The Importance of Base Frame Fabrication in Microtia Reconstruction

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Technical advance

Keywords: Microtia, Auricular reconstruction, Base frame, Costal cartilage

Posted Date: July 21st, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-41625/v1>

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Abstract

Background The base frame provides stable support for the helix, antihelix, and tragus-antitragus complex in microtia reconstruction, and this support is vital to attain a highly defined outline for a reconstructed auricle. The success of base frame sculpting depends on appropriate treatment of the cartilage, mainly the sixth and seventh costal cartilages, which may have different characteristics. The aim of this study is to demonstrate the relevant details for base frame fabrication in various scenarios.

Methods This study included 352 patients with microtia who underwent autologous auricular reconstruction between 2016 and 2019. Concerning the different sizes and characteristics of the costal cartilage used for base frame reconstruction, we describe related methods for fabrication and introduce corresponding strategies for proper management.

Results Relevant techniques in base frame fabrication have been shown to produce favorable results. The elaborately sculpted base frame establishes a stable foundation and natural protrusion of the helix, antihelix and tragus-antitragus complex. The base frame contributes to the integrity of a harmonious appearance of the reconstructed ear.

Conclusions The elaborate design and appropriate utilization of costal cartilage for base frame sculpting is one of the most significant and fundamental processes in microtia reconstruction. It contributes to achieving a clearly defined outline of the auricle with harmonious integrity, which is as important as the other projected subunits.

Background

Ear reconstruction, in some sense, is a highly complicated process of reproducing a harmonious concave-convex auricular contour, which relies mainly on the successful fabrication of such intricate protruding subunits as the helix, antihelix, and tragus-antitragus complex. Significant improvements in framework fabrication have been made in recent decades [1–6]. It is noteworthy that the base frame is a reliable foundation for the important structures mentioned above, or in some contexts, it may integrate into and become a part of them. Therefore, base frame sculpting is of great importance in microtia reconstruction, and it is no less important than the other projected subunits. However, the different characteristics that arise because of the complicated conditions of the sixth and seventh costal cartilage are among the most demanding challenges in base frame fabrication. The aim of this article is to demonstrate the relevant details for base frame fabrication in various scenarios and introduce corresponding strategies for proper management.

Methods

Patients and methods

From October of 2016 to December of 2019, a total of 352 patients (age range, 6 to 52 years; 237 male patients and 115 female patients) underwent two-stage reconstruction for microtia (right sided, 229; left sided 102; bilateral, 21) with autogenous costal cartilage by modified Brent and Nagata's techniques, as described before [7].

Harvesting the Rib Cartilage

We prefer to harvest three costal cartilages (sixth, seventh, and eighth) from the contralateral chest. The sixth and seventh costal cartilages are for base frame, antihelix and tragus-antitragus complex reconstruction. The eighth costal cartilage is used to form the helix and crus helicis.

Base Frame Fabrication

In general, the sixth and seventh costal cartilages are mainly for base frame fabrication. Gradually evolved through our experience, different approaches to fabricating the base frame and relative projected subunits have been established to attain relatively fine results (Table 1, Table 2).

Part A General Procedure of Base Frame Fabrication

We find that the base frame can be well constructed if the synchondrosis of the two ribs is completely integral and either of the costal cartilages is broad enough referring to the template from the contralateral normal side. In our experience, we consider it appropriate to keep the average thickness of the base frame between 4 mm and 5 mm and reduced by 1 mm to 2 mm in diameter compared to the normal side, considering the thickness of the skin. Moreover, a groove is often carved into the base frame to accommodate the antihelix. Furthermore, the edge of the dorsal part of the base frame should be sculpted as smoothly as possible. As described above, this approach yields a stable base frame with proper thickness and smooth edge (Fig. 1, type A1).

However, the synchondrosis is frequently separate or connected incompletely. The base frame is unstable to bear the structures of the antihelix complex and helix fixed on it afterwards. Therefore, the separate upper part of the base frame is fixed by stainless steel wire at a distance of 2.5 mm from the edge. It is enough to ensure stability and firmness of the base frame by two or three fixation points (Fig. 2, type A2).

Part B Base Frame and Antihelical Complex Fabrication

As mentioned in Part A, notching often occurs when the synchondrosis is not firmly connected. Thus, a Y-shaped antihelix is commonly added to hide the rough appearance and thus improve the stability of the framework and give prominence to the smooth contour of the antihelix.

