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Forehead deformities after tissue expansion: Retrospective analysis and recommendations

Yajing Qiu[a,1], **Congzhen Qiao**[a,1], **Jingyan Yang**[b], **Yunbo Jin**[a], **Hui Chen**[a,*], **Xiaoxi Lin**[a,*]

[a] *Department of Plastic and Reconstructive Surgery, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, 639 Zhizaoju Road, Shanghai 200011, P.R. China*
[b] *Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, NY, United States*

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KEYWORDS
Tissue expansion;
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Summary *Background:* Tissue expanders can lead to bone deformity as well as bone resorption. Not all changes in the cranial bone can be completely normalised after tissue expander extraction. This study aimed to investigate the potential factors for persistent forehead deformities after tissue expansion.
Patients and methods: Cases of forehead tissue expansion performed from 2011 to 2015 were retrospectively reviewed. Demographic and clinical data were collected. Two plastic surgeons (Y.Q. and C.Q.) evaluated changes in the forehead by comparing preoperative and most recent postoperative photographs. The Fisher exact, chi-square and Student *t* tests, and univariate and multivariate logistic regression analyses were performed in this study.
Results: Sixty-seven patients underwent forehead expanded flap reconstructions and continuous follow-ups were done in the outpatient service. The mean duration of the follow-ups after expander removal was 33.86 months. Overall, 28 (41.8%) patients had forehead changes. Age, sex, indications for tissue expansion and follow-up time were not associated with forehead changes. There were significant differences in the total injection volume and expansion period between patients with forehead changes (41.8%) and those without (58.2%). No significant negative correlation was found between the duration of pressure bandage usage post-operatively and the occurrence of forehead changes.
Conclusions: Our recommendations for performing tissue expansion in the skull area are as follows: (1) always choose expanders with the largest base dimension; (2) perform tissue

[1] These authors contributed equally to this work.
* Corresponding authors.
E-mail addresses: chenhui9801640@163.com (H. Chen), linxiaoxi@126.com (X. Lin).

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expansion as quickly as possible and (3) do not cause overexpansion. In addition, there was no proven benefit of using pressure bandages when skeletal changes occurred.

Introduction

Various techniques can be used to repair large facial defects. Although the skin graft and microscopic free flap can be used as a single-stage surgery, they fall short because of the lack of similarity to the surrounding recipient tissue. Given the perfect match of skin colour, thickness and texture, facial tissue expansion is considered the ideal approach for the reconstruction of large facial defects.[1-4]

After a tissue expander is removed in the second stage, a hollow is often noted at the donor site because of central bone resorption and surrounding connective tissue formation.[5] In most patients, the hollow gradually becomes inconspicuous.[6] However, not all changes in the cranial bone can be completely normalised after expander extraction. In this study, we reviewed patients who underwent tissue expansion of the forehead skin for the reconstruction of facial defects in our department to investigate the potential factors for persistent forehead deformities.

Patients and methods

We retrospectively reviewed data of 75 patients who underwent forehead expanded flap reconstructions from January 2011 to December 2015 in our department at Shanghai Ninth People's Hospital. Reconstructive surgeries were performed by three senior surgeons (X.L., Y.J. and H.C.). The indications for tissue expansion were vascular malformations, congenital pigmented naevi and extensive scars on the face. The following data were collected from medical records: sex, age, diagnoses, area of the defect, age at the start of tissue expansion, expansion period, total injection volume, the use of pressure bandage and post-operative follow-up time.

Patients' preoperative and follow-up photographs were collected from our database. Two plastic surgeons (Y.Q. and C.Q.) compared the patients' preoperative photographs and their last follow-up photographs; evaluations of the patients' forehead change were based on whether significant change of the curve or significant displacement of the peak of the forehead contour occurred in the lateral position.

Self-assessment scale of the severity of forehead deformity was explained to the patients' or their guardians' (for paediatric patients) (Table 1), and the corresponding self-assessed results were collected.

