Different Designs Of The Fabricated Three-Dimensional Cartilaginous Framework In Total Auricular Reconstruction By Autologous Costal Cartilage Grafts

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Auricular reconstruction represents a meticulous reconstructive and aesthetic problem to the plastic surgeon. To date the most frequently relied upon technique for auricular reconstruction is the autologous costal cartilage grafting where the most important factor affecting the outcome of surgery is the fabricated three-dimensional cartilaginous framework for the constructed ear. In this study we compare the aesthetic outcome of the different framework designs. 27 ears were reconstructed in 25 patients using costal framework. The best aesthetic results were obtained with the contour accentuated framework which yielded good results in 100% of Cantilever pinnal framework to 76.9%. The results suggest that contour accentuated framework is the best framework design to be used in auricular reconstruction. As the construction of this type of framework needs a well developed chest wall, it is recommended that auricular reconstruction is attempted after the age of 8 years.

Keywords: Otoplasty, Microtia, Contour accentuated, Auricular reconstruction

Management of ear deformities can be of the most rewarding yet humbling challenges that face the reconstructive surgeon (1). Ear deformities fall into the zone of psychological perception. The patients suffers traumatic in origin, represents a meticulous reconstructive and aesthetic problem to the plastic surgeon (3). The aim of auricular reconstruction is to have an ear that has a sufficiently natural appearance which will pass unnoticed by others (4). It should provide a reasonable copy of the other ear in a limited number of surgical procedures and with minimal complications (5). Adequate size and proper symmetrical positioning of the ear are more important than the degree of inclination or protrusion in achieving a natural looking face (6).

Alternatives for auricular reconstruction include autologous costal cartilage graft, prosthetic reconstruction with osseointegrated implants or the use of alloplastic frameworks (e.g. porous polyethylene) (7). To date the most frequently relied upon technique for auricular reconstruction is the autologous costal cartilage grafting (8)(9). Auricular reconstruction by autologous costal cartilage graft was first described by Gillies in 1920 (10), however, the technique of auricular reconstruction most favored by the majority of plastic surgeons these days is that of Brent (5), who followed the original concept of Tanzer (11). Brent was Tanzer and Brent who established the concept of auricular reconstruction as a multistage procedure, in order to maximize both the benefits of the implanted cartilage and the characteristics of the covering skin (16)(17).

One of the most important factors affecting the outcome of total auricular reconstruction is the fabricated three-dimensional costal cartilage framework with all the auricular features (18). During construction of the cartilaginous framework, fundamental principles must be followed to preserve the living nature of the sculpted cartilage: continuous isotonic saline irrigation, and avoiding use of powerful tools that could damage the chondrocytes, The perichondrium should be preserved except when it is necessarily excised during the carving process, to facilitate adherence of skin flap and to ensure subsequent survival of the cartilage graft as a viable sculpture (19). During carving of the costal cartilage, several factors bear directly on the eventual results; Firstly, the eminences and concavities should be exaggerated as they tend to be shallower during the phase of consolidation. Secondly, a firmer attachment of skin to the cartilaginous framework can be achieved through providing multiple perforations through the cartilage along the helical sulcus and the triangular fossa (20). To prevent flattening of the ear rim which may be caused by the tension of the usual tight skin cover, a thicker and more substantial helix should be carved. Exaggerating the framework details compensates for the overlying skin thickness (21). The use of a very thin skin flap over the framework allows heightened definition of cartilage detail, better skin-cartilage coaptation, and appears to play a vital role in preventing late deformation of the cartilage framework (22).
**Framework designs**

*arved base piece and Helical cartilage piece): Figure 2*

After scraping the perichondrium with a scalpel, the gas-sterilized contour pattern of the normal ear is traced on the contralateral 6th & 7th rib. The base block is then carved with a scalpel and wood carving chisel to create the natural convolutions of the scapha and the triangular fossa. The 8th rib is turned over and a helical sulcus is carved on its visceral side, rendering the cartilage thinner and more flexible. Finally the helix is wired to the base block with several fine stainless steel wire sutures (23).

