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Donor-Site Morbidity Following Harvest of Autologous Costal Cartilage in Microtia Reconstruction

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Abstract

Objectives: The objective of this study is to evaluate donor-site morbidity after costal cartilage harvest for microtia reconstruction. **Methods:** A total of 70 patients who underwent autologous costal cartilage harvest for microtia reconstruction from March 2008-March 2009 were included. Anterior chest wall deformity was evaluated with chest topography, and scar quality at baseline and at 6-months follow-up, and final outcomes analyzed with SPSS. **Results:** In 70 patients, 52 (74%) were male, 18 (26%) were female, and altogether 40 (57%) patients developed deformity. At 6-month follow-up, the incidence of anterior chest wall deformity was highest at 80% in Block-III, and least at 0% in Block-I. The 6 - 10 years age group was the largest group at 84% (21), and also with highest incidence of deformity in association to Block-IV harvest at 83%. The incidence of donor-site deformity was higher in female gender at 66%, and 54% in males. But in the sub-group, male had higher incidence of deformity at 75% in both Block-III, and Block-IV when compared to the respective females. The 120 - 135 cm height group had the highest deformity at 67% with Block-IV costal cartilages harvested. At the three measurement points: 1) xiphisternum, 2) intersecting points between PSL and LCM, and 3) intersecting points between MCL and LCM, significant differences (mean) were observed in chest circumference from baseline to 6-month follow-up, and between the left and right chest hemi-circumference (postoperatively). Acceptable donor-site scar was observed in all but 3% (2) developed hypertrophic scar. **Conclusion:** The development of chest wall deformity was observed when more than one costal cartilage was harvested, particularly the 6th (complete), 7th, 8th block. Therefore, to minimize the deformity, we recommend harvesting only the necessary amount of cartilage, and at the lowest level possible to avoid injury of costochondral junction. Additionally, age, height, gender and chest development are equally important factors which influence donor-site deformity in microtia reconstruction.

Keywords

Chest Wall, Autologous Costal Cartilage, Deformity, Microtia

1. Background

Microtia is a congenital malformation of the auricle/pinna (outer ear), with a varying severity ranging from minimal structural abnormalities to a complete absence of earlobe (anotia), with or without the external auditory meatus. Undoubtedly, the external ear possesses an aesthetic value, specifically in females who adorn their ears with an array of ornaments. Even men with malformed ears must limit the range of hairstyles they can wear. Also, children with congenital microtia can have a psychosocial impact and are more prone to bullying when they look different than their peers. This can lead to personality disorders later in life, which can result in the limitation of social activity because of the deformed ear shape [1]. Therefore, there is a recognized need to reconstruct the ear in both genders, and particularly in children. Sometimes, an ear reconstruction is needed to provide support or hold the frame of spectacles.

In 600 BC, Sushruta Samhita [2] described the application of local cheek skin flaps for reconstruction of the ear lobe. Since then, there have been many advances and refinement in the reconstruction of microtia to attain a more natural looking ear [3]-[7]. Autologous cartilage remains one of the most reliable materials that produces excellent results due to high viability, resistance to softening, shrinking, and extrusion, and reduced rate of resorption [7]-[11]. Several other dedicated proponents of costal cartilage throughout the globe ensured the role of autologous costal cartilage as the implant material of choice [12]-[23].

Although advancement in surgical techniques has aided in the construction of high-profile auricles, some disadvantages are still encountered with the use of autologous cartilage. Chest wall deformity is one such serious problem. Various articles have been published on chest wall donor-site complications [8] [24]-[26], but donor-site morbidity after harvest of costal cartilage has not been previously investigated in detail. Previous work has not examined the incidence of pain, contour deformity and scar quality as important issues for the patient [27]. Techniques to minimize donor-site morbidity have been discussed previously by Nagata [28]. His technique puts emphasis to leave the perichondrium completely intact and return the morselized pieces of costal cartilage to the perichondrial pocket to fill the dead space after fabrication of the 3-dimensional costal cartilage ear framework to reduce donor-site contour deformity.

Granting some previous data on chest wall deformity have been reported, the factors that can influence the severity of the deformity are still not clearly understood. Thus, this study was undertaken to evaluate whether different factors like age, gender, height, and number/quantity of costal cartilage harvested by using physical examination.

2. Patient and Methods

2.1. Study Design

A total of 70 patients, age ≥ 6 years to 32 years, both genders, that underwent reconstruction of unilateral microtia with autologous costal cartilage harvest (Rt. Side) from March 2008 to March 2009 at Plastic Surgery Hospital of Chinese Academy of Medical Science, Peking Union Medical College were included in this series, with IRC (reg. no. 10286) approval. The different variable considered were height, gender, age, size and number of harvested costal cartilage, site of harvesting costal cartilage, method of skin incision, standardization of operative technique, measurement of chest circumference preoperatively and postoperatively, and patient photographs. Bilateral microtia, post-traumatic ear and pre-op chest deformity were excluded from this study.

2.2. Timing of Surgery

The first stage of microtia reconstruction was initiated at the age of ≥6 years and required a chest circumference of ≥50 cm at the level of xiphoid process with the height ≥ 120 cm.