If the cartilages are thick enough, commonly more than 5 mm in thickness, and simultaneously have no notch at the synchondrosis, the Y-shaped antihelical complex may be carved directly from the base frame. This procedure may be suitable for patients with strong cartilages (Fig. 3, type B).

Part C Base Frame and Helix Fabrication

In some cases, we find that the sixth rib cartilage, is a bit narrow compared to the template from the contralateral side. Thus, to stably support the helix and maintain a proper width of the upper part of the auricle, laterally adding a piece of cartilage to broaden its width is recommended (Fig. 4, type C1).

In some adult and adolescent patients, for example, when the sixth and seventh rib cartilages are very thick, commonly > 5 mm, and the eighth rib cartilage is simultaneously relatively short, we can carve the edge of the lower part of the seventh rib cartilage, as an extension of the helix body (Fig. 5, type C2). In this way, in helix fabrication, there is no need to extend the short eighth rib cartilage using more residual cartilage.

Occasionally, we may encounter rib cartilages with special characteristics in some adult patients whose cartilages are calcified or too brittle. Such cartilage is very difficult to sculpt and liable to fracture during

fabrication or even after the operation. Therefore, we cut off the outer edge of the base frame and use it as the helix (Fig. 6, type C3). If the outer edge of the framework body is separated at the synchondrosis, then the connection procedure with stainless steel wire is necessary, as described above.

Part D Base Frame and Tragus-antitragus Complex Fabrication

The tragus-antitragus complex defines the width for the reconstructed auricle. However, if the seventh rib cartilage, is comparatively narrow by reference to the template, we advocate adding a piece of cartilage laterally to broaden its width (Fig. 4, type D). By doing so, the tragus-antitragus complex could be placed in a proper position.

Part E Base Frame and Ear Lobule Fabrication

In anotia or some lobule-type patients, the residual tissue is limited in quantity or misplaced and cannot be utilized as the lobule. Since no remnant skin can be transposed to an appropriate position, the lower part of the base frame should be kept as thick as possible. If necessary, a cartilage cube can be fixed at the bottom of it to protrude the contour of the ear lobule (Fig. 7, type E).

Results

Follow-up ranged from 6 to 48 months, with a median of 18 months. All the patients were interviewed using a questionnaire during their follow-up session or by means of telephone as described before [8–10]. It demonstrated that most of patients were satisfied with the cosmetically refined auricle with harmonious integrity. Four patients categorized in Part A and one patient categorized in Part B complained about a heavy-looking framework after the second stage of the operation because of the thick base frame. Three patients categorized in Part C and two patients categorized in Part D complained about exposure of the steel wire at the junction. One adult patient categorized in Part E complained about the rigid appearance of the ear lobe. There were no pneumothoraxes or infections in this series.

Case Reports

Case 1

The patient was a 15-year-old boy with lobule-type microtia on the left side (Fig. 8). The base frame was fabricated as an integral whole using the technique described in type A1. The postoperative results 1 year after surgery were favorable. The auricle showed a natural contour, approximating the shape of the normal side.

Case 2

Case 2

was an 11-year-old boy with concha-type microtia on his right side. The narrow upper part of base frame was broadened using the method in type C1 (Fig. 9). The framework was stable, and no breakage or incisure occurred when followed up. The reconstructed auricle appeared harmonious with satisfactory shape.

Case 3

The patient in this case was a 14-year-old girl with lobule-type microtia on the left side. The separate upper part of the base frame is fixed by stainless steel wire and the narrow lower part was broadened by a piece of cartilage as described in type A2 and D (Fig. 10). Over an 8-month follow-up period, the reconstructed auricle acquired a natural and clearly refined contour.

Case 4

The patient was a 10-year-old girl with lobule-type microtia on her left side (Fig. 11). The residual tissue was limited in quantity and could not be utilized as the lobule. Thus, the earlobe was reconstructed using the method demonstrated in type E. It appeared smooth and natural with clearly defined morphologic features 6 months postoperatively.

Discussion

In auricular reconstruction, more attention has been paid to the protruding subunits, such as the helix, antihelix, and tragus-antitragus complex. However, it is easy to overlook the significance of the base frame in framework fabrication. The base frame mostly supports the width and length of the auricle and is a reliable basis for the protrusive structures fixed on it and integral into them as an indivisible entity. A framework with a solid foundation can resist the persistent contraction of the skin flap effectively and maintain a harmonious appearance. Thus, the successful fabrication of the base frame is of great importance to the overall aesthetics of the auricle [11, 12]. However, no report has elaborated on the fabrication of base frame with various sizes and different characteristics systematically.

We find that when the synchondrosis of the two ribs is firmly connected or even integral as a whole, then it is more convenient to construct the base frame appropriately as elaborated in type A. Concerning the thickness of the skin flap, the base frame is reduced by 1 mm to 2 mm in diameter compared to the template from the normal side. Meanwhile, when the base frame is sculpted to an appropriate thickness, it is more likely to achieve a delicate reconstructed auricle in appearance after the second stage of the operation. Otherwise, it would appear to be too cumbersome if the base frame is made too thick at the first stage. Considering the integral harmony, we think it appropriate to keep the average thickness of the base frame between 4 mm and 5 mm. Moreover, the dorsal part of the base frame should be sculpted as smoothly as possible; otherwise, it would appear to be too sharpened at the edge and inevitably negatively impact the survival of the fasciae and skin during the second stage of the operation. Taking these steps will maintain the stability of the framework to the utmost degree and present a delicate rather than cumbersome contour at follow-up.

In many cases, we may encounter separate sixth and seventh costal cartilages, which will obviously influence the stability of the framework. To reinforce the framework and lessen the possibility of distortion, it is necessary to fix the divided cartilages together with nylon sutures or steel wires [13]. We prefer to use stainless steel wire because it is more reliable than nylon suture for resisting tensions in different directions. It is worth noting that the degree of wire tightness is relevant for the width of the framework. That is, we should screw the steel wires properly by referring to the template from the normal side. Otherwise, the base frame will be inevitably narrowed if the wires are screwed too tightly and if the size of the template is not considered. To lessen the exposure of the steel wires, we have replaced steel wires about 0.25 mm in diameter with those 0.20 mm in diameter. It's convenient to cut and remove the comparative thinner wires several months later at follow-up or during the second stage. Several months after the first stage of the operation, proper occlusion occurred between the skin and framework. During

the second stage, we may even find a complete membrane around the base framework. That is, the whole framework has got reliable nutrients from blood supply and is quite stable several months later. Therefore, it's safe to remove wires without experiencing a regression of the framework.

To conceal the notching of the synchondrosis and prevent the staircase effect, the antihelix is often fixed on it. Meanwhile, a groove is recommended to carve into the base frame to rest the Y-shaped antihelix complex in order to add stability to the antihelix complex. Thus, this groove further enables a natural and smooth presentation of the antihelix, scapha, and triangular fossa. In some adults or adolescent patients with strong cartilages and no notch at the synchondrosis, we found that the Y-shaped antihelical complex could be carved directly from the base frame as shown in type B. Nevertheless, we advocate not carving the subunit of helix on the base frame simultaneously. The eighth rib is still the best selection for helix protrusion at a desired height.

We think it important to maintain the proper width of the base frame, which is highly important to the accurate position and integrity of the reconstructed auricle, especially the projected subunits such as the helix, tragus and antitragus. When the sixth rib, is a bit narrow as described in type C1, it will no doubt influence the stability of the front part of the helix, which is one of the most prominent parts of the ear and mainly supports the width of the auricle. On the other hand, if the seventh rib cartilage is not broadened properly, the tragus would seem to be off-center as mentioned in type D. Moreover, the contour of the auricle would be top-heavy and inharmonious. Concerning the phenomenon, we advocate to attach a cartilage cube laterally to widen the base frame and then fix the relevant subunits in the proper position [14].

Sometimes the base frame may assist with helix fabrication when it is thick enough and when the eighth costal cartilage is comparatively short, and the edge of the framework could be perfect for the extension of the short helix, as shown in type C2. Thus, neither additional residual cartilage nor the ninth rib is needed to connect and extend the helix. Occasionally, the base frame could be the source of the helix if the eighth rib is calcified or brittle. For this procedure, Brent sculpts the framework as one piece, not unlike a wood carving [2]. However, the cartilage is not as thick in Asian patients as in other populations. In our experience, we detach a stripe of cartilage from the outer edge of the base frame, normally the sixth and seventh costal cartilages, and slide it up the base frame to augment the rim's protrusion similar to the helix. Steel wire fixation is necessary if the edge of synchondrosis is separate. Nevertheless, to smooth the incisure that occurs at the joint, a piece of perichondrium is often harvested and wrapped around the incisure.