To achieve optimal helical stability and projection, the helical cartilage is attached anterior to the inferior crus first. This creates maximum width while maintaining the normal, low projection of the crus helix. Stability is then achieved when wrapping the helix around the superior pole of the frame. Finally projection is maximized where it is most needed by fixing the terminal helix on top of the main cartilage block along

In 1999 Brent(24) developed a new method to create a tragal strut as part of the original framework. He used a second cartilage sturt fixed to the base block and arched to form the tragal arch through fixing it to the crus helix by horizontal mattress sutures (24).

![Figure (1): Anatomy of the lateral aspect of the Auricle (Allison, 1990)(25)](image1)

A. Location of incision on opposite chest wall, B. Freeing of 6-8th ribs from attached muscles, C. Lying out the contour of framework on 6 & 7th ribs, D. Completed base carving, E. Creation of the helical sulcus, F-G. Wiring of the helix to the base block.
Cantilever pinnal frameworks (Triangular and Helical pieces but NO base piece): Figure 3
This framework has no base piece, instead it depends on a triangle and an arch fabricated from costal cartilage for its contour and strength and the scapha and triangular fossa are represented by an empty space. The framework is designed on the epsilateral 5th, 6th and 7th ribs or 6th, 7th and 8th ribs. The top cartilage (5th or 6th) forms the inferior crus which is left with its natural union to the next cartilage (6th or 7th) which forms the antihelix root and the superior crus. The lower cartilage (7th or 8th) is separated from the others and carved to form an arch which will compose the root, body and tail of the helix. The two components are assembled using 6/0 monofilament nylon sutures (26).

Expansile framework:
The framework is designed on the visceral side of an epsilateral rib. The detailed antihelix and its crura serve delicate, flexible spine of cartilage which can be adjusted and fixed to the antihelical crura. In the completed skin coaptation, aids the desirable overemphasis of details and affords stable adherence to the overlying soft tissues (25)

Contour-acentuated Frameworks (Eminences accentuated by added cartilages on base piece): Figure 4
The prominence of the helix is accentuated by using the entire width of the cartilage. The cartilages not chosen for the helix are placed on the base block to constitute and over accentuate antihelix-posterior conchal wall complex. A prominent helix and antihelix produce an intervening scapha without carving of the base block. The helical cartilage is wired to the lateral rim of the base block. Although this reduces the depth of the scapha, it avoids tilting of the helix which leads to obliteration of the helical sulcus which in turn reduces the size of the base block by the thickness of the helical cartilage The triangular fossa is constructed by introducing a small fragment of cartilage into the position of the crura. The constructed framework thus has a larger bulk and more surface area than the conventional one (27)

In order to achieve a well defined contour of crus helix, valve-like tragus, incisura intertragica and a clearly defined cymba conchae, Nagata (28) harvested the 6th, 7th, 8th & 9th ribs en bloc. He constructed the base frame from the 7th & 8th costal cartilages. He constructed a helix and crus helices unit from the 9th cartilage. The antihelix, superior and inferior crus unit, the incisura intertragica and tragus unit as well as the insufficient portions of the base frame were constructed from the remains of the 7th & 8th cartilages. Each constructed unit was placed over and fixed to the base frame (29).
Patients and methods
25 patients were operated upon for auricular reconstruction in Kasr El-Aini University Hospital. 27 reconstructions were done (2 bilateral)

Preoperative preparation
-Full History including family history of similar cases and history suggestive of associated anomalies in cases of congenital microtia was obtained
-General examination was done to detect any associated anomalies and any general medical condition
-Local examination was done to classify the degree of microtia according to classification:
  Grade III (Lobule-type microtia): Only an ear lobule remnant exists but without the concha, acoustic meatus and tragus.
  Grade II (Concha-type microtia): A remnant ear lobule exists with the concha, acoustic meatus, tragus and incisura intertragica.
  Grade I (Small concha-type microtia): A remnant ear lobule exists with a small indentation representing the concha.
-Otorhinolaryngologic examination & In bilateral cases and those associated with meatal atresia we added:
  -A computerized tomography
  -An Audiogram

Preoperative design and location planning of cartilage framework
The planning initiated by tracing an x-ray film pattern of the normal opposite ear. This pattern was latter gas-sterilized to be used in

Operative details

First Stage: Creation and implantation of the framework

1-Obtaining the cartilage:
The cartilage was obtained through a transverse incision over the contralateral 6th intercostal space. The X-ray pattern of the opposite ear was placed over the union between 6th & 7th costal cartilages and followed to harvest the base piece and the 8th cartilage was harvested to form the helical rim. The X-ray film pattern was placed in different directions over the costal cartilages to decide which direction was best to remove the cartilage. An extra cartilage wedge was taken and banked in the preauricular area to be used during auricular elevation.

