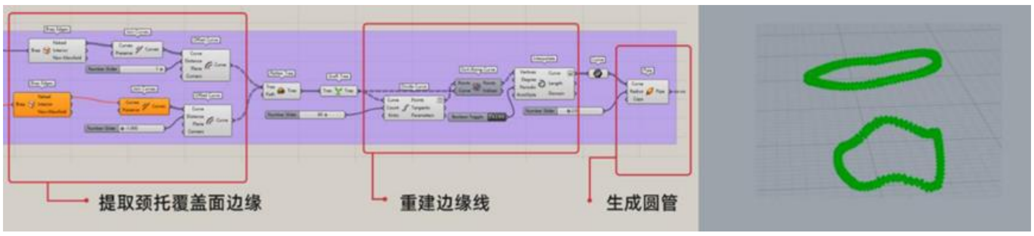

Fig. 7 Smoothing model edges

(5) Creating elastic fixation straps. To facilitate patient use, a self-adhesive elastic band was used to connect the front and back parts of the neck brace. To facilitate the adjustment of the elastic band mounting position, a program was written as shown in Figure 8 to extract the cross-sectional line of the neck brace coverage and select the midpoint to establish the elastic band mounting position.

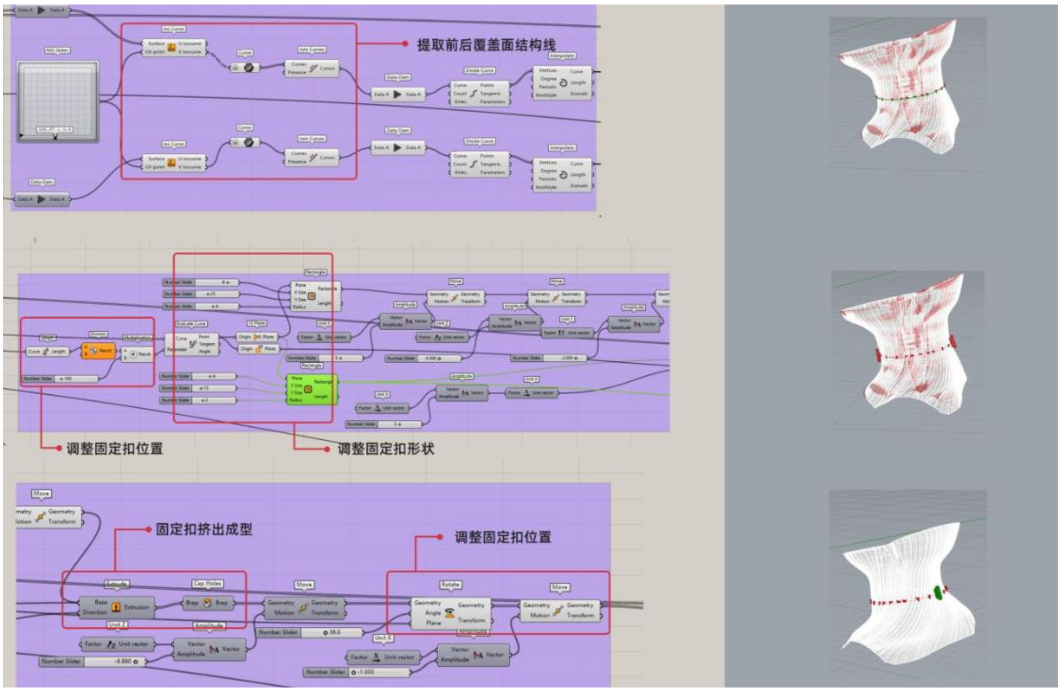

Fig. 8 Creating elastic fixation straps

(6) Generating round holes. To enhance the permeability and save material at the same time, round holes are generated on the overlay surface of the model. Firstly, the covering surface is divided into a certain number of square meshes, and the meshes at the edges of the covering surface are combined and filtered and deleted. Then generate circles within each grid, and combine and cut the area where the circular holes are generated with the covering surface, as shown in Figure 9.

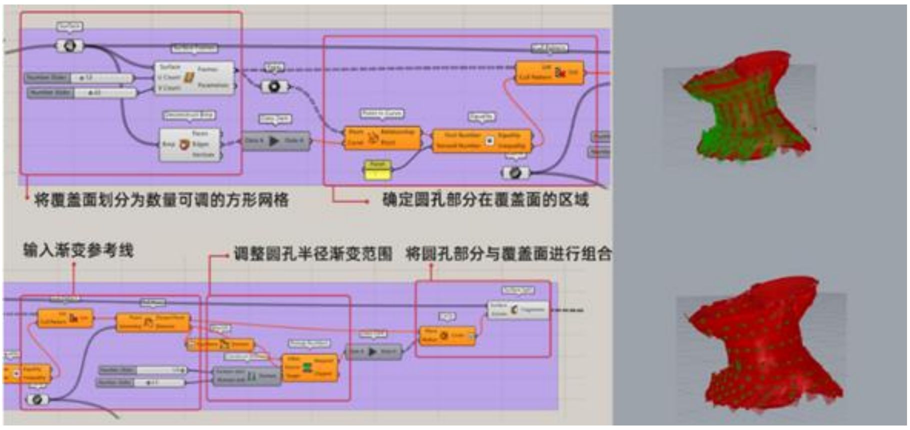

Fig. 9 Generating round holes

(7) Optimizing products. The cut coverage is converted into a mesh, then the thickness of the model is increased, and finally the edge round tube, elastic band assembly, and the body of the neck brace are combined, as shown in Figure 10