As demonstrated in type E, when there is no utilizable remnant skin left to transpose to appropriate position, we prefer to harvest cartilage from the ipsilateral side because the curve of the cartilage is helpful to protrude the lower part of the base frame which has to be kept as thick as possible. If necessary, a block of residual cartilage could be added beneath the base frame to further protrude the subunit of the ear lobule, especially in those patients who also present with moderate-severe hemifacial macrosomia and an obvious depression around the auricular region. In addition, we recommend dissecting the skin flap in a larger region and maintaining the subcutaneous pedicle simultaneously, which achieves adequate looseness and facilitates blood supply to the skin flap. In this way, the procedure ensures the skin will accommodate the thickened base frame appropriately and reduce the risk of skin necrosis or cartilage exposure.

During the process of base frame fabrication, several techniques may be applied

simultaneously, as shown in Table 2. In addition to the general procedure, we find that the method of type A2 is used alone or combined with other techniques more frequently.

The separate sixth and seventh costal cartilages are the most common cases we may encounter. Therefore, the primary task is to maintain the stability of the base frame. In addition, type D also occurred quite often. It reminds us that the narrow seventh rib cartilage is another important aspect we should consider. This part influences the entire symmetry of the framework. The contour of the auricle will be top-heavy and inconsistent if the seventh rib cartilage is not broadened properly. In this table, we find that two or three types of techniques are combined simultaneously in base frame fabrication. These combinations indicate that we may often encounter complicated conditions of rib cartilage with different characteristics. To overcome such difficulties, the flexible application of different types of techniques mentioned above in proper combinations is necessary. We find that the response rate in Part D was a bit lower than that in other Parts. And to some extent, response rates may link to satisfaction and could be informative for surgeons in making surgical decisions. In future work, we need to enhance patient satisfaction through better accentuation of the definition of the tragus-antitragus complex.

Conclusions

Elaborate design and appropriate utilization of the costal cartilage for base frame sculpting is a crucial and fundamental procedure in microtia reconstruction, which is as important as the other projected structures. It contributes to achieving a natural appearance of the auricle with harmonious integrity at follow-up.

Declarations

Ethics approval and consent to participate

We confirm that this work has been conducted according to the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and to general Good clinical practice principles and respecting clinical expertise, patient and parents' values, and the best research evidence for the patient's care. The study was approved by the Ethics Committee of Shanghai Ninth People's Hospital affiliated to Shanghai Jiao Tong University School of Medicine (reference no. 2016–135-T84). Patients signed informed consents to undergo the procedures described and consent was obtained from a parent on behalf of any participants under the age of 16.

Consent for publication

Written and signed informed consents for publication of the cases were obtained from the patients, including intraoperative images. Consent was obtained from a parent on behalf of any participants under the age of 16. A copy of the consent document can be provided upon request.

Availability of data and materials

Not applicable.

Competing Interests

The authors have no conflicts of interest to declare.

Funding

Not applicable.

Authors' contributions

ZX is the first author who has attended the implementation of the innovation of the operation, summarized the innovation and write the manuscript. RZ is the corresponding author who has put forward the new idea, put it into practice and instructed the study. QZ, FX, DL and YL are surgical assistants of RZ during the operations. They have finished the follow-up of patients and made contribution to the innovation of the operation. All authors have read and approved the manuscript.

Acknowledgments

The authors thank Dr. Françoise Firmin, M.D., Ph.D., Dr. Chunxiao Cui M.D., Ph.D., Dr. Tianya Li M.D., Ph.D., Dr. Xia Chen M.D. and Dr. Wei Chen M.D., Ph.D. for contributing to the work.

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Tables

Table 1 Summary of base frame fabrication with individualized conditions of ribs in microtia reconstruction

Type	Related structures	Individualized condition	Procedure
base frame general procedure	A1	integral 6 th and 7 th ribs with proper width and thickness	
base frame steel wires fixation	A2	separated 6 th and 7 th ribs with proper width and thickness	
base frame; antihelical complex direct carving on base frame	B	integral and thick 6 th and 7 th ribs with proper width	
base frame; helix block broadening	C1	narrow 6 th rib with proper thickness	cartilage
base frame; helix rib plus short 8 th rib	C2	thick 7 th rib and short 8 th rib	lower edge of 7 th
base frame; helix as helix substitution	C3	calcified or brittle 8 th rib	edge of 6 th and 7 th ribs
base frame; tragus-antitragus complex cartilage block broadening	D	narrow 7 th rib with proper thickness	

base frame; ear lobule	no residual tissue utilized as lobule	thickened
lower part of 7 th rib plus	E	
bottom		cartilage block at the

Table 2 Patient characteristics of different types of base frame fabrication in microtia reconstruction

Type	No. of Patients (%)	No. of Response at follow-up (%)
A1	57 (16.19)	53 (92.98)
A2	158 (44.89)	143 (90.51)
B	12 (3.41)	11 (91.67)
C1	14 (3.98)	13 (92.86)
C1 + A2	11 (3.13)	10 (90.91)
C2	12(3.41)	11 (91.67)
C2 + A2	9 (2.56)	8 (88.89)
C3	7 (1.99)	6 (85.71)
C3 + A2	6 (1.70)	6 (100.00)
D	15 (4.26)	12 (80.00)
D + A2	14 (3.97)	11 (78.57)
D + C1 + A2	4 (1.14)	3 (75.00)
E	23 (6.53)	21 (91.30)
E + A2	5 (1.42)	4 (80.00)
E + D	3 (0.85)	3 (100.00)
E + D + A2	2 (0.57)	2 (100.00)
Total	352	317(90.06%)

Figures

Figure 1

Schematic representation of the general procedure of base frame fabrication. Upper. The base frame is well constructed with completely integral synchondrosis and proper thick cartilage. Lower left. A groove is carved into the base frame to accommodate the Y-shaped antihelix complex. Lower right. Completed framework ready for reconstruction.

Figure 2

Schematic representation of base frame fabrication with separate synchondrosis. Left. The separate upper part of the base frame is fixed by stainless steel wires. Right. The firmly fixed three-dimensional framework.

Figure 3

Schematic representation of base frame fabrication with adequate thick cartilage. Left. The Y-shaped antihelical complex carved directly from the base frame. Right. Completed three-dimensional framework.

Figure 4

Schematic representation of base frame fabrication with narrow cartilage. Left. A piece of cartilage with the same thickness of the base frame is added laterally to broaden the width of a narrow sixth or seventh cartilage. Middle. The narrow sixth cartilage is broadened, and the separate synchondrosis is connected. Right. The narrow lower part of the seventh cartilage is broadened.

Figure 5

Schematic representation of thick base frame fabrication with relatively short eighth rib cartilage. Left. The edge of the lower part of the base frame is carved as an extension of the helix body. Right. Completed three-dimensional framework.

Figure 6

Helix fabrication with calcified or brittle cartilage. Left. Schematic representation of helix fabrication with calcified or brittle cartilage. Middle. The outer edge of the base frame is cut off and used as the helix. Right. Completed framework ready for reconstruction.

Figure 7

Schematic representation of base frame fabrication in anotia or some lobule-type patients whose residual tissue cannot be utilized as the lobule. Left. Note that the lower part of the base frame is kept as thick as possible. If necessary, a block of cartilage is added at the bottom of the lower part of the base frame to protrude the contour of the ear lobule. Middle. Lateral view of the completed three-dimensional framework. Right. A block of cartilage is added at the bottom of the lower part of the base frame to protrude the contour of the ear lobule.

Figure 8

Case 1. A 15-year-old boy who presented with congenital microtia. The base frame is constructed with completely integral synchondrosis and proper thick cartilage using our method in type A1. Left. Preoperative oblique view of lobule-type microtia. Right. Postoperative oblique view 1 year after ear elevation.

Figure 9

Case 2. An 11-year-old boy who presented with congenital microtia. The narrow upper part of base frame was broadened by a piece of cartilage with the same thickness as described in type C1. Left. Preoperative lateral view of concha-type microtia. Right. Postoperative oblique view 8 months after ear elevation.

Figure 10

Case 3. A 14-year-old girl who presented with congenital microtia. The separate upper part of the base frame is fixed by stainless steel wire and the narrow lower part was broadened by a piece of cartilage as described in type A2 and D. Left. Preoperative oblique view of lobule-type microtia. Right. Postoperative oblique view 8 months after ear elevation.

Figure 11

Case 4. A 10-year-old girl who presented with congenital microtia and whose residual tissue was limited in quantity and could not be utilized as the lobule. The earlobe was reconstructed together with the base frame as a whole. Left. Preoperative oblique view of lobule-type microtia. Right. Postoperative oblique view 6 months after ear elevation.