2-Framework fabrication:
The framework was fabricated using a scalpel and a wood-carve chisel. The perichondrium was carefully preserved except when it was necessarily excised during carving process.
Three patterns of frameworks were fabricated:

The base block was carved to create natural convolutions (Scapha, antihelix and triangular fossa). The 8th cartilage was turned over and a helical sulcus was carved on its visceral side and then wired to the base block with several 2/0 proline sutures.

*A cantilever pinna framework (13 ears)*
Cartilages harvested were shaped into a triangular piece and an arch to form the framework and the helix with no base piece. The convolutions were represented by empty spaces.

*Contour accentuated framework (9 Ears)*
Prominence of the helix was created by the entire width of the cartilage. The accentuated antihelix, and posterior conchal wall complexes was accentuated by cartilages not chosen for the helix and fixed over the base block. This framework design was applied in patients above 10 years of age where the chest wall was well developed to allow framework design without defects.

3-Framework implantation:
It was implanted through a small transverse incision over the auricular vestige after distorted native cartilage remnant was excised. A thin flap was raised by sharp dissection carried superiorly and posteriorly into the hairline and inferiorly into the neck. Finally the pocket was completed by dissecting 1-2 cm peripheral to the projecting framework markings.
The framework was introduced into the pocket. When skin overlying the framework exhibited excessive inflation with 60-70 cc of saline and deflation over a 30-minutes period.
Finally a small suction drain was inserted and incision closed, and a dressing was applied that accurately conformed to the convolutions of the implanted framework. Suction drain was removed 2-3 days postoperatively and stitches removed on the 10th postoperative day.

**Second Stage: Detachment of the constructed auricle, ear lobe transposition and middle ear surgery**

1-Auricle elevation
It was done 2-3 months after implantation. The postauricular sulcus was defined by separating the constructed auricle from the head and covering its undersurface with a thick split thickness skin graft. An incision was made several millimeters behind the rim taking care to preserve a protective connective tissue cover over the cartilaginous framework. The retroauricular skin was advanced into the newly created sulcus -over was used to secure the graft. To augment the auricular elevation a subfascial mastoid pocket was created just behind the deepest point of the detached ear to harvest the cartilage wedge graft banked in the preauricular area.

2-Ear lobe transposition
The lobule was detached through anterior and posterior incisions and mobilized to the inferior pole. Then the lobule was spited into two adipocutaneous layers so that the inferior pole of the framework can be wrapped by the lobule.

3-Atresia repair
The congenital aural atresia was repaired by an otorhinolaryngologist during this stage through a posterior incision 1 cm behind the implanted cartilage. The entire cartilaginous framework was elevated and retracted anteriorly to permit the drilling necessary for creating the external auditory canal which was lined by a split thickness skin graft. An oval piece of skin was excised at the appropriate site on the framework to create the external auditory meatus. The edges of the lining skin graft of the canal were sutured to skin at the edges of the meatus.

**Third Stage: Tragus reconstruction and deepening of the concha**

The tragus and conchal cavity were created 6-8 weeks after the second stage. A U-shaped incision was deepened almost to the mastoid periosteum and the flap was undermined well into the preauricular region creating a pocket where the U-shaped flap was rolled on itself to form a tragus. The flap was held in the inverted position by three mattress sutures emerging from the pocket onto the preauricular region and tied over a gauze pledge. A full thickness skin graft from the opposite auriculocephalic sulcus was sutured to the flap edges before its inversion, furnishing a lining for the pseudomeatus and conchal floor.

**Postoperative evaluation**

1-Occurrence of complications
2-Surgeons evaluation (immediate and 6 months postoperatively): Reconstructed auricle was evaluated by assessment of the helix, antihelix, triangular fossa, adequate contour, elevation and irregularities of the framework.
- Good: One defective parameter
- Fair: Two defective parameters
- Poor: Three or more defective parameters
3-Patient and parent satisfaction

**Results**

<table>
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<th>No</th>
<th>Age</th>
<th>Sex</th>
<th>Side</th>
<th>Microtia Type</th>
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<td>Rt.</td>
<td>Concha-Type</td>
<td></td>
<td>Cantilever Pinnal</td>
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</tbody>
</table>

*Table (1)*

- A total of 25 patients with microtia were operated upon, with age ranging from 4-38 years with an average of 11.8 years
- There was male predominance (76% of cases) while 24% of cases were females
- There was right side predominance. 16 Patients had right side affection (64%), left side affection was present in 7 patients (28%) and affection was bilateral in 2 patients (8%). (Table 2)
- Type (Grade III), 11.2% were of the concha-type (Grade II) and one case was traumatic in origin (3.6%) (Table 3)
• There was associated deformities in 8 patients (32%) in the form of hemifacial microsomia in 6 cases (24%) and hypospadias in 2 cases (4%)

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<th>Age range (years)</th>
<th>Number of Patients</th>
<th>Percentage</th>
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<td>4-6</td>
<td>6</td>
<td>24%</td>
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<tr>
<td>7-9</td>
<td>5</td>
<td>20%</td>
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<tr>
<td>10-12</td>
<td>7</td>
<td>28%</td>
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<tr>
<td>13-15</td>
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<td>8%</td>
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<td>15-19</td>
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<td>20 and more</td>
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<td>16%</td>
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Table (2)

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<th>Type of Microtia</th>
<th>Number</th>
<th>Percentage</th>
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<tr>
<td>Lobule-type (Grade III)</td>
<td>23 Ears</td>
<td>85.2 %</td>
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<tr>
<td>Concha-type (Grade II)</td>
<td>3 Ears</td>
<td>11.2 %</td>
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<tr>
<td>Traumatic</td>
<td>1 Ear</td>
<td>3.6 %</td>
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</table>

Table (3)

Aesthetic results
• We fabricated three types of frameworks: the contour accentuated in 8 patients (one was bilateral) (33.33%), Tanzer in 5 patients (18.5%) and Cantilever pinnal in 12 patients (one was bilateral) (48.1%)
• In patients under 8 years of age whose chest walls were not fully developed, the contour accentuated framework was not used as the defective costal cartilage would not allow for a proper framework
• 23 constructed ears were evaluated as good (85.18%), 3 were evaluated as fair (11.12%) and only one ear was evaluated as poor (3.7%)
• Contour accentuated frameworks were used to reconstruct 9 ears and the results were good in all reconstructions (100%)

• (20%)
• A Cantilever pinnal framework was used to reconstruct 13 ears, 10 were evaluated as good (76.9%), two as fair (15.4%) and only one case as poor (7.7%) (Table 4).

<table>
<thead>
<tr>
<th>Fabricated Framework</th>
<th>Total</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
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<tr>
<td>Contour accentuated</td>
<td>9 (33.35%)</td>
<td>9 (100%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
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<tr>
<td>Tanzer</td>
<td>5 (18.51%)</td>
<td>4 (80%)</td>
<td>1 (20%)</td>
<td>0 (0%)</td>
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<tr>
<td>Cantilever Pinnal</td>
<td>13 (48.14%)</td>
<td>10 (76.9%)</td>
<td>2 (15.4%)</td>
<td>1 (7.7%)</td>
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<tr>
<td>Total</td>
<td>27</td>
<td>23 (85.18%)</td>
<td>3 (11.12%)</td>
<td>1 (3.7%)</td>
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</tbody>
</table>

Table (4)

Complications
Ear related complications (3 ears) (11.1%)
• Major infection and graft extrusion happened in one ear (3.7 %) where the cartilage was removed and the reconstruction was repeated after 3 months and the result was evaluated as good
• Moderate infection with loss of part of the cartilage happened in one ear (3.7%) and the result was evaluated as poor
• Skin necrosis over the helix with exposure of the framework occurred in one ear (3.7%) and was treated by tempoparietal fascial flap coverage and skin grafting, the result was good

Non-ear related complications (2 cases) (8%)
Two cases (8%) encountered chest complication, the first had pneumothorax discovered intraoperatively and was managed by suturing of the pleura and follow up chest X-ray. The other had a hypertrophic scar

Patient/Parent satisfaction
• 21 patients with results evaluated as good and one patient with result evaluated as fair were pleased with the result and glad they had the surgery (92%).
• One patient was undecided (4%)
• Two patients were unsatisfied with the result including a bilateral case with one side was evaluated as a poor result and another patient with fair result (8%)
A 10 year-old female with lobule-type microtia reconstructed with *contour accentuated framework*. The result was good and patient was satisfied

Above Left: Preoperative view  
Above Right: Contour accentuated framework designed  
Below left: After implantation of framework  
Below Right: After elevation of auricle and lobule rotation

A 6 year-old male with lobule-type microtia reconstructed using a Cantilever pinnal Framework. The result was evaluated as fair

Left: Preoperative view  
Middle: A Cantilever pinnal framework designed  
Right: After auricle elevation and lobule rotation

A 8 year-old male with lobule-type microtia

Middle: After framework implantation  
Right: After auricle elevation and lobule rotation

**Discussion**

Since Gillies (10) introduced total auricular reconstruction using autologous costal cartilage graft in 1920, it was Tanzer (11) in 1959 and Brent (12)(13)(14)(15) who made the greatest advancement in the field of ear reconstruction. They introduced the concept of multistage treatment which is now the state-of-the-art solution for microtia. The most important factor affecting the aesthetic outcome of total auricular reconstruction with rib cartilage graft is the fabricated cartilage framework. Many designs for fabricating a cartilage framework of the constructed ear have been introduced including framework consisting of a carved base piece and a helical cartilage, *Cantilever pinnal framework* where the framework is formed of a
triangular area and an arch with no base piece and *Contour accentuated framework* where the eminencies are accentuated over the base piece by added cartilages.

In this study we compare the different framework designs in terms of the final aesthetic result. A total of 27 auricular reconstructions were done in 25 patients using autologous costal cartilage grafting. There was distinct male predominance and the condition was right sided in 64% of cases. This concurs with the results of other studies (25) (34)(35). 85.5% of cases were of the congenital lobule-type microtia, 11.2% of cases were of the congenital concha-type and 3.7% of cases were traumatic in origin.

Three types of fabricated cartilage framework were used and the best results were achieved when using the contour accentuated frameworks (good result was achieved in 100% of cases). On the other hand 76.9% when the Cantilever pinnal framework was used.

The overall rate of ear complications was 11.1% which matches the results of other studies (4)(8)(19)(34). Major infection was encountered in one ear (3.7%) where the framework was removed and case revised later with good final aesthetic result. Minor infection was encountered in one ear (3.7%) with loss of part of the framework affecting the final outcome evaluated as poor. Skin necrosis occurred in one ear (3.7%) and was successfully treated with tempoparietal fascial flap and skin cover not affecting the final outcome. Chest complications were encountered in 2 cases (8%) and were managed successfully.

Ear reconstruction was performed in different age groups, however, according to the results it is recommended that reconstruction should be attempted at the age group from 8-10 years. At this age the thoracic cage is usually developed to a degree that allows the formation of a contour accentuated framework of adequate size which yields the best aesthetic results (100% in this study). These results come in accordance with the results of other studies(12)(13)(21)(24). In this work reconstruction was attempted at a younger age, as it was important to both the child and his parents to get reconstruction before school age. However, in those cases we used either th Cantilever pinnal frameworks (which gave good results in 76.9% of cases).

**Conclusion**

The ideal method for total auricular reconstruction is the use of costal cartilage graft for fabrication of a cartilage framework for the constructed ear. The design of the fabricated framework is one of the most important factors affecting the final aesthetic outcome. Of the different framework designs, the contour accentuated framework appears to yield the best aesthetic results and it is recommended to be used in all cases. The best age to perform the reconstruction is between 8-10 years when the chest wall is well developed to allow for the formation of a contour accentuated framework.

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