2.3. Operative Technique

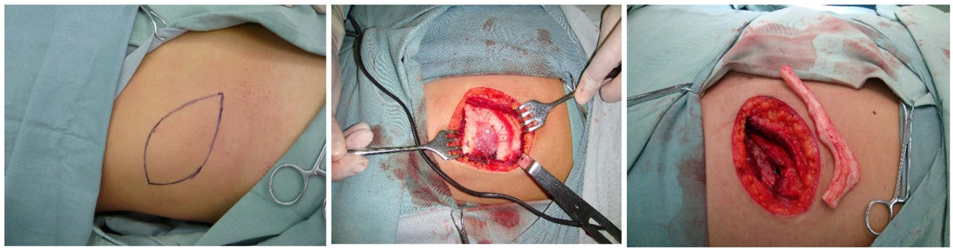
The reconstruction was accomplished in three stages. A tissue expander was implanted under the subcutaneous in retro auricular mastoid region. After 30 - 60 days with completion of expander inflation, costal cartilage was harvested, sculpted and grafted in the second stage or reconstruction. Suction drain was applied to enable the shape of the ear to come through. The surgeon modified the technique by carving more precise and finer details in the framework to mimic the normal ear. After 6 months, in the third stage, construction of tragus, helical root and conchal excavation was completed. This technique solved the problem of skin and improved the definitions in the cartilage framework.

2.4. Design of Chest Incision

The shape and position of 6th, 7th, and 8th costal cartilages were confirmed by palpation of the landmarks on the right side of the chest for donor-site regardless of the microtia side. Then, an oblique fusiform skin incision (8 cm * 4 cm) was made over the vicinity of 7th costal cartilage 2 - 2.5 cm laterally to the inferior portion of sternum (**Figure 1**). The right side of the chest was chosen because full thickness costal cartilage (extra perichondrial dissection) was taken as a graft. It would leave a permanent defect in the bony chest cage and heart unprotected, if taken from the left side.

2.5. Method of Costal Cartilage Harvesting

To minimize the postoperative donor-site pain, infiltration with a 20 ml local anesthetic (5 ml 2% lidocaine, 5 ml 75% ropivacaine diluted in 30 ml of 0.9% normal saline, with 1/3 adrenalin) was done before incision. An incision was then made on the skin and underlying subcutaneous fat, and secured with retractors until an adequate surgical field was exposed. Fascia of the rectus abdominis and external abdominis oblique muscles were exposed. Aforementioned local anesthesia (total 10 ml) was infiltrated, and an oblique incision was made between the two muscles with a scalpel. The costal cartilage was visible beneath a layer of loose areolar tissue (**Figures 1(b)-(c)**). Caution was maintained not to puncture the intra-thoracic cavity when incision was made.



(a) (b) (c)

Figure 1. (a) Incision design, (b) Right 6^{th}, 7^{th}, 8^{th} costal cartilages before harvest, (c) Right costal cartilage after harvest.

The perichondrium (6^{th} through 8^{th} costal cartilage) was completely exposed and intercostal muscles were identified. The perichondrium was then incised after confirming and marking the necessary shape and size of the costal cartilage by referring to the previously prepared sterilized template of normal opposite ear. The template was aligned symmetrically with the contralateral ear using the ear's relationship to the nose, lateral canthus, and position of the lobule. Initially, perichondrium of 7^{th} costal cartilage was undermined for easier harvest of the cartilage. The perichondrium was carefully undermined by a raspatory at the appropriate site of costal cartilage, avoiding excessive and sudden movements, and keeping in mind not to stress the cartilage or injure the underlying intra-thoracic cavity and scarring of costal cartilage. Either of the four different blocks of costal cartilage were harvested as needed: Block-I, 7^{th} costal cartilage; Block-II, 7^{th} and 8^{th} costal cartilage; Block-III, 6^{th} (axial half), 7^{th} and 8^{th} costal cartilage; Block-IV 6^{th} (complete), 7^{th} and 8^{th} costal cartilage. In the process of undermining the posterior surface of the costal cartilage, the tip of the perichondrial rasp was in contact with the costal cartilage itself to prevent accidental puncture of the intra-thoracic cavity like pneumothorax.

The perichondrium was left completely intact at the donor site. A saline test was performed to exclude a pleural leak. The rectus abdominis and external abdominis oblique muscles were lifted with retractors/hooks and 0.9% normal saline was poured into the donor-site cavity. Then the thoracic pressure was increased by 15 - 20 cmH2O and checked for air bubbles to rule out a leakage. If a pleural tear was made during perichondrial dissection, it was immediately repaired with sutures. Hemostasis was strictly maintained. The remnant cartilage was returned to the perichondrial pocket and sutured with 3 - 0 Monocryl (Ethicon co). The wound was closed in layers including muscles, subcutaneous, and skin. Antibiotics were administered for 5 days postoperatively.

2.6. Evaluation of Donor Site

Patients' donor sites were examined during their hospitalized period and at intervals of week 1, 2, 4 weeks, and at months 3, 6, and 12 months postoperatively. Assessments were carried out on all patient donor-site including 1) quality of scar, 2) chest contours, and 3) symmetry.

2.6.1. Scar Quality

The scars were assessed regarding the width, degree of flattening, and color [25], and were categorized into; 1) Excellent (narrow < 2 mm, flat, excellent color matching), 2) Good (slightly spread < 3 mm, flat, good color matching), 3) Acceptable (moderately spread < 4 mm, slightly depressed/elevated, good color matching), 4) Poor (wide > 4 mm, significantly depressed/elevated, erythematous, hypertrophic).

2.6.2. Topography

The rib cage topography was evaluated with the patient in a standing position at rest. Based on retrusion of anterior chest wall, symmetry of anterior portion, and lateral border of chest compared with contralateral side, the silhouettes were classified into three categories: 1) Normal (no retrusion, protrusion, and asymmetry), 2) Mild chest wall retrusion, and 3) Severe chest wall retrusion.

2.6.3. Chest Measurements

The costal margins were drawn on the anterior chest wall with a skin-marking pen along the lowest edge of anterior chest wall. This edge was determined by palpation with the patient in a standing position at rest. Measurements of the costal margin at the deformity were taken at different points: 1) from anterior midline to the most prominent point of defect (*i.e.* triangular highest curving point), 2) from mid-clavicular line to the defect point of lower costal margin, 3) from anterior midline to posterior midline, and 4) comparison of bilateral costal margins (**Figure 2**).

Figure 2. Post-operative measurement of costal margin at harvested site and compared to contralateral side of the chest.

The chest circumference was measured at a total of five different points at two time points (baseline and at 6-months follow-up) at the level of 1) sternal angle, 2) nipple, 3) xiphisternum, 4) intersection of parasternal line (PSL) and lower costal margin (LCM), and 5) intersection of mid-clavicular line (MCL) and lower costal margin (LCM). The chest hemi-circumference measurements were also taken bilaterally at these five points at the 6-months follow-up (Figure 3). All the measurements were taken in an upright standing position during normal inspiration. Comparison of pre- and post-operative chest radiography was also done.

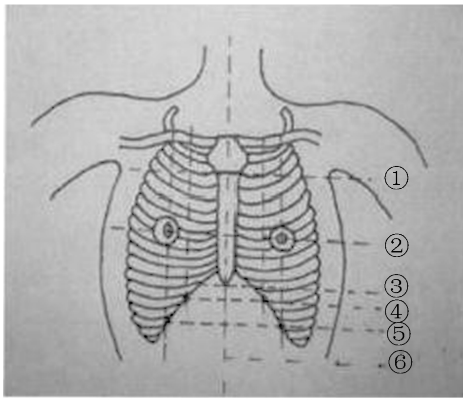


Figure 3. (1) Sternal angle, (2) Nipple, (3) Xiphoid process of sternum, (4) PSL and LCM, (5) MCL and LCM, (6) Anterior central midline.

2.7. Statistical Analysis

The differences in both the chest circumference from baseline to 6-month follow-up, and differences in right and left chest hemi-circumference at 6-month follow-up (of all five points) were expressed as mean ($x \pm s$). The differences in the mean at the two time points (baseline and 6-month follow-up) were compared and data were analyzed with paired "t"-test. Statistical analysis was done using SPSS 12.0 (IBM), means were compared using ANOVA, categorical variables were compared using paired t-test. $P < 0.05$ was considered to be statistically significant.

Table 1. Costal cartilage harvest patient demographic.

Age (years)	Male	Female	Total
6 - 10	20	5	25 (36%)
11 - 15	15	6	21 (30%)
16 - 20	9	4	13 (18%)
>21	8	3	11 (16%)
Total	52 (74%)	18 (26%)	70

3. Results

In this study of 70 (N) microtic patients, 52 (74%) were male and 18 (26%) were female, with age ranging from 6 to 32 years old. The largest group was in the age range of 6 to 10 years group with 25 (36%) patients (**Table 1**). Only patients with unilateral microtia were selected with 45 patients of the right ear, and 25 of the left. The incidences of different types of microtia deformities were classic sausage-shaped lobular type at 86% (60), and concha-type at 14% (10). In all patients, either one of the right costal cartilage blocks (6th,7th, 8th) were harvested, and Block-II (7th and 8th costal cartilage) was the commonest type harvested at 50% (35/70) (**Table 2**).

Table 2. Incidence of deformity in different types of cartilage block harvested.

Cartilage block	Total patients (N)	Patients with deformity (n)	Incidence of Deformity
Block-I (7th)	4 (6%)	0	00%
Block-II (7th, 8th)	35 (50%)	20	57%
Block-III; 6th (axial half), 7th, 8th	10 (14%)	8	80%
Block-IV; 6th (complete), 7th, 8th	21 (30%)	12	57%
Total	70 (100%)	40	57%

In all patients, the desired shape and size of costal cartilage was harvested without any difficulty. There was no injury to pleura and intercostals muscle during the operation. Deviation of xiphoid process of sternum was not found in this study. There were 5 (7%) obese patients (two boys of 8 years with 66 kg and 70 kg weight respectively, and three boys of 10, 11 and 13 years with 76 kg, 84 kg and 90 kg weight respectively) who complained of chest donor-site pain, especially aggravated by any kind of movement and coughing, and were unable get out of bed on the 1st postoperative day. They were finally able to ambulate on the 3rd/4th post-operative day. The pain peaked on the 1st post-operative day then decreased slowly. Oral analgesics were administered round the clock to alleviate pain. 65 (93%) patients could walk on the first day after surgery without severe pain. None of the patients complained of clicking sensation in their chest when moving or performing certain activities.

3.1. Chest Wall Deformity

In 70 donor sites, 40 (n) patients developed donor-site deformity. At 6-month follow-up, the incidence of anterior chest wall deformity was the highest in Block-III at 80%, where out of 10 patients, 8 developed donor-site deformity, followed by Block-II and Block-IV both at 57%, and the least occurrence of deformity in Block-I at 0%, where out of 4 patients none developed deformity (**Table 2**).

At 6-month follow-up, the incidence of chest wall deformity was inversely proportional to age. Highest incidence was observed in the 6 - 10 years age group at 84% (21), 11 - 15 years age group at 57% (12), 16 - 20 years age group at 31% (4), and the least in >21 years age group at 27% (3) (**Table 3**). In the 6 - 10 years age group, the outcome shows that highest incidence of deformity was seen in association to Block-IV harvest at 83% (10/12) (**Table 4**). This comparison of age group and the type of costal cartilage block harvested revealed that better results were found in the older age group than in the younger.

Table 3. Incidence of deformity in different age groups.

Age (years)	Total patients (N)	Patients with deformity (n)	Incidence of Deformity
6 - 10	25	21	84%
11 - 15	21	12	57%
16 - 20	13	4	31%
>21	11	3	27%
Total	70	40	57%

Table 4. Patients' age and type of costal cartilage harvested.

Age (years)	Block-I; 7th	Block-II; 7th, 8th	Block-III; 6th (axial half), 7th, 8th	Block-IV; 6th (complete), 7th, 8th	Total
6 - 10	0 (0%)	7 (35%)	4 (50 %)	10 (83%)	21
11 - 15	0 (0%)	6 (30%)	4 (50%)	2 (17%)	12
16 - 20	0 (0%)	4 (20%)	0 (0%)	0 (0%)	4
>21	0 (0%)	3 (15%)	0 (0%)	0 (0%)	3
Total	0	20	8	12	40

Evaluation of costal margin defect with chest wall topography demonstrated a difference in incidence in regard to gender. Chest wall deformity with asymmetry of anterior lower costal margin was observed in 12 out of 18 females at 66%, and 28 males out of 52 at 54%. But in the sub-group, there is a higher incidence of deformity in males at 75% in both Block-III (9), and Block-IV (6) when compared to the respective females in the subgroup (Table 5).

Table 5. Patients' age and type of costal cartilage harvested.

Gender	Block-I; 7th	Block-II; 7th, 8th	Block-III; 6th (axial half), 7th, 8th	Block-IV; 6th (complete), 7th, 8th	Total
Male	0 (0%)	13 (65%)	6 (75%)	9 (75%)	28/52
Female	0 (0%)	7 (35%)	2 (25%)	3 (25%)	12/18
Total	0	20	8	12	40

Table 6. Patients' height and type of costal cartilage harvested.

Height (cm)	Block-I; 7th	Block-II; 7th, 8th	Block-III; 6th (axial half), 7th, 8th	Block-IV; 6th (complete), 7th, 8th	Total
120 - 135 cm	0 (0%)	2 (10%)	4 (50%)	8 (67%)	14
136 - 150 cm	0 (0%)	6 (30%)	2 (25%)	4 (33%)	12
151 - 165 cm	0 (0%)	8 (40%)	2 (25%)	0 (0%)	10
>166 cm	0(0%)	4 (20%)	0 (0%)	0 (0%)	4
Total	0	20	8	12	40

Out of the 12, 8 (67%) patients that developed deformity were in the 120 - 135 cm group height, which was the highest age range with Block-IV costal cartilages harvested (Table 6). The deformities were more conspicuous and severe when two or more costal cartilages had been harvested (Figure 4).

Figure 4. A 9-year-old boy with height of 134 cm. (Anterior and anterolateral view) chest wall deformity was observed at the right side of the chest (arrow) 8 months after harvest of 6^{th} ,7^{th} ,8^{th} costal cartilages.

3.2. Evaluation of Chest Scars

Chest scars were classified as excellent, good, acceptable and poor. At 6-month follow-up period, all the patients were satisfied with the donor-site chest scars. Nonetheless, 2 (3%) patients presented with hypertrophic scars (Figure 5). The younger age group had better chest scars compared to the older group. No difference was found in the scar quality between males and females at 6-month follow-up.

Figure 5. 21-year-old male presented with hypertrophic scar at the right side of the chest after harvesting costal cartilage.

3.3. Statistical Analysis of Chest Circumference

By the statistical analysis of preoperative and postoperative chest circumference of patients after 6-month follow-up of harvesting sixth to eighth costal cartilage (Table 7), there was no significant difference from the point sternal angle and nipple, but significant difference was found from xiphisternum, the intersection between PSL and LCM, and the intersection between MCL and LCM ($P < 0.05$).

In Table 8, comparison between left and right side of anterior chest after 6 months of harvested sixth to eighth costal cartilage there was also no significant difference in sternal angle and nipple but was observed significant difference in xiphisternum, the intersection between PSL and LCM, and intersection of MCL and LCM (P < 0.05). Usually, the patient's anterior chest wall was examined after 6 months of second stage operation. Levels of rib deformity do not always coincide with the levels of harvested costal cartilage. In our series, the highest chest deformities have occurred when the sixth costal cartilage was also harvested.

Table 7. Preoperative and postoperative measurement of chest circumference (x ± s, cm).

Chest	Patients	SA	Nipple	Xiphisternum	PSL and LCM	MCL and LCM
Pre-op	70	69.95 ± 10.85	68.6 ± 10.97	67.25 ± 10.43	65.81 ± 9.82	64.42 ± 9.76
Post-op	70	69.14 ± 10.46	68.64 ± 10.60	63.74 ± 10.24	62.47 ± 9.36	60.98 ± 9.30
P		P > 0.05	P > 0.05	P < 0.05	P < 0.05	P < 0.05

Pre-op, Pre-operatively; Post-op, Post-operatively.

Table 8. Postoperative correlation of bilateral anterior chest wall in study group (x ± s, cm).

Chest	SA	Nipple	Xiphisternum	PSL and LCM	MCL and LCM
Left	34.55 ± 5.23	34.51 ± 5.39	33.51 ± 5.46	33.47 ± 5.11	31.85 ± 4.36
Right	34.55 ± 5.26	34.07 ± 5.30	30.98 ± 4.52	30.34 ± 4.05	28.97 ± 3.73
P	P > 0.05	P > 0.05	P < 0.05	P < 0.05	P < 0.05

SA Sternal Angle; PSL Parasternal Line; LCM Lower Costal Margin; MCL Mid-clavicular Line.

4. Discussion

Costal cartilage is the most reliable material for microtia reconstruction because adequate volume is available for fabricating ear framework. But the degree of chest wall deformity is variable after harvesting costal cartilage because it depends on technique of surgical procedure and methods of measurement. However, various authors have reported different data of chest wall deformity. There have been many modifications in the technique of ear reconstruction since Tanzer's pioneering work [8]. Originally multistage procedure has been brought down to three stages as described above. This study examined the donor-site morbidity following costal cartilage harvest to investigate the extent of defects that arise after such a procedure. Chest wall deformity is found after harvesting costal cartilage in microtia reconstruction. This indicates that the degree of chest wall deformity is created with any harvest of costal cartilage.

Previous reports have shown concern regarding complications after harvest of costal cartilage in the short-term follow-up [29] [30]. Tanzer and Thomson *et al.* [24] [25] have reported of post-operative chest wall deformities in 16% and 25% of patients respectively when costal cartilage was harvested together with the perichondrium. But the evaluation was based on gross physical observation without radiographic studies. Many authors [8] [31]-[33] over the years have suggested the preservation of the perichondrium and the rim of upper margin of the sixth costal cartilage to minimize chest deformity.

Nagata [28] [34] rarely offers the procedure to children younger than 10 years since there is a higher risk to develop chest wall deformity. However, when he had to, he left a sleeve of perichondrium behind to promote healing of cartilage tissue and aid regeneration of cartilage at the donor-site. Our study also supports that, small amounts of cartilage can be regenerated but variable degrees of chest wall deformity always exist after harvesting one or more costal cartilage.

Recently, Zhang Qing Guo [35] successfully achieved deepening of concha and prominent indentation of reconstructed ear with a modified retro-auricular expanded skin flap method and autologous costal cartilage framework. Guo also described a "modified rim preserved technique" of sixth costal cartilage during costal cartilage harvest, to minimize the degree of donor-site deformity.

Efforts must be made to keep the scar as short as possible without compromising the harvest procedure itself. The incision is placed slightly obliquely to allow maximum access and also to prevent skin tension while the wound is closed. Small wound incision is particularly important in female patients where the costal cartilage harvest site is a cosmetically sensitive area. However, this should not be an impediment to harvesting sufficient amounts of cartilage to sculpt the cartilage ear framework. In some instances, when the costal cartilage is difficult to harvest, in such patients the incision is extended obliquely in the desired direction.

Chest scars are evaluated on the basis of width, flattening, and color matching with surrounding normal skin. The width of the incision scar is the most common factor to vary. The increasing width may be caused by the continuous respiratory movement of the chest wall. It might be assumed that the chest has a strong tendency to form hypertrophic scars. However, in our study, only 2 patients (3%) have presented with hypertrophic scars.

Pain is another common problem associated with harvesting costal cartilage, especially in obese patients. In this study, some patients have complained of pain on the 1st postoperative day. However local anesthesia was administered to all patients during the operation, as it has been shown to be successful in alleviating pain. This study confirmed its benefit, particularly in the first 24 hours. No clicking at the donor-site has been found in our study patients.

Timing of microtia reconstruction using costal cartilage is based on three primary factors. First, a sufficient amount of costal cartilage must exist, specifically the synchondrosis of the fifth through seventh ribs. Second, in microtia repairs, the normal ear should reach 85% of the normal adult size at 6 years, so as to attain a symmetrical size in the reconstructed ear. Third, children's body image sensitivity begins around this age. Most surgeons begin microtia repair when the child is between 6 and 10 years of age [24] [32] [36]. Nagata [15]-[18], [37] reported that better results in shape and size could be obtained in patients when surgery was performed at 10 years of age, or when the chest circumference at the level of the xiphoid process is at least 60 cm.

4.1. Incidence of Rib Deformity

Development and shape of anterior thoracic cage is mainly supported by ribs, costal cartilage, and sternum with surrounding tissues. Chest wall deformity after costal cartilage harvest was previously reported but not in detail. The deformed ribs did not always coincide with the level of the cartilage harvested. The upper ribs had a high tendency to deform when the neighboring cartilages were harvested, even in patients where the cartilage was harvested further away. The sixth rib had more inclination towards deformity than others, and rib deformities were also observed despite preservation of their costal cartilages. These results suggested that the shape of the ribs was maintained not only by their connecting costal cartilages, but also by surrounding structures such as articulations with upper or lower costal cartilages and intercostal muscles.

4.2. Relationship between Age, Height and Chest Wall Deformity

Early surgery for microtia reconstruction is recommended to reduce the psychological impact to both patient and parents. However, surgery at early increases the risk of thoracic deformity, as reported by many in the literature [26]. Thomson and Winslow [38] have recommended framework construction for microtia at 2 to 3 years of age and completion of surgeries by age 6, because cartilage frameworks with perichondrium will grow. But, in reviewing 88 postoperative donor sites, he has also considered that the patients were too young for adequate rib growth, resulting in a rate of 25% abnormal chest contour, as chest wall retrusion after costal cartilage harvest [25]. The ideal age for costal cartilage harvesting in microtia reconstruction is generally accepted at 6 years of age because the ear shell has reached almost adult size [36]. Netscher and Peterson [39] have described ribs ossify from one primary center in the shaft, which appears near the angle about eighth week, and the secondary centers which appear at about 16 years and complete rib ossification occurs at 25 years of age. The most rapid growth period of costal cartilage is during the first 4 years of life, and the second growth spurt occurs between 12 and 18 years of age. Therefore, it is wise to initiate the costal cartilage harvest after 6 years of age for adequate rib development. We usually initiate the surgery for microtia reconstruction when the patient is at the preschool age of 6 years.

In reviewing chest donor-site topography, some difficulties were encountered to describe normal, acceptable and abnormal because most of the patients had some degree of chest wall retrusion at the donor-site on "deep" inspiration. We accepted the presence of retrusion or some depression at the harvesting site in the resting state. In our series of 70 patients, correlation between age and harvested costal cartilage, 40 (57%) patients were found chest wall deformity. Out of 12 patients, 10 (83%) patients presented with donor-site deformity when 6^{th} (complete), 7^{th} and 8^{th} costal cartilages were harvested in the age 6 to 10 years of age. This higher incidence of deformity in younger age group may be due to the ongoing chest development and the level of lower costal margin being a little lower than the older age group. Furthermore, Chinese thin body shape in younger age group can make the deformity more obvious. Therefore, in this age group chest development is easily affected after costal cartilage harvest.

Height of the patient is another important factor to observe in microtia reconstruction. We measure the height at variable age of patients because we have to observe the patient's nutritional status and development of the chest to minimize chest wall deformity. According to patient's height, a total of 40 deformities, 8 (67%) patients of deformity were found in the group of patient's height 120 - 135 cm, which was the highest range with harvested 7, 8 and full of 6 costal cartilages in 12 patients. But other patients had also occurred chest wall retrusion with harvested 7, 8 or 7, 8 and axial half of 6th or 7th costal cartilage. However, this study revealed the degree of chest wall deformity existed at any harvest of costal cartilage in smaller in height of the patients. Deformity in females is less conspicuous than males because of breast growth and locally more abundant subcutaneous fat. Additionally, in our series, number of males are higher and also their body image are comparatively thinner than female patients.

There is definitely required technical skill and experience to harvest costal cartilage especially when the perichondrium is to be left completely intact at the donor site. Harvest of one block costal cartilage may cause little influence on the skeletal thorax. Harvest of two or more costal cartilages bridging between the ribs and the sternum may cause a conspicuous thoracic deformity, especially in young patients. In our study, we have reported a high rate of chest wall deformity in 40 (57%) patients (28 males and 12 females) and the evaluations are based on chest wall topography with asymmetry of anterior lower costal margin. Deviation of xiphoid process of sternum was not found in our patients. But in radiological examinations (X-ray) of chest, there is not any abnormal finding after 6 months of harvesting costal cartilage in microtia reconstruction, and also patient party are unable to do CT of chest because of their economic condition. The number of patients in this series is to draw conclusions and to define the deformity.

Measurement of chest wall after 6 months of harvesting costal cartilage comparison between preoperative and postoperative, and postoperative left and right side of the chest, we have found the significant statistical difference ($P < 0.05$) at the point xiphoid process, the crossing point between parasternal and lower costal margin, and crossing point between mid-clavicular line and lower costal margin. However, we again emphasize that chest wall deformity always existed in variable degree after harvesting costal cartilage.

4.3. Mechanism of Chest Wall Deformity

The skeletal thorax consists of the sternum, ribs, costal cartilage, and vertebrae. These structures form costal rings oblique to the coronal plane of the body. The thoracic cage structure is maintained by the elasticity of the ribs and ligaments. If the costal rings are transected, the thorax can spring open [40]. In our study patients, sixth to eighth costal cartilages which articulate with the sternum or with the upper costal cartilages are harvested, the anterior end of the ribs loses their stability against the sternum. In consequence, the ribs contradictorily curve inward with growth. This finding could be explained by respiratory excursion of the thorax. The normal costal rings rise with inspiration, approaching the coronal plane as the ribs flare outward during inspiration [40]. At the same time, the ribs are pulled inward by the negative respiratory pressure and the contraction of the diaphragm, which attaches to the inner surface of the anterior half of the seventh to twelfth ribs. However, the impaired ribs may be deformed by the muscle forces acting upon them without the additional support of the costal cartilage connection between the ribs and the sternum.

4.4. Injury to the Rib Growth

The costal cartilages are usually obtained from the CCJ to their sternal ends. Therefore, the growth of the connecting ribs may have been disturbed while other costal rings have increased in size, and then it results to the deformity. Roy and Sarnat [41] [42] have described the sixth or the seventh ribs possess the strongest growth capacity of the 12 pairs of ribs. By these correlations, higher incidences of rib deformity occurred at this level of harvesting costal cartilage.

To improve the outcome for patients undergoing cartilage harvest, efforts must be made to further reduce donor-site morbidity. Refinements and modifications technique of harvesting costal cartilage in microtia reconstruction may achieve better result in the future.

5. Limitation and Recommendation

The limitation of this study was unable to do further radiological investigation through CT imaging and short follow-up period and several social factors. Further research will be necessary to develop new techniques through tissue engineering to reduce the donor site morbidity.

6. Conclusion

Autologous costal cartilage is the primary material for fabricating an ear framework that remains clinically both stable and inert. We emphasize that some degree of chest wall deformity is inevitably created with any amount or number of costal-cartilage harvest. To avoid significant deformity, it is important that only the necessary amount of costal-cartilage is harvested and at the lowest level as far as possible. Additionally, avoidance of injury to the germinal growth center of the costochondral junction is also of paramount importance. Patients with younger age, smaller in height and male have more chance to develop deformity. Therefore, the patient's age, gender, height and chest development are equally important factors that influence the donor-site deformity in microtia reconstruction.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Du, J.M., Chai, J.K., Zhuang, H.X., *et al.* (2008) An Investigation of Psychological

Profiles and Risk Factors in Congenital Microtia Patients. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, **61**, S37-S43. https://doi.org/10.1016/j.bjps.2007.09.002

[2] McDowell, F. (1969) The Classic Reprint. Ancient Ear-Lobe and Rhinoplastic Operations in India. *Plastic and Reconstructive Surgery*, **43**, 515-522.

[3] Tagliacozzi, G. (1597) De Curtorum Chirurgia per Institionem. Gaspare Bindonus.

[4] Dieffenbach, J.F. (1845) Die Operative Chirurgie. F.A. Brockhaus, Vol. 1, 744-746.

[5] Ely, E.T. (1968) An Operation for Prominence of the Auricles. *Plastic and Reconstructive Surgery*, **42**, 582-583. https://doi.org/10.1097/00006534-196812000-00012

[6] Gillies, H.D. (1920) Plastic Surgery of the Face Based on Selected Patients of War Injuries of the Face Including Burns with Original Illustrations. H. Frowde.

[7] Tanzer, R.C. (1959) Total Reconstruction of the External Ear. *Plastic and Reconstructive Surgery*, **23**, 1-15. https://doi.org/10.1097/00006534-195901000-00001

[8] Tanzer, R.C. (1971) Total Reconstruction of the Auricle: The Evolution of a Plan of Treatment. *Plastic and Reconstructive Surgery*, **47**, 523-533. https://doi.org/10.1097/00006534-197106000-00001

[9] Brent, B. (1980) The Correction of Microtia with Autogenous Cartilage Grafts. I. The Classic Deformity. *Plastic and Reconstructive Surgery*, **66**, 1-12. https://doi.org/10.1097/00006534-198007000-00001

[10] Brent, B. (1980) The Correction of Microtia with Autogenous Cartilage Grafts. II. Atypical and Complex Deformities. *Plastic and Reconstructive Surgery*, **66**, 13-21. https://doi.org/10.1097/00006534-198007000-00002

[11] Brent, B. (1987) Total Auricular Construction with Sculpted Costal Cartilage. The Artistry of Reconstructive Surgery. Mosby, 113.

[12] Microtie, F.F. (1992) Reconstruction par la technique de Brent. *Annales de Chirurgie Plastique et Esthétique*, **37**, 119-131.

[13] Fukuda, O. (1974) The Microtic Ear: Survey of 180 Patients in 10 Years. *Plastic and Reconstructive Surgery*, **53**, 458-463. https://doi.org/10.1097/00006534-197404000-00014

[14] Tanzer, R.C. (1963) An Analysis of Ear Reconstruction. *Plastic and Reconstructive Surgery*, **31**, 16-30. https://doi.org/10.1097/00006534-196301000-00003

[15] Nagata, S. (1994) Modification of the Stages in Total Reconstruction of the Auricle: Part I. Crating the Three-Dimensional Costal Cartilage Framework for Lobule-Type Microtia. *Plastic and Reconstructive Surgery*, **93**, 221-230. https://doi.org/10.1097/00006534-199402000-00001

[16] Nagata, S. (1994) Modification of the Stages in Total Reconstruction of the Auricle: Part II. Grafting the Three-Dimensional Costal Cartilage Framework for Concha-Type Microtia. *Plastic and Reconstructive Surgery*, **93**, 231-242. https://doi.org/10.1097/00006534-199402000-00002

[17] Nagata, S. (1994) Modification of the Stages in Total Reconstruction of the Auricle: Part III. Grafting the Three-Dimensional Costal Cartilage Framework for Small Concha-Type Microtia. *Plastic and Reconstructive Surgery*, **93**, 243-253. https://doi.org/10.1097/00006534-199402000-00003

[18] Nagata, S. (1994) Modification of the Stages in Total Reconstruction of the Auricle: Part IV. Ear Elevation for the Constructed Auricle. *Plastic and Reconstructive Surgery*, **93**, 254-266. https://doi.org/10.1097/00006534-199402000-00004

[19] Brent, B. (1981) A Personal Approach to Total Auricular Construction: Case Study. *Clinics in Plastic Surgery*, **8**, 211-221. https://doi.org/10.1016/s0094-1298(20)30447-8

[20] Brent, B. (1974) Ear Reconstruction with an Expansile Framework of Autogenous Rib Cartilage. *Plastic and Reconstructive Surgery*, **53**, 619-628. https://doi.org/10.1097/00006534-197406000-00001

[21] Brent, B. (1975) Reconstruction of Ear, Eyebrow, and Sideburn in the Burned Patient. *Plastic and Reconstructive Surgery*, **55**, 312-317. https://doi.org/10.1097/00006534-197555030-00007

[22] Osorno, G.M.D. (1999) Autogenous Rib Cartilage Reconstruction of Congenital Ear Defects: Report of 110 Cases with Brent's Technique. *Plastic and Reconstructive Surgery*, **104**, No. 7. https://doi.org/10.1097/00006534-199912000-000011951-1962

[23] Weerda, H. and Siegert, R. (1998) Classification of Auricular Malformations. Auricular and Middle Ear Malformations, Ear Defects and Their Reconstruction.

[24] Tanzer, R.C. (1978) Microtia—A Long-Term Follow-Up of 44 Reconstructed Auricles. *Plastic and Reconstructive Surgery*, **61**, 161-166. https://doi.org/10.1097/00006534-197802000-00001

[25] Thomson, H.G., Kim, T. and Ein, S.H. (1995) Residual Problems in Chest Donor Sites after Microtia Reconstruction: A Long-Term Study. *Plastic and Reconstructive Surgery*, **95**, 961-968. https://doi.org/10.1097/00006534-199505000-00002

[26] Ohara, K., Nakamura, K. and Ohta, E. (1997) Chest Wall Deformities and Thoracic Scoliosis after Costal Cartilage Graft Harvesting. *Plastic and Reconstructive Surgery*, **99**, 1030-1036. https://doi.org/10.1097/00006534-199704000-00017

[27] Brent, B. (1977) The Acquired Auricular Deformity: A Systematic Approach to Its Analysis and Reconstruction. *Plastic and Reconstructive Surgery*, **59**, 475-485. https://doi.org/10.1097/00006534-197704000-00001

[28] Kawanabe, Y. and Nagata, S. (2006) A New Method of Costal Cartilage Harvest for Total Auricular Reconstruction: Part I. Avoidance and Prevention of Intraoperative and Postoperative Complications and Problems. *Plastic and Reconstructive Surgery*, **117**, 2011-2018. https://doi.org/10.1097/01.prs.0000210015.28620.1c

[29] Laurie, S.W.S., Kaban, L.B., Mulliken, J.B. and Murray, J.E. (1984) Donor-Site Morbidity after Harvesting Rib and Iliac Bone. *Plastic and Reconstructive Surgery*, **73**, 933-938. https://doi.org/10.1097/00006534-198406000-00014

[30] Skouteris, C.A. and Sotereanos, G.C. (1989) Donor Site Morbidity Following Harvesting of Autogenous Rib Grafts. *Journal of Oral and Maxillofacial Surgery*, **47**, 808-812. https://doi.org/10.1016/s0278-2391(89)80038-2

[31] Brent, B. (1992) Auricular Repair with Autogenous Rib Cartilage Grafts: Two Decades of Experience with 600 Patients. *Plastic and Reconstructive Surgery*, **90**, 355-374. https://doi.org/10.1097/00006534-199209000-00001

[32] Brent, B. (2002) Microtia Repair with Rib Cartilage Grafts. *Clinics in Plastic Surgery*, **29**, 257-271. https://doi.org/10.1016/s0094-1298(01)00013-x

[33] Brent, B. (1999) Technical Advances in Ear Reconstruction with Autogenous Rib Cartilage Grafts: Personal Experience with 1200 Cases. *Plastic and Reconstructive Surgery*, **104**, 335-338. https://doi.org/10.1097/00006534-199908000-00002

[34] Kawanabe, Y. and Nagata, S. (2007) A New Method of Costal Cartilage Harvest for Total Auricular Reconstruction: Part II. Evaluation and Analysis of the Regenerated Costal Cartilage. *Plastic and Reconstructive Surgery*, **119**, 308-315. https://doi.org/10.1097/01.prs.0000244880.12256.7c

[35] Zhang, Q., Quan, Y., Su, Y., Shi, L., Xie, Y. and Liu, X. (2010) Expanded Retroauricular Skin and Fascial Flap in Congenital Microtia Reconstruction. *Annals of Plastic Surgery*, **64**, 428-434. https://doi.org/10.1097/sap.0b013e3181b0bb7e

[36] Tanzer, R.C. (1987) The Correction of Microtia. In: Burt, B., Ed., *The Artistry of Reconstructive Surgery*, Mosby, 93-98.

[37] Nagata, S. (1993) A New Method of Total Reconstruction of the Auricle for Microtia. *Plastic and Reconstructive Surgery*, **92**, 187-201. https://doi.org/10.1097/00006534-199308000-00001

[38] Thomson, H.G. and Winslow, J. (1989) Microtia Reconstruction: Does the Cartilage Framework Grow? *Plastic and Reconstructive Surgery*, **84**, 908-915. https://doi.org/10.1097/00006534-198912000-00007

[39] Netscher, D.T. and Peterson, R. (1990) Normal and Abnormal Development of the Extremities and Trunk. *Clinics in Plastic Surgery*, **17**, 13-21. https://doi.org/10.1016/s0094-1298(20)31263-3

[40] Steindler, A. and Thomas, C.C. (1955) The Mechanism of Respiration. Introduction and Definition. Kinesiology of the Human Body. C.C. Thomas.

[41] Snellman, O. (1973) Growth and Remodelling of the Ribs in Normal and Scoliotic Pigs. *Acta Orthopaedica Scandinavica*, **44**, 1-91. https://doi.org/10.3109/ort.1973.44.suppl-149.01

[42] Roy, E.W. and Sarmat, B.G. (1956) Growth in Length of Rabbit Ribs at Costochondral Junction. *Surgery, Gynecology and Obstetrics*, **103**, 481-486.

Abbreviations

PSL	Parasternal Line
LCM	Lower Costal Margin
MCL	Mid-Clavicular Line