Original Article

An ear-shaped film with a "leg"

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Background: The reconstructed auricle projection is an essential element of ear reconstruction. The novel use of an ear-shaped film with one or two "legs" can successfully provide a healthy auricular contour, length, and width, hence improving the three-dimensional (3D) contour of the reconstructed auricle.

Methods: Sixty-one patients (31 men and 30 women) with unilateral ear reconstruction (22 on the left and 39 on the right side) who underwent auricular reconstruction using the novel ear-shaped film at the Plastic Surgery Hospital of the Chinese Academy of Medical Sciences between February 2021 and June 2022 were enrolled in this retrospective study.

Results: Using the Jarque-Bera and paired *t*-test, we found no statistically significant differences between the reconstructive and healthy ears in terms of length (5.93±0.56 *vs.* 5.89±0.49 cm, P=0.208), width (3.15±0.31 *vs.* 3.13±0.30 cm, P=0.224), height (2.48±0.33 *vs.* 2.51±0.36 cm, P=0.079), and perimeter (10.83±1.06 *vs.* 10.69±0.95 cm, P=0.164), using the novel ear-shaped film. The reconstructed auricle location was deemed satisfactory for all patients and their families.

Conclusions: The novel ear-shaped film may reflect the structure and height of the auricle during ear reconstruction surgery. Implementing this method is easy, and its impact is significant. This technique can be widely used in all types of otoplasties.

Keywords: Reconstructed auricle; ear reconstruction; ear-shaped film; congenital microtia

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Introduction

Microtia is a common congenital deformity (1). It is caused by various etiologically heterogeneous and multifactorial genetic mutations that are not fully understood yet (2). Abnormal appearance and conductive hearing loss can lead severe psychosocial consequences (3). Ear reconstruction with autologous rib cartilage still remains the gold standard for this disease, however, it is also one of the most challenging operations in plastic surgery (4). The intraoperative design of the cartilage framework is the key to improving the appearance and symmetry of the bilateral auricles, despite the complexity of the operation (5,6). Consequently, this task can only be accomplished by creating a template matching the contour, length, and width of a healthy ear.

An ear-shaped film made from X-ray film has always been used to emulate the contralateral ear appearance. However, the traditional ear-shaped film cannot provide stereo auricular information, which is one of the most demanding challenges to achieve in auricular frame fabrication (7). Nowadays, Three-dimensional (3D) templates have been created by using 3D printing combined with 3D scanning or established through virtual reality technology (8-10). However, these technologies require

Figure 1 The traditional ear-shaped film and the novel type of ear-shaped film with one or two "legs".

advanced or specialized devices and are not amenable to widespread adoption at all levels of care. Consequently, we designed an ear-shaped film with one or two "legs" based on a two-dimensional (2D) X-ray film that could reflect the details of the auricular structure and height, which has been used in auricular reconstruction surgery with remarkable results (11). We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-22-477/rc).

Methods

Clinical data

Sixty-one patients (31 men and 30 women) with unilateral ear reconstruction (22 on the left and 39 on the right side) who underwent auricular reconstruction using the novel ear-shaped film at the Plastic Surgery Hospital of the Chinese Academy of Medical Sciences between February 2021 and June 2022 were enrolled in this study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Medical Ethics Committee of Plastic Surgery Hospital of the Chinese Academy of Medical Sciences (No. 2021-1). All patients and their families signed an informed consent form.

All participants in this study were patients with unilateral microtia who were in good health. The exclusion criteria were as follows: (I) patients with any auricular deformity of the healthy side, such as Stahl's ears, prominent ears, or cryptotia; (II) highly uncooperative patients; and (III) patients with auricular trauma and surgery history of the healthy side.

How to make an ear-shaped film with a "leg"?

This study used a soft ruler, drawing pen, and a piece of X-ray film. A piece of film of sufficient size (allowing for an approximate "leg" length) was cut. The patient stood against the wall, with the affected ear facing the wall and the healthy ear facing the practitioner, and his/her head gently rested against the wall to support and keep the head relatively stable during the ear-shaped film production. The physician used a marker pen to outline the healthy ear on the film (helix, crus of helix, crura of antihelix, tragus, antitragus, lobe, scapha, and concha) and to determine the location of the highest projection point of the healthy ear (there may be one or more outermost projection points, marked as required) (*Figures 1,2*). The perpendicular distance was recorded from the outermost point on the helix to the cranial plane behind the ear and drew an equivalent distance in the vertical direction of the tangent line at the corresponding point on the ear-shaped film, with one or two "legs" of which the width is 0.5 cm to provide adequate support for the film (*Figure 2A-2C*). The novel ear-shaped film was trimmed carefully along the contour with scissors. After cutting, the ear-shaped film was compared with the healthy ear to observe whether it better reflected the detailed structure and height of the ear (*Figure 2D-2H*).

How to use the ear-shaped film to fabricate an ear framework?

Auricular reconstruction method was modified based on which we previously described (12). We inserted a kidney-

Highlight box

Key findings

- We designed an ear-shaped film with one or two "legs", which could reflect the details of the auricular structure and height and had been used in auricular reconstruction surgery with remarkable results.

What is known and what is new?

- The traditional ear-shaped film can not provide the stereo information of the normal ear.
- The novel ear-shaped film adds to the achievement of the auricular symmetrical and contented appearance with harmony and integrity in patients with multiple kinds of ear deformities and concave temporal bone morphology.

What is the implication, and what should change now?

- The novel ear-shaped film has the advantages of being simple to create, easy to extend, and precisely mirroring the 3D structure of the normal contralateral ear, and should be extended to all kinds of otoplasty.

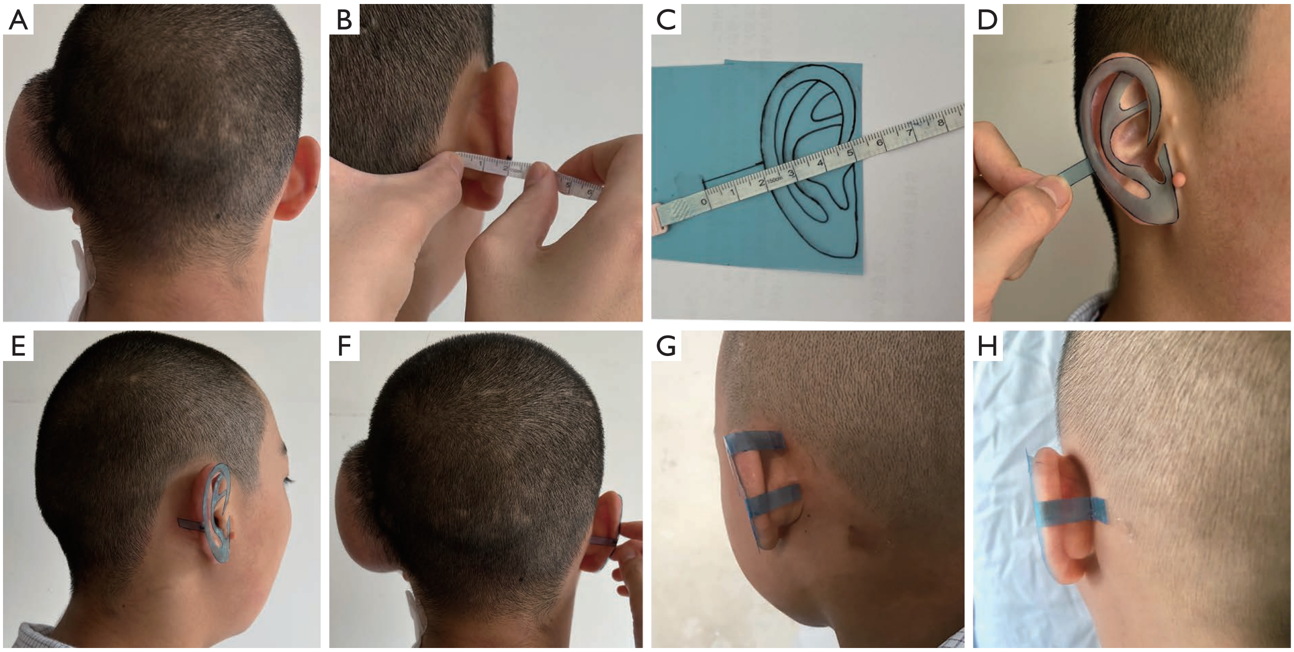

Figure 2 The method of making an ear-shaped film with one or two "legs". Doctor who stands behind the patient marks the location and number of the highest projection point of the ear. Measure the vertical distance from the highest projection point to the temporal bone (A,B). Depict the specific details of the ear in the film. Draw the length of the "leg" with a width of 0.5 cm horizontal to the line in which direction is tangent to the highest projection point (C). After drawing the ear-shaped film, compare its details and height with a healthy ear and repeatedly optimize the ear film shape (D-F). The amount of the "leg" depends on the number of the auricular highest projection point (G). The "leg" can be designed in a foldable style as needed so that it can be adjusted to the appropriate height before being cut to a determined length (H).

shaped tissue expander in the patient's mastoid region subcutaneously, and the period of expansion was 2 months. Subsequently, we harvested the sixth, seventh, and eighth costal cartilages in children, individually (*Figure 3A*). The framework we fabricated was composed of three levels, with each level representing a different elevation. The carving process was strictly followed the outline of the ear-shaped film that was placed directly against the cartilage (*Figure 3B*). Notably, we held the leg of the ear-shaped film using forceps when curving the details of the auricular, and held its main body when comparing the height of the reconstructed ear and the normal ear. The main body of the framework was the second level and was mainly carved from the sixth rib (*Figure 3B*). We resected a piece of crescent-shaped cartilage to carve the scapha (*Figure 3C*). We cut an L-shaped cartilage from the seventh costal cartilage to form the triangularis (*Figure 3D*). Then we split the seventh costal cartilage horizontally, and placed the upper part which was cut into a desired shape at the top of the level to form the helix and the crus helicis (*Figure 3E*). We added a cartilage strip to the lateral part of the sixth cartilage framework to form the superior crura of the antihelix (*Figure 3E*). The projection of these constructions formed an antihelix and the superior and inferior crus of the antihelix. The third level was made from the sixth and eighth rib and was the base of the framework, maintaining its prominence of the framework (*Figure 3F*). After building the three levels, the leg of the ear-shaped film was used to determine whether a cartilage block was placed beneath the framework. The height of the cartilage block was decided by the difference between the length of the ear-shaped film's leg and the normal side auricular height as illustrated in the figure (*Figure 3G*). Three parts of the carved structures were assembled with titanium wires, and a 3D framework was created (*Figure 3H*). We then removed the expander and encapsulated the entire framework with the fascia and the enlarged retroauricular skin which was thin and non-hair-bearing (*Figure 4*). After 6–12 months of the reconstruction operation, we excised an extraneous soft tissue to deepen the conchal floor and utilized the remnant ear to form tragus. A small skin graft (approximately 3×2 cm^2) from the chest wall was used to deepened the

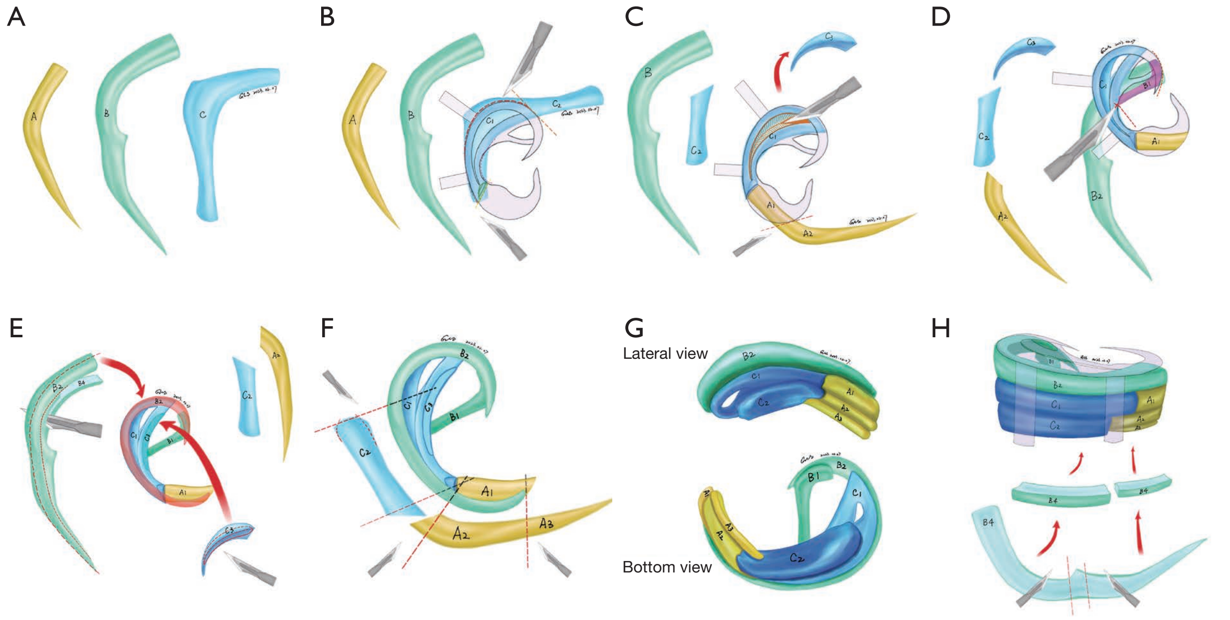

Figure 3 The application of the novel ear-shaped film in operation. The sixth, seventh, and eighth costal cartilage were harvested individually. The yellow one represents the eighth costal cartilage. The green one represents the seventh costal cartilage. The blue one represents the sixth costal cartilage (A). The main body of the framework was mainly carved from the sixth rib with the ear-shaped film placed directly against the cartilage (B). The scapha was curved by excising a piece of crescent-shaped cartilage according to the direction of the ear-shaped film. The arrow means taking out the cartilage from that place (C). The triangularis was curved by excising a piece of seventh costal cartilage (D). The partial seventh and sixth costal cartilage were placed at the top to form the helix and the crus helicis, respectively. The arrows mean putting the cartilage into the correct place (E). A block of cuneal cartilage was added to the lateral part of framework, if the sixth cartilage is not wide enough (F). The lateral view and bottom view of the reconstructive auricular framework (G). Another block of cartilage would be added beneath the framework, if the height of the framework was shorter than the leg of the ear-shaped film. The arrows mean putting the cartilage into the correct place (H).

superior cranioauricular sulcus. Simultaneously, we would adjust the position of the reconstructive auricular framework to keep it in a symmetrical position with bilateral sides by grafting a small skin behind the ear or adding cartilage blocks, if needed.

Evaluation criteria

The reconstructed ear length, width, perimeter, and height were compared to a healthy ear. The postoperative results were self-assessed by the patient or the patient's family.

Ear length: perpendicular distance from the highest point on the border of the helix to the lowest point of the lobule.

Ear width: perpendicular distance from the attachment point of the auricle and face to the outermost point of the helix.

Ear height: perpendicular distance from the outermost point on the helix to the cranial plane behind the ear.

Ear perimeter: curve length of the auricle, which starts from the attachment point of the auricle and skin of the face to the attachment point of the lobule and face.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation (SD). Normality was primarily analyzed using the Jarque-Bera test. Data comparisons were performed using paired *t*-tests. All statistical analyses were performed using the SPSSAU data scientific analysis platform (https://spssau.com). $P<0.05$ was considered to indicate a statistical difference.

Results

From February 2021 to June 2022, 61 patients were enrolled

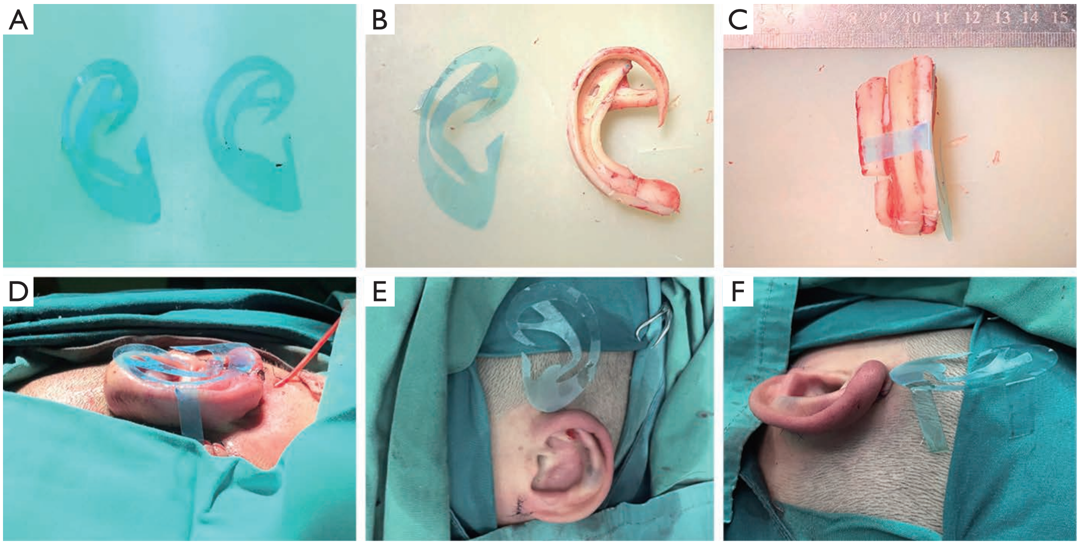

Figure 4 The leg of the ear-shaped film can provide the stereo auricular information in the intraoperative guide for the auricular framework fabrication. Intraoperative application with the novel ear-shaped film (left) *vs.* conventional ear-shaped film (right) (A). The novel ear-shaped film can reflect the structural details and height of the healthy ear intraoperatively and guide the sculpting of the reconstructed auricular scaffold (B-D). The unique ear-shaped film has been applied to patients with ear abnormalities other than unilateral microtia (E,F).

in a retrospective study of the technique outlined. Their median age was 8 [interquartile range (IQR), 7–11] years, and the mean follow-up period was 9.97±2.24 months. Of the 61 patients, 31 (50.82%) were male, and 30 (49.18%) were female, with 39 (63.93%) in the right ear and 22 (36.07%) in the left ear. No statistically significant differences existed between the reconstructed and healthy ears in terms of length, width, height, and perimeter (*Table 1*). Moreover, the satisfaction rate of patients and their families with the shape of the reconstructed auricle was 100% (*Table 1*). This result indicated that the "leg" of the ear-shaped film could provide the stereo auricular information in the intraoperative guide for the auricular framework fabrication (*Figure 3*), and that the patient's normal ears were symmetrical with the reconstructed ears. The typical cases are shown in *Figures 5,6*.

Discussion

Auricular deformities (microtia) can cause physical, social, and psychological impacts on patients' well-being (13). Autologous costal cartilage ear construction remains the most commonly used method in external auricle reconstructive surgery (14). Matching the height of the normal contralateral side is a vital and critical step in ear reconstruction (15). This achieves the auricle's symmetrical and contented appearance with harmony and integrity (16). A perfect ear-shaped film can accurately reflect the size and width of the healthy ear to help the surgeon determine the reconstructive ear position and the number of costal cartilages to be collected. The transparent film can project the detailed structures of the normal side onto the affected side to guide the surgeon in carving the costal cartilage and how it should be joined.

However, traditional X-ray film templates cannot provide the stereo auricular information of the normal ear. 3D models of the normal ear constructed using scanning technology combined with 3D printing cannot lie directly against the cartilage (17). Moreover, the projection of a virtual image of a normal ear on the affected side using VR glasses and virtual reality technology requires high technical skill and precludes intraoperative flexibility from multiple angles. Owing to its complexity, projecting a virtual image of the normal ear on the affected side using VR glasses does not allow for a flexible intraoperative comparison of the model with the rib cartilage scaffold from multiple angles. It also increases the potential risk of intraoperative infection (18).

Consequently, we designed a unique ear-shaped film with one or two "legs" that can reflect the protrusion measured along a notional plane spanning from the upper or middle protrusive point of the helical border to the scalp. The "leg" can also stably support the ear-shaped film. Notably, the

Table 1 Data summary

Variables	Specific values	Paired *t*-test, P value
Age (years), median [IQR]	8 [7–11]	–
Gender, n (%)		–
Male	31 (50.82)	
Female	30 (49.18)	
Follow-up (months), mean ± SD	9.97±2.24	
Perimeter of the healthy ear (cm), mean ± SD	10.69±0.95	0.164
Perimeter of the reconstructive ear (cm), mean ± SD	10.83±1.06	–
Width of the healthy ear (cm), mean ± SD	3.13±0.30	0.224
Width of the reconstructive ear (cm), mean ± SD	3.15±0.31	–
Length of the healthy ear (cm), mean ± SD	5.89±0.49	0.208
Length of the reconstructive ear (cm), mean ± SD	5.93±0.56	–
Height of the healthy ear (cm), mean ± SD	2.51±0.36	0.079
Height of the reconstructive ear (cm), mean ± SD	2.48±0.33	–
Satisfaction, n (%)		–
Completely satisfied	45 (73.77)	
Satisfied	16 (26.23)	
Unsatisfied	0 (0.0)	

IQR, interquartile range; SD, standard deviation.

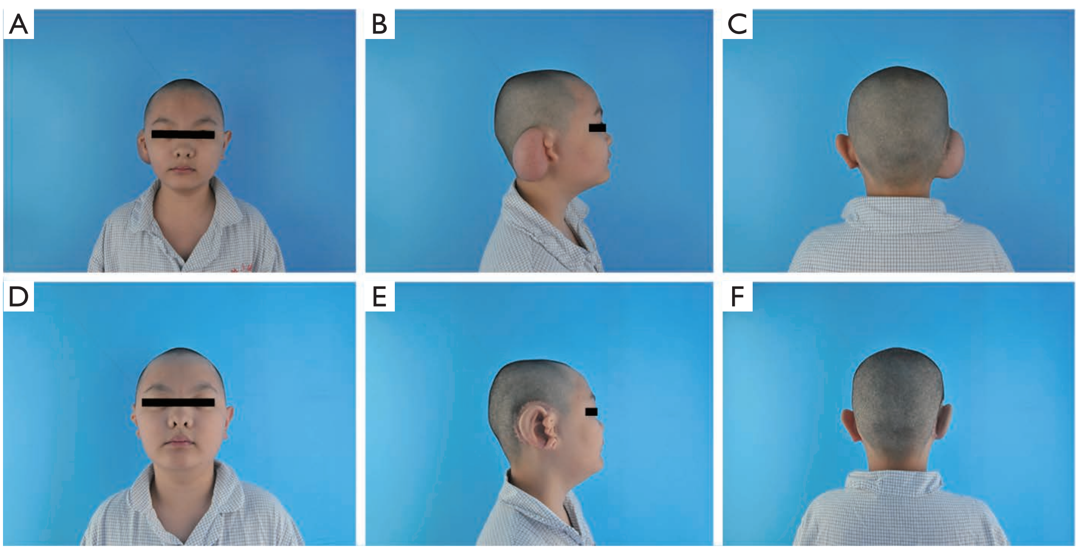

Figure 5 A 10-year-old male patient had right microtia, and he received the auricular reconstruction using the novel ear-shaped film. Preoperative frontal view of patient 1 (A). Preoperative lateral view of patient 1 (B). Preoperative rear view of patient 1 (C). Postoperative frontal view of patient 1 (D). Postoperative lateral view of patient 1 (E). Postoperative rear view of patient 1 (F). The images are published with the patient's and his parent's consent.

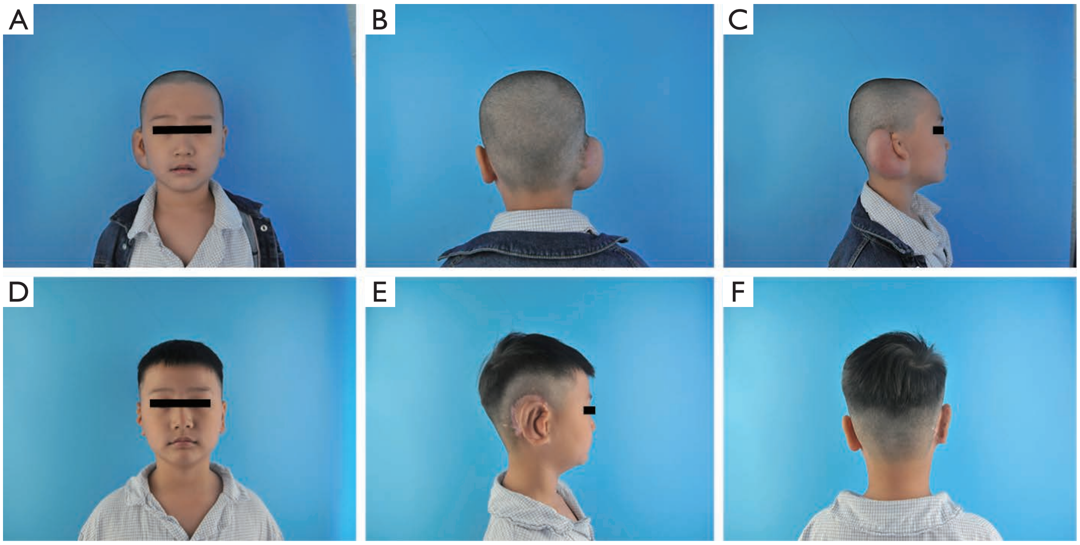

Figure 6 The novel ear-shaped film was used on the 7-year-old microtia boy. Preoperative frontal view of patient 2 (A). Preoperative lateral view of patient 2 (B). Preoperative rear view of patient 2 (C). Postoperative frontal view of patient 2 (D). Postoperative lateral view of patient 2 (E). Postoperative rear view of patient 2 (F). The images are published with the patient's and his parent's consent.

"leg" connects to the principal part of the film. Otherwise, it may be separated from the main body by soaking in an iodine tincture or ethyl alcohol for asepsis. This novel type of ear-shaped film facilitates us to mimic the delicacy and the projection of the usual opposite ear, estimate the need for skin grafting, and achieve a cosmetically refined auricle. Moreover, it is likely optimal to hold the "leg" of the film but not the rest, when using it to guide the framework sculpture without covering any details provided by the film's main body. Before using the special ear-shaped film, we measured the height of the healthy auricle by a steel ruler, but this required repeated comparisons during intraoperative sculpting and generally 2–3 comparisons for the most experienced surgeons to determine the final height of the auricular framework. However, with the novel ear-shaped film, young and experienced surgeons rarely must make a second adjustment or complete the procedure quickly and easily.

Furthermore, when the length of the "leg" is uncertain, it can be folded to adjust its optimum height (*Figure 2H*). It helps assess the auricular height of patients with concave temporal bone morphology. In general, for these patients, the auricular framework and a cartilage mass with uncertain height were inserted into the irregular temporal cavity multiple times, the depth of which cannot be simply measured by a ruler, to ensure symmetry with the opposite side. The operation will be more easy and efficient if the particular ear-shaped film is used to adjust the appropriate height of its "leg" as a template to fabricate the framework.

Sixty-one patients were included in this study. The results did not show any statistical differences in the reconstructive ear length, width, perimeter, and height compared with the normal side. It confirmed that the novel ear-shaped film reconstructed the shape and size of the deformed ear like the normal contralateral ear. However, this study had some limitations. First, we were limited by the number of patients included in the study. Second, this ear-shaped film is theoretically suitable for all kinds of auricular deformities (*Figure 4E,4F*). However, this study only evaluated its use in patients with unilateral microtia for two reasons: (I) during the epidemic, patients with other auricular deformities did not require reoperation and were not followed up quickly; (II) in other otoplasties, the patient's original ear is used as the basis, conforming to the contralateral side as much as possible, as opposed to being strictly shaped to the opposite side, as in the case of unilateral microtia. Consequently, it is impractical to assess the effect of the application of the novel ear-shaped film on other otoplasties. Additionally, we were limited by using the auricular height but not the auriculocephalic angle as the evaluation criterion. This is because it is easier to accurately measure and compare the height rather than the angle when surgeons sculpt and implant the costal cartilage scaffold during operation. In addition, all patients in this study had a residual ear on the affected side, which could easily interfere with the auriculocephalic angle measurement.

Future research will also measure the auriculocephalic angle to permit side-by-side comparisons with other studies.

Conclusions

This study indicates that the ear-shaped film with one or two "legs" has the advantages of being simple to create, easy to extend, and precisely mirroring the 3D structure of the normal contralateral ear, and hence has numerous applications in auricular reconstructive surgery.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-22-477/rc

Data Sharing Statement: Available at https://tp.amegroups.com/article/view/10.21037/tp-22-477/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-22-477/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Medical Ethics Committee of Plastic Surgery Hospital of the Chinese Academy of Medical Sciences (No. 2021-1). Patients and their families have signed informed consent.

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