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<Original Article>

## Anthropometric Study of Ear Position and its Clinical Application to the Total External Ear Reconstruction

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ear positioning template

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### ABSTRACT

Total ear reconstruction is still one of the most challenging surgical procedures for plastic surgeons for two reasons: 1) anatomical complexity to achieve deep definition 2) there is no standard guide to position the new ear in an appropriate position. The latter seem to be underrecognised because I have seen many reconstructed ear located in a wrong place both in the literatures and clinical setting. Therefore I performed anthropometric study to understand the proper position of the external ear. Three measurements ex-t (=transverse distance of ear from lateral canthus), ps-t (=transverse distance of ear from posterior margin of sideburn), and sa-sba (=vertical length of the external ear) were taken by using standard anthropometric method. All three measurements revealed sex-related significant difference ( $p < 0.005$ ). Newly defined reference 'ps-t' seems to be useful guideline to avoid interiorly inclined, malposition of the new ear. I applied these data into creating ear positioning template which found to be able to produce consistent results in terms of appropriate ear positioning. Clinical cases will be shown to prove the effectiveness of my newly developed ear positioning template based on this anthropometric study.

### INTRODUCTION

Total ear reconstruction with autogenous tissues is one of the greatest technical challenge a reconstructive surgeon may encounter [1]. The reconstructive surgeon must delicately carve and fabricate the rib cartilage into three dimensional framework that recreates the ear's sophisticated shape and then position this framework in the proper location for the new external ear [2-5]. Positioning the

new external ear in a proper position seem to be underrecognised, although author believes positioning poses challenge for the surgeon. Anterior inclined ear is one of the common unfavorable results. **Figure 1** shows the example of too much anterior inclination of new ear performed at other institution. Because of the variable location of the remnant lobule in microtia patients, it is also a common mistake to create the ear at the site of remnant

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Fig.1 Unfavorable result of external ear reconstruction by other; axis of the external ear is too much anteriorly inclined



Fig.2 In hemifacial microsomia, vestige ear is more likely located in the face mask. If you reconstruct a new external ear there, you will see the new ear located in the cheek (wrong place).

lobule. In hemifacial microsomia a case, remnant lobule is more likely to be located in the face mask (Fig.2), therefore if surgeon places the new external ear at the site of remnant lobule, ear will be located in cheek which is not acceptable. To prevent inappropriate positioning of the external ear, we planned to study anthropological normal ear position based on direct measurement of adult normal population to establish the basic quantitative data for the future use. Based on this study I created newly developed external ear positioning template to position the reconstructed ear at precise location during total autogenous ear reconstruction. The aim of the present study is to report (1) basic quantitative data of the ear position and vertical ear length obtained by anthropometric methods directly from 20-30 years-old normal adult; (2) newly developed ear posi-

tioning template for total ear reconstruction; and (3) clinical application of ear positioning template for total ear reconstruction.

## MATERIALS and METHODS

### *Anthropometric study of the ear position:*

The study population consists of 100 Japanese adult (50 male, 50 female, aged 20 to 30 years without apparent facial deformities. We took three linear anthropometric measurement: (1) transverse distance of ear from lateral canthus (ex-t), (2) transverse distance of ear from posterior margin of sideburn (ps-t), and (3) total ear height (sa-sba) (Fig.3). Total ear height was measured as the distance from the caudal-most projection of the lobule to the cephalic-most projection of the helix. Ps is a newly introduced reference point: ps (posterior margin of the side burn) is defined where ex-t crosses at the posterior margin of side burn. Distance between the lateral canthus (ex) to tragus of the external ear (t), ex-t, was measured. Both right and left side was measured for each measurements. The technique of taking measurements I used was standard method described previously [6-7]. All measurements were taken using a standard caliper (GPM, Swiss) by a single investigator. Statistical procedures were used for all calculations. Statistical differences between group means were tested by the Student's t-test. Group means, standard deviations, and 95 percent confidential interval (CI) for individual predicted values, as well as mean values, were calculated for the measurement variables. CI for individual predicted values were calculated since the purpose of this study was to

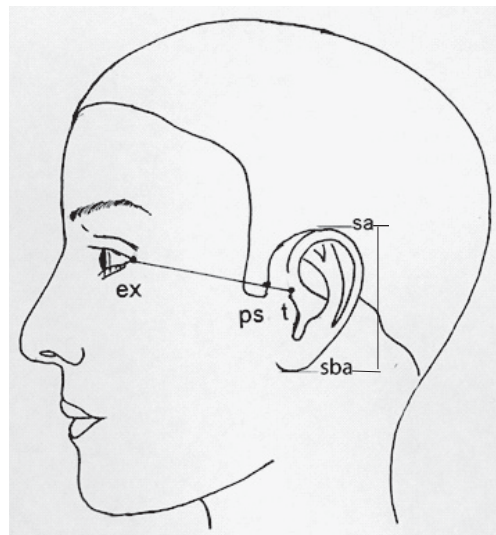


Fig.3 Anthropometry of the ear position

produce normative values. Test statistics associated with probabilities of 0.05 or less were considered significant, and all probability (p) values quoted were two-sided.

**Creating the ear positioning template:**

Based on current anthropometric study in addition to others [6-9], I designed newly developed ear positioning template. The basic design of template for normal ear framework is based on the combination of normal ear proportion proposed by Tolleth [10, 11] and normal ear cartilage framework proposed by Nagata [12-20]. Normal ear framework was superimposed in the normal ear with the 2mm- thickness lateral skin envelope and 1.5mm medial skin envelope. References included in this template were: ① Outline of normal external ear. ② Ear framework pattern with grid ③ Frankfurt horizontal line(FHL) ④ Upper level of the ear, parallel to FHL ⑤ Lower level of the ear, parallel to FHL ⑥ Proposed hair line ⑦ Axis of the ear (20 degrees from vertical) ⑧ Otobasion ⑨ Posterior border of the sideburn(ps) ⑩ Ante-

rior border of the external ear ⑪ Arc of potential lateral canthal position(ex)80mm, 90mm, and 100mm ⑫ Arc of potential posterior edge of sideburn(ps), 15mm, 20mm, and 25mm of the external ear (Fig.4). Design of ear positioning template can be either enlarged or reduced to match the size of new ear to plan, then these were copied into transparent film (OHP film, product number:27040, A-One CO.LTD. Tokyo, Japan). By doing so, any size of template can be easily produced, therefore one can plan to reconstruct exact size one wish to create. Three type of ear positioning template are available; 1) pre-operative evaluation. 2) pre-operative marking 3) intra-operative confirmation.

**RESULTS**

**Anthropometric analysis:**

Combined data from all 200 ears are depicted in Table 1. The average total ear height for male was 64.7mm, and for female was 59.7mm. The average distance of ex-t for male was 94.5mm, and for female was 90.4mm. The average distance of ps-t for male was 21.2mm, and for female was 20.5mm. Table 1 lists data classified according to sex. As expected based on head size, significant sex-related differences were noted in the distance from the lateral palpebral commissure (ex) to the tragus of external ear (t) (p< 0.001). Measured distance for men were approximately 4.4percent longer in men than in women. Similarly, the height of the auricle was significantly larger in men than in women by approximately 7.7 percent (p< 0.001). The distance from posterior edge of sideburn (ps) to tragus of the external ear (t) was also significantly larger in men than in women by approximately 3.3 percent (p< 0.005). There was no significant difference of measurements value between left and right in all three measurements.

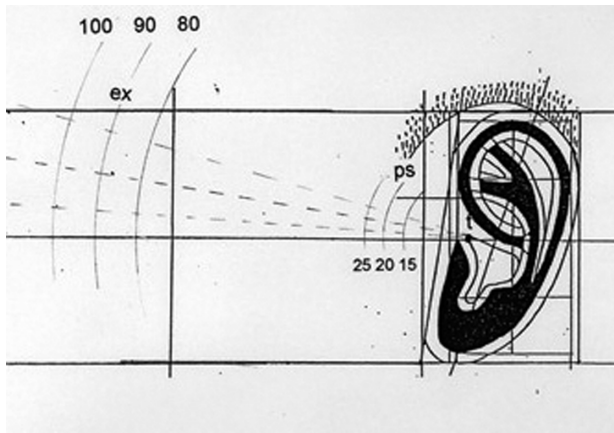


Fig.4 Basic design of ear positioning template

Table1 Anthropometric measurement of ear position in 20-30 years-old normal adult

	Male(N=50) (mm)									Female(N=50) (mm)									gender difference
	Right			Left			ovreall			Right			Left			ovreall			
	Mean	SD	95%CI	Mean	SD	95%CI	Mean	SD	95%CI	Mean	SD	95%CI	Mean	SD	95%CI	Mean	SD	95%CI	
ex-t*	94.6	3.8	93.5-95.7	94.5	3.9	93.5-95.5	94.5	3.8	93.9-95.2	90.5	3.2	89.6-91.4	90.4	3.4	89.4-91.36	90.4	3.3	89.8-91.1	p<0.001
ps-t**	21.3	1.5	20.9-21.7	21.1	1.4	20.7-21.5	21.2	1.5	21-21.6	20.5	1.3	20.2-20.9	20.5	1.1	20.2-20.8	20.5	1.2	20.3-20.7	p<0.005
sa-sba***	64.1	4.6	62.8-65.4	65.2	4.5	63.9-66.4	64.7	4.5	63.3-67	59.4	3.3	58.5-60.4	59.9	3.5	58.9-60.9	59.7	3.4	59-60.35	p<0.001

\*ex-t=Transverse distance of ear from lateral canthus

\*\*ps-t=Transverse distance of ear from posterior margin of sideburn

\*\*\*sa-sba=Vertical length of ear



Fig.5 Typical lobule type microtia prior to the surgical markings



A



B

Fig.6 In upright position, normal ear position was checked with template, references such as lateral canthus, and eyebrow are marked on the template (A), then the template was used determine the new ear site for microtia ear (B)

***Clinical application of the ear positioning template:***

A 10 years-old patient was presented with unilateral microtia. We planned total autogenous auricular reconstruction for her. Level of the ear was checked with the patient in a upright position. Under general anesthesia, before preparation, preoperative marking was started (Fig.5). First, topographic relationship of the opposite, normal ear with facial features was examined. Ear pattern was overlapped on the normal ear. Three parallel lines were used to

determine the upper and lower level of the ear. Reference points such as palpebral fissure, tail of the eyebrow, ala (al, sbal), hairline, and sideburn were then marked on the template (Fig.6). Next attention was turned to the microtia side. With the aid of reference points on the template, topographic relationship of the opposite, normal ear with facial features was duplicated on the microtia side. New ear and other references were marked on the patient with fine marking pen. Markings were then redraw with xylene-based marking pen (Magic ink No.500, Teranishi Chemical Industry Co, Ltd. Osaka, Japan), which we found less likely to diminish during surgery. After completion of all the markings on the patient, template was reapplied and the accuracy of markings was checked (Fig.7). Topographic relation



Fig.7A Checking the normal side to obtain normal references marked on the template



Fig.7B Ear positioning template was placed on the face to check the accuracy of the pre-surgical markings.

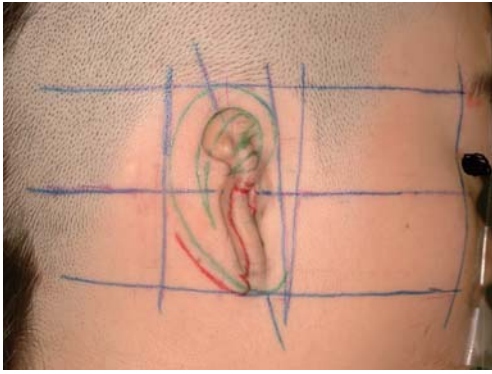


Fig.8 Preoperative marking including incision design is demonstrated

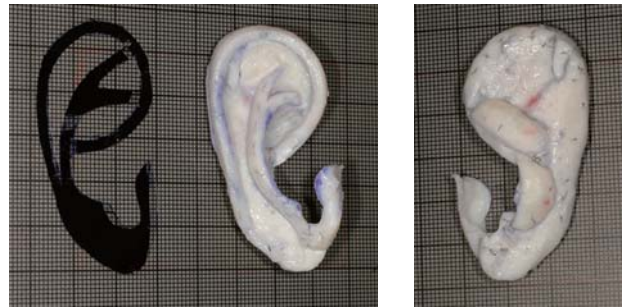


Fig.10 Completed three dimensional cartilage framework; Frontal view with template (A) and posterior view (B)

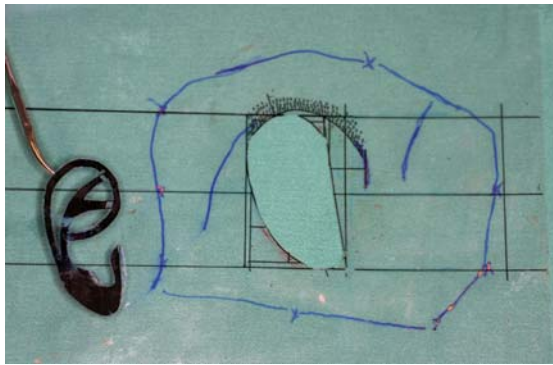


Fig.9 On the template, references such as hair line, and the area of surgical drape were marked, and the ear template part was removed to facilitate reconstructed ear

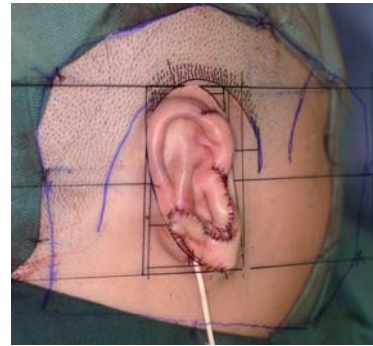


Fig.11 After completion of skin closure, ear position was confirmed with ear positioning template

between remnant lobule and new ear site is now clarified. W-shaped posterior lobule and mastoid skin incision was marked without difficulty (Fig.8). Immediately prior to skin incision, ear positioning template was placed on the surgical site, and references such as hair line, sideburn, outline of surgical site, and suture knots were marked with marking pen. Ear part of template was cut out to facilitate the reconstructed ear at the time of confirmation of positioning (Fig.9). While skin flap dissection and preparation proceed, 6th to 9th costal cartilage was harvested from ipsilateral chest. All the remnant cartilage was removed from remnant ear. Next on the side table, fabrication of three dimensional cartilage framework was performed (Fig.10). Completed framework was inserted in the skin pocket, and the template was applied to check the planned position of the new ear (Fig.11). Outline of the new ear was marked as reference. Cartilage framework was sutured to the recipient bed with 4-0 clear nylon. Af-



Fig.12 Post-operative view of the lobule-type microtia

ter completion of skin suture, the template was again applied to confirm the position of the new ear. Fig. 12 shows post-operative view of the same patient. Post-operative view clearly showed that ear position is appropriate and the definition of external ear

is deep and appropriate.

#### **Clinical cases**

**Case 1:** A 10-years old male born with left concha type microtia was referred from plastic surgeon at the other institute. We planned two-staged total auricular reconstruction. At the first stage, all the remnant cartilage were removed except tragal portion, and new three dimensional cartilage framework was placed that was draped with skin flaps. At the second stage 6 months later, ear elevation was performed. Post operative photograph showed that new ear was in proper anatomical position (Fig. 13B).

**Case 2:** An 11-years old female born with right lobule type microtia was referred from pediatrician at the other institute. We planned two-staged total

auricular reconstruction. At the first stage, all the remnant cartilage were removed, and new three dimensional cartilage framework was placed that was draped with skin flaps. At the second stage 6 months later, ear elevation was performed. Post operative photograph showed that new ear was in proper anatomical position (Fig.14).

**Case 3:** A 16-years old male was presented with right microtia and micrognathia. We performed the first-stage total ear reconstruction for this patient. Ipsilateral 6<sup>th</sup> to 9<sup>th</sup> costal cartilage was harvested through 8 cm transverse incision over his right lower chest without pneumothorax, three-dimensional costal cartilage framework was fabricated with carving knife and 38G double-armed steel wires. After careful prepariton of four skin flap and complete removal od remnant cartilage, cartilage framework

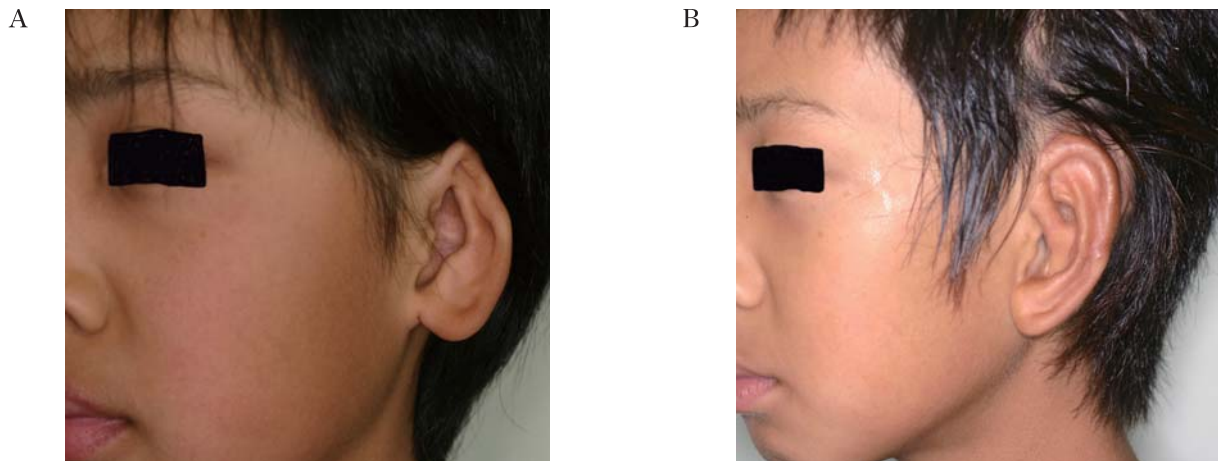


Fig.13 Pre- (A) and post-operative view (B) of the concha-type microtia

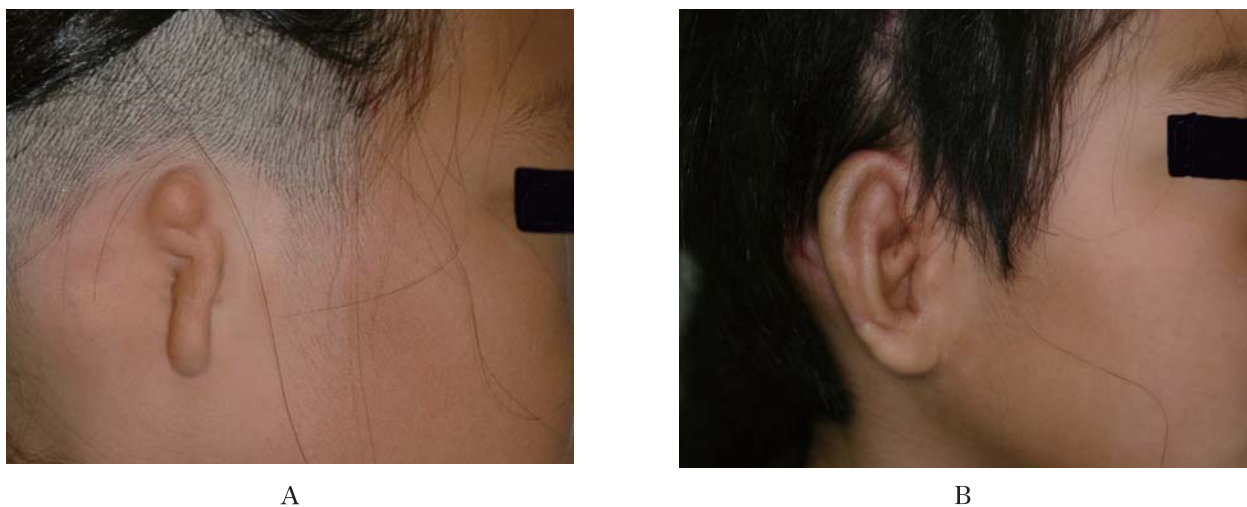


Fig.14 Pre- (A) and post-operative vew (B) of the lobule-type microtia

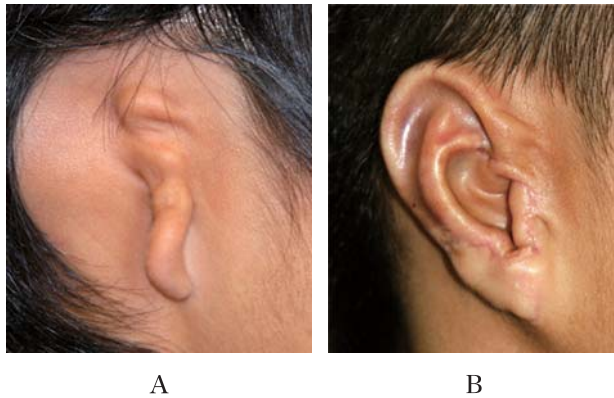


Fig.15 Pre- (A) and post-operative view (B) of the lobule-type microtia

was implanted in appropriate position with the help of ear positioning template. Post-operative course was uneventful without skin necrosis, post-operative infection. Fig.15 showed pre- and post-operative view. Post-operative view clearly showed the deep, natural definition of the external ear in an appropriate position.

## DISCUSSION

One of the common mistakes to misplace the new ear is too much anterior inclination of the auricle (external ear) as shown in Fig 1. This post-operative deformity causes deletion of the space between sideburn and external ear. This is the reason I created new reference point (ps) to check the distance between sideburn and external ear. According to our study, 95% CI of ps-t lies somewhere between 20-21mm. Therefore if we place external ear 20-21 mm from posterior edge of sideburn, we would be able to avoid the anterior inclined post-operative deformity. Ex-t is easier to measure compared to the suggested measurement by others [6-8]. Normal data presented in this study gives us a guide to avoid mistakes to place reconstructed ear in the face mask. These measurements also help to understand the abnormal anatomy of the remnant lobule: where is the lobule located in relation to the new ear site, can the remnant ear be used for the reconstruction?

**Position of the external ear:** Historically position of the ear has been the interest of artist such as Leonard Da Vinci [21]. Later attention was paid by anthropologist /plastic surgeon [6-9]. The ear skillfully reconstructed but inappropriately placed is less satisfactory than a lesser model more correctly positioned. Tolleth described the important mea-

surements to determine for positioning the ear are axis, level, and the distance from the orbit, all of which were included in my new ear positioning template [10, 11]. Traditional auricular reconstruction methods pioneered by Tanzer [22-24], and Brent [1, 25- 32] use templates on radiographic film for positioning of the cartilage framework. In unilateral microtia cases, the contour of the normal ear was traced on the radiographic film, and the pattern was drawn on the microtia site. This method is still the most popular method to position the new ear. However we found that markings tend to diminish during surgical procedure at the time of implantation of the framework, surgeon may lost the clue where to place framework in an appropriate position. Resulting common malposition of the ear for non-expert surgeon is interiorly inclined auricle that can result from avoiding hair-bearing scalp on the construct. The other problem of reverse film technique is that distortion can result from copying the shape of the auricle onto the film. Traced external ear is more likely to become too big or too wide. And practically speaking traced line is usually not smooth, unless one is a professional artist, and it is difficult reconstruct beautiful curve of the external ear. Cartilage framework based on such rugged curve won't create beautiful framework that is the key for the successful ear reconstruction [1, 4, 5]. In cases of unilateral microtia except hemifacial microtia, the location of the reconstructed ear is predetermined by first noting the topographic relationship of the opposite, normal ear with facial features, and duplicating its proportion at the proposed reconstruction site [1, 25-32]. Ear positioning template allows us to duplicate the planned, appropriate position of the new ear anytime during surgical procedure that include axis, level, and the distance from the orbit.

### ***New definition of ear position:***

After I have seen many misplaced reconstructed ear by others, I came to the conclusion that we need new definition of the ear position, with which surgeon would avoid misplacement of the new reconstructed ear. This is the proposed, new definition of the ear position [33]: the proposed new definition is that the external ear is not located in the face mask but rather in the head, being attached to the face mask at the posterior edge. When projected on the skull, the external ear is located on the posterior part of the temporal bone, not on the facial bone Fig.16 clearly showed that most of the external ear in not located in the face mask.





Fig.16 external ear is projected on the skull that illustrate ear is located far back on the head; ear is not located in the face mask

***Special consideration in hemifacial microsomia:***

Ear reconstruction in hemifacial microsomia population is still challenging for many reason. [33] Because of on-going facial deformity during the growth period, and the fact that ear reconstruction usually performed in the middle of growing period around 10 years of age, it is still a challenge where to place the new ear. It is rather common post-operative disaster that nice ear was reconstructed in a wrong position according to the site of remnant lobule, which ended up locating too low, too anterior ear. Because of abnormal remnant ear, often located in the face mask, and abnormal anatomy including skeletal and soft tissue effect, and frequent abnormal vessels, symmetry is practically very difficult to achieve with current standard management. However, I found that ear positioning template helps to understand the dimension and abnormal anatomy around ear site. In cases of hemifacial microsomia, making an exact copy of the other side would not lead to an ideal reconstructed ear, since facial features in both skeletal and soft tissues are smaller than normal [2, 23- 30]. Therefore we make the new ear placing it slightly closer to the lateral orbital rim compared the opposite side of the face, but never place the new ear in the face mask. Other important thing is when you try to identify the proper new ear position; one must ignore the position of the remnant if the remnant ear is located in the face mask. Other factor is timing of surgery. Standard time to make a new ear is around 10years of age. Since face maturation occurs around 15-15 years of age, it is likely that new reconstructed ear tends to dislocate 4-5yaers after skeletal and soft tissue growth.

Therefore our current recommendation of the timing for surgery in hemifacial microsomia patients is after 15-16 years of age after completion of facial maturation [34]. Advantage of our new template are 1) easy to use, 2) not expensive, 3) can be performed anytime, anywhere, 4) no need for prosthetic support of which many reported 5) pre-operative accurate diagnosis of low hair line is easy by using template in terms of severity, and amount of hair coverage in the new ear site.

**SUMMARY**

We believe that the data obtained in this study have generated some very useful parameters for the relationship of ear and face. These data may serve not as an absolute guide but serve as an aid to the surgeon's clinical judgment. What I lacked was the data to describe the growth change of the parameters I studied. I will continue working toward establishing age-matched data-base on the ear position. This paper also described a new tool to position the reconstructed ear at more accurate location during total autogenous auricular reconstruction. Ear positioning template can be used in four different situations: 1) Preoperative evaluation; relationship between the new ear site and remnant/ surrounding anatomy. 2) Aid for preoperative marking; especially helpful for making decision on skin incision 3) Intra-operative confirmation of the new ear. 4) Postoperative evaluation of the location of the new ear. We believe that ear positioning template is very useful tool for total auricular reconstruction which was proved by my surgical outcome demonstrates in this paper.

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