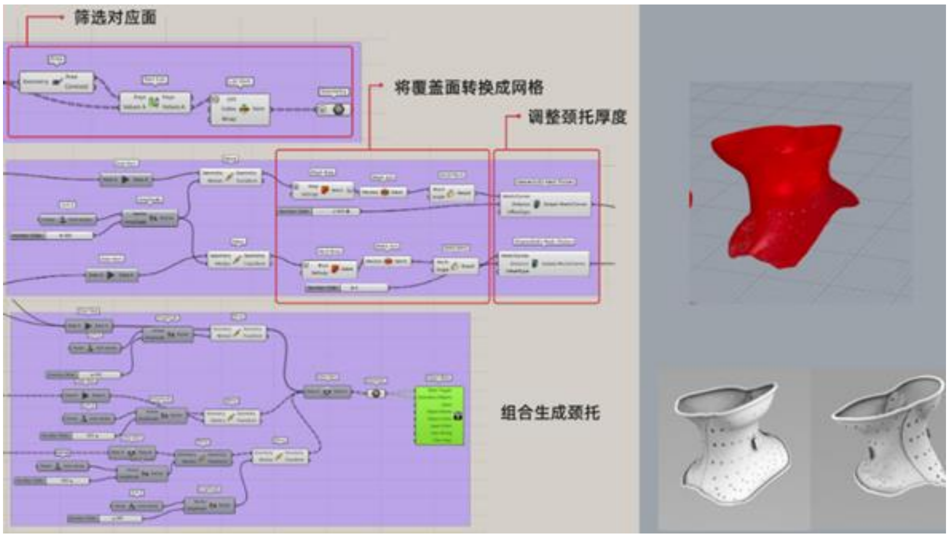

Fig. 10 Optimizing products bracket

The final digital model of the rehabilitation neck brace for burns is shown in Figure 11, and the neck brace wearing diagram is shown in Figure 12

Fig. 11 Model Rendering

Fig. 12 Wearing Diagram

4 Experiments

The effectiveness and advantages of the parametric-based inverse modeling design solution were verified by modeling program efficiency testing, modeling program deviation verification, and neck brace stress analysis. The modeling program efficiency test proved that the program can not only improve the efficiency of neck brace design, but also generate models quickly for non-specialists with simple training. The deviation of the modeling program verified that the models generated by the parametric modeling program were better matched than the conventional neck brace, as shown in Figure 13. The neck brace pressure analysis demonstrated that the design of the neck brace based on parametric inverse modeling met the criteria required for compression therapy, as shown in Figure 14.

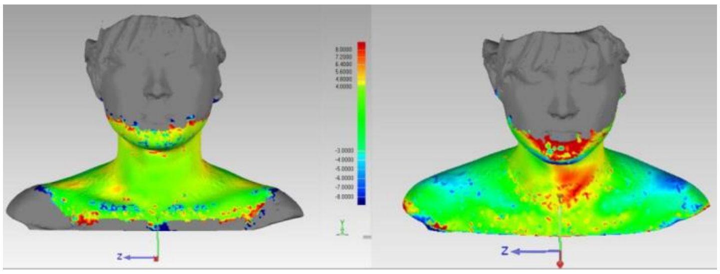

Fig. 13. Deviation chromatogram

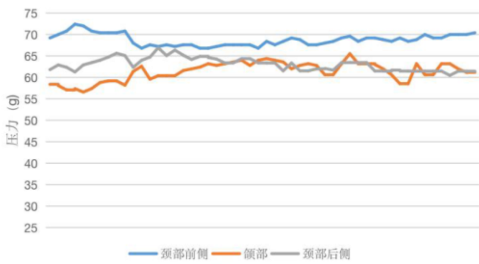

Fig. 14. Pressure signal line graph

5 Conclusions

In this paper, we propose a digital design method for 3D printed neck brace based on parametric inverse modeling technology and verify its feasibility and advantages through practical application. It was demonstrated through experiments that the method can improve the comfort of maxillary and cervical burn patients and improve the therapeutic effect, as well as promote medical-industrial collaborative design, reduce the learning cost of users and improve the efficiency of customized design. In the post-validation phase, the prototype could not be worn by patients with maxillary and cervical burns, and it is planned to invite specific patients for testing and validation at a later stage, and to conduct an in-depth study of the wall thickness values of the neck brace using finite element analysis.

References

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