Table 1 Self-assessed scale of forehead change.

Score	Definition
1	My forehead change is unnoticeable and never bothers me.
2	My forehead deformity is noticeable but still tolerable.
3	My forehead deformity is barely tolerable, but I still do not want surgery for revision of the contour of my forehead.
4	My forehead deformity is intolerable and always interferes with my social activities. I want surgery for revision of the contour of my forehead.

Statistical analysis

Descriptive statistics are expressed as mean values (standard deviation) for continuous variables and as percentage (frequency) for categorical variables. Differences in demographics between those with forehead changes and those without were compared using the Fisher exact and chi-square tests for categorical variables and Student *t*-test for continuous variables. Univariate and multivariate logistic regression analyses were performed to identify factors associated with forehead changes. The significance level was set at $P < 0.05$. All analyses were performed using Stata SE 14.0 (StataCorp, College Station, TX).

Results

Among 75 patients, 67 were available for follow-up: 35 patients had vascular anomalies that showed no response to laser therapy or interventional radiology, 27 had congenital pigmented naevi and 5 had extensive scars. The mean age of patients was 19.16 (13.72) years, and there were 37 (55.2%) female patients. The youngest patient at the start of tissue expansion was 4 years old, and the oldest was 49 years old (Table 2).

In this study, 80 ml and 100 ml rectangular expanders were mostly used. The mean expansion period was 4.7 (1.34) months, mean total injection volume was 319.57 (98.85) ml and the mean duration of follow-up since expander removal was 33.86 (14.52) months.

Twenty-eight patients (41.8%) had forehead changes without normalisation at their last follow-ups (Figure 1). Age, sex, indications for tissue expansion and duration of follow-up were not associated with forehead changes. There were significant differences in the total injection volume and expansion period between those with forehead changes (41.8%) and those without (58.2%) (Table 3). Univariate analysis showed that the incidence rate of change was higher among patients with more than a 250 ml injection (odds ratio [OR]: 5.778; 95% confidence interval [CI]: 1.177–28.358; $P = 0.031$) and among those with longer than 6 months' expansion (OR: 4.145; 95% CI: 1.126–15.262; $P = 0.033$). Multivariate analysis showed that the occurrence of forehead change was associated with expansion

Figure 1 Pre-operative (left) and post-operative photographs with a follow-up of 59 months (right). The patient's self-assessed scale score of the forehead deformity was 4.

Table 2 Demographic characteristics of the study population with tissue expansion.

Patient demographics	
Sex	
Male, *n* (%)	30 (44.8)
Female, *n* (%)	37 (55.2)
Age, mean (SD), yo	19.16 (13.72)
Indications for tissue expansion	
Vascular anomalies, *n* (%)	35 (52.2)
- Arteriovenous malformations with no response to interventional radiology, *n* (%)	14 (20.9)
- Port wine stains with no response to laser therapy, *n* (%)	20 (29.8)
- Involuted infantile haemangiomas with fibrofatty tissue and anetodermic skin, *n* (%)	1 (1.5)
Congenital pigmented naevi, *n* (%)	27 (40.3)
Extensive scars, *n* (%)	5 (7.5)
Total injection volume, mean (SD), ml	319.57 (98.85)
Expansion period, mean (SD), months	4.7 (1.34)
Duration of follow-up, mean (SD), months	33.86 (14.52)

Abbreviations: SD, standard deviation.

Table 3 Demographic characteristics of the study population with persistent forehead deformity.

	Forehead deformity		*P*-value
	No	Yes	
Sex			
Male, *n* (%)	18 (46.2)	12 (42.9)	
Female, *n* (%)	21 (53.8)	16 (57.1)	0.809
Age, mean (SD), yo	17 (12.4)	22 (15.1)	0.129
Total injection volume, mean (SD), ml	281.8 (79.1)	372.1 (100.8)	<0.001*
Expansion period, mean (SD), months	4.4 (1.2)	5.1 (1.5)	0.035*
Duration of follow-up, mean (SD), months	36.4 (14.8)	30.3 (13.5)	0.087
Use of a pressure bandage			
No, *n* (%)	11 (28.2)	4 (14.3)	
Yes, *n* (%)	28 (71.8)	24 (85.7)	0.239
Duration of pressure bandage usage, mean (SD), months	2.3 (2.2)	2.5 (2.1)	0.623

Abbreviations: SD, standard deviation.
* The significant level was set at $P < 0.05$.

Table 4 Self-assessment results.

SCORE	Patients, No. (%)	Female/male, No.	Mean age (SD), yo.
1	1 (3.6%)	1/0	6 (0)
2	11 (39.3%)	6/5	18.8 (14.0)
3	10 (35.7%)	4/6	28.5 (18.5)
4	6 (21.4%)	5/1	19.4 (7.5)

Abbreviations: SD, standard deviation; No., number; Yo, years old.

Table 5 TWO DO'S AND TWO DONT'S for tissue expansion in the skull area.

Do's	Dont's
Always choose expanders with the largest base dimension.	Do not overinflate expanders by three-fold or more beyond the manufacturer's recommended full capacity.
Perform tissue expansion as quickly as possible.	Do not make tissue expansion last longer than 6 months.

volume. When the expansion volume was more than 250 ml, the risk of forehead change was more than six times higher (OR: 6.587; 95% CI: 1.172–37.020; $P=0.032$). According to the self-assessment results, 16 of 28 patients or their guardians were not satisfied with the forehead deformity, with 10 (14.9%) barely tolerable (Score 3) and 6 (8.9%) intolerable (Score 4) (Table 4).

Overall, 52 (77.6%) patients used a pressure bandage for a duration of 2 weeks to 6 months after tissue expander removal, and the bandage compression was expected to restore the contour of their foreheads. However, no significant negative correlation was found between the duration of post-operative pressure bandage usage and the occurrence of forehead deformity.

Discussion

Resorption and deformation of the underlying bone after tissue expansion have been frequently reported.[6-8] The most serious case was full-thickness erosion of the skull bone secondary to scalp expansion reported by Fudem and Orgel.[9] Animal studies have confirmed the occurrence of osteoclastic bone resorption by both histological examination and micro-computed tomography (CT) at the periphery of the expanders.[10-12] However, Moelleken et al. reported that the pathophysiology of bony changes is a significant but reversible remodelling effect.[10] In most cases, Colonna et al.[13] found complete normalisation confirmed by CT scans at 9 months post-operatively. In our study, forehead deformity still exists in some cases after more than 4 years of follow-up.

Typical changes of the forehead in our study were projection on the glabellar region and a flat or sloping forehead. These changes may be the comprehensive results of bone resorption, erosion, remoulding, displacement and connective tissue formation. Here, we evaluated the forehead changes by comparing the patients' preoperative photographs and their last follow-up photographs. We believe that these visible changes are more meaningful for patients than the bone changes examined by CT scans because the forehead is one of the major components of the face and is readily visible. According to the self-assessed results of forehead deformity by patients or their guardians, it was clear that these changes had a substantial impact on their social activity and social communication.

The forehead change rate in our study was quite high. One possible reason for this finding is that the expander pressure is very high on the forehead. In our clinical practice, we chose the size of expanders depending on the height and width of the patient's forehead. The base dimensions of expanders were still within the dimensions of the forehead to ensure that only the forehead skin tissue was expanded. Thus, the 80 ml and 100 ml rectangular expanders were mostly used in our study. In these cases, expanders were often inflated three or four times larger than the manufacturer's recommendations, which caused extremely high base pressure on the forehead. This may be the reason for the high rate of forehead deformity after expansion in our study. Hence, we recommend the use of expanders with the largest base dimension possible to avoid this issue.

Additionally, our expansion period was considered relatively long. The longest expansion period was 9 months in this study. We found that patients with longer than 6 months' expansion of the forehead were at a higher risk of bone change. The patients in our study received the expander injection twice a week. The volume of each injection depended on the tensile strength, tension of the skin overlying the expander and the level of patient discomfort. The final volume of tissue expansion depended on the area of the defect. Prolonged expansion using large-volume expanders has been regarded as one of the reasons for bone resorption.[1] Tissue expansion in a shorter time period may help reduce cranial deformity.

When we took a closer look at our data, we found that patients with more than 250 ml expansion were at greater risks of persistent forehead changes. However, expansion of 250 ml and greater is commonly seen in the clinic if a large amount of skin tissue is required for the reconstruction. It is difficult to prohibit the use of large-volume expansion to avoid bone changes of the forehead. In our experience, we recommend plastic surgeons with TWO DO'S AND TWO DONT'S (Table 5) for tissue expansion in the skull area in the hope to reduce the incidence of cranial deformity.

One possible way to avoid bone resorption and connective tissue formation is to use specific materials to separate the expander from the underlying bone. Animal studies have shown that titanium plates[11] and polydioxanone foils[5] may reduce bone resorption. Further clinical trials are required to confirm that these materials are safe and effective.

One limitation of our study is the lack of continuous CT scan results. Five patients underwent preoperative CT scans because of maxillofacial deformities. Among them, two had forehead changes after tissue expansion. To assess changes in the cranial bone, one patient underwent a second CT examination at 1-year follow-up and another patient

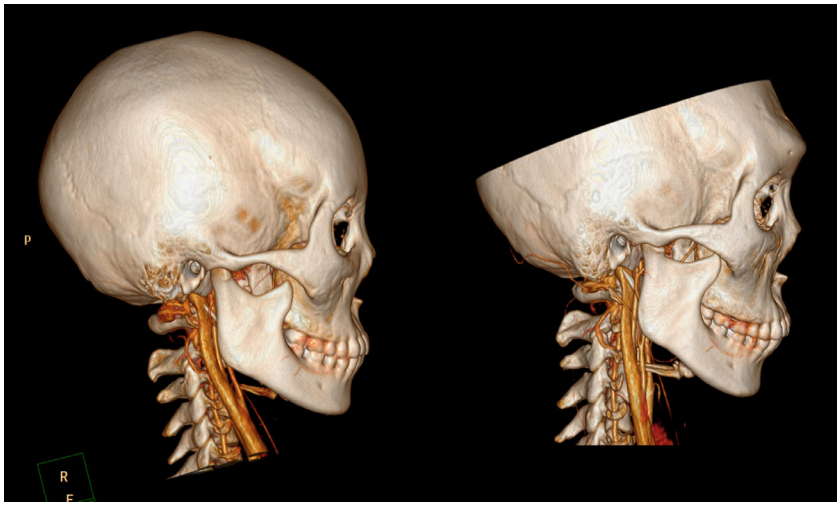

Figure 2 Computed tomography scans of the same patient pre- (left) and post-operatively (right) with a follow-up of 59 months.

underwent a second CT examination at 5-year follow-up after expander removal. After reviewing the CT scan results, we found that skull deformity in the CT scan was consistent with the photograph evaluation (Figure 2).

Conclusions

The forehead is ideal for tissue expansion. However, resorption and deformation of the underlying bone caused by tissue expansion jeopardize the donor site appearance. Therefore, we recommend surgeons when performing tissue expansion in the skull area to (1) always choose expanders with the largest base dimension; (2) perform tissue expansion as quickly as possible and (3) avoid overexpansion. Additionally, there was no proven benefit of using pressure bandages when skeletal changes occurred. Perspective studies on the forehead deformities caused by tissue expansion are required in the future.

Declaration of Competing Interest

None.

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Ethical approval

The Institutional Review Board and Ethics Committee of Shanghai Ninth People's Hospital approved this study and the use of the patients' data.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.09.020.

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