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New methods for specialized subjective and high-precision objective evaluation of constricted ears

A pilot study

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Abstract

The effects of therapy on constricted ears are evaluated subjectively and objectively. However, previous methods are not specific, comprehensive, precise, or effective in diagnosing and predicting surgical outcomes. This study aimed to present a personalized, subjective evaluation scale and new objective indices utilizing a digital method for the accurate evaluation of constricted ears.

Nine consecutive patients with constricted ears were selected. To perform subjective evaluations, the patients' parents were contacted by telephone within 3 to 6 months after surgery and asked to answer questions using a scale. To perform objective evaluations, the constricted and normal ears of each patient were scanned using a 3-dimensional scanner before and 14 days after surgery. The vertical height of the auricle (VHA), transverse diameter of the auricle, minimum length of the helix (MLH), length of the inner auricle (LIA), and transverse diameter of the inner auricle were calculated using Mimics software. The Wilcoxon matched pairs signed-rank test was used for data analysis.

High satisfaction scores were reported. The folds of the ear and helix had the highest median scores, whereas the crus of the antihelix had the lowest. The difference in LIA and postoperative MLH was greater than that in VHA and preoperative MLH. The mean values of the 5 indices of the normal ear were greater than those of the indices of the preoperative constricted ear ($P < .05$).

The specialized subjective scale reported in this study allows comprehensive and personalized assessment of constricted ears. The new objective indices are more effective than existing methods and the digital measurement method is precise and reliable. These methods will allow the treatment of constricted ears to be better evaluated, leading to improvements in patient management and treatment selection.

Abbreviations: CF = cartilage flap, CT = computed tomography, LIA = length of the inner auricle, MLH = minimum length of the helix, MR = magnetic resonance, TDA = transverse diameter of the auricle, TDIA = transverse diameter of the inner auricle, VHA = vertical height of the auricle.

Keywords: 3-dimensional, constricted ear, dimensional measurement accuracy, personal satisfaction

1. Introduction

Constricted ear is a type of auricular abnormality wherein the rim of the auricle is tight. The terms "cup ear," "lop ear," "canoe ear," "lidded helix," and "cockleshell ear" have been applied to describe various forms of constricted ears. Tanzer[1] classified constricted ears into 3 major groups and 2 subgroups: group I, flattened or folded superior rim of the helix, leading to decreased vertical height of the ear; group IIA, moderate form of a constricted helix, which may involve failure in the folding of the superior crus of the antihelix, widening of the conchal cavity, and hood-like broad rolling of the helix and scapha; group IIB, a more severe type wherein both the superior and inferior crura of the antihelix fail to fold and a flattened antihelix body appears, significantly reducing the vertical height of the ear; and group III, the auricle is rolled into a tube-like form, wherein the concha cannot be seen and the size of the entire ear decreases.

Treatment varies depending on the type of abnormality.[2,3] Mild deformities can resolve spontaneously or be treated using ear molding. Most authors recommend that the optimum time for nonsurgical intervention is during the neonatal period, allowing growth restriction of constricted ears to be relieved.[4,5] Various surgical methods are applied depending on the severity of the deformity. Mild and moderate forms are often corrected by local tissue transplantation.[6] Severe deformities are considered to be a form of microtia, requiring subtotal auricular reconstruction.[7] Excellent results have been reported with different therapies.[5,6]

The effects of therapy on constricted ears were previously evaluated subjectively and objectively. Surveys of satisfaction, observed symmetry, and appearance were often applied as subjective methods, with anthropometry of the auricle as the

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Table 1

Patient characteristics.

Case	Sex	Age (years and months)	Diagnose (Tanzer classification)
1	Male	1 y 10 mo	I
2	Male	1 y 8 mo	IIB
3	Male	1 y 7 mo	IIB
4	Male	1 y 9 mo	IIB
5	Male	1 y 2 mo	IIB
6	Female	1 y 2 mo	I
7	Male	2 y 4 mo	I
8	Male	1 y 5 mo	I
9	Male	5 y 4 mo	IIA

objective method.[5,8,9] However, these subjective evaluation methods were not all-inclusive and lacked specificity. Objective parameters are mostly measured by calipers and rulers, using the vertical height of the auricle (VHA) as the main index. These methodologies and indices might be inappropriate, incomprehensive, and imprecise.[8,10]

With the above in mind, the aim of this study was to introduce new methods for assessing constricted ears. These methods include a personalized, subjective evaluation scale and new objective indices that can be applied using a digital device (for measurements) and software (for performing calculations).

2. Patients and methods

Ethical approval for this study was obtained from the Institutional Review Board of the Plastic Surgery Hospital of Peking Union Medical College. Between August 2017 and January 2018, 12 consecutive patients with mild to moderate constricted ears underwent surgery in the Department of the First Center of Auricular Reconstruction of the Plastic Surgery Hospital of the Chinese Academy of Medical Sciences and Peking Union Medical College. Nine of these patients were enrolled in the study. Three patients with bilateral cases or concomitant auricular deformities were excluded. The age of the patients ranged from 1 year, 2 months to 5 years, and 3 months. Eight of the patients were male and 1 was female. There were 4 group I cases, 1 group IIA case, and 4 group IV cases, as categorized based on the study by Tanzer (Table 1).[1] All patients underwent tumbling cartilage flap (CF) surgery performed by a single surgeon using the procedure introduced by Pan et al.[6]

2.1. Subjective evaluation

A specialized subjective scale for constricted ears was designed on the basis of clinical features and the previous experiences of other authors. The appearances of the helix, antihelix, crura of the antihelix, scapha, and conchal cavity were used as esthetic units to evaluate outcomes. Patients' perceptions about the height, width, size, and folds of the ear were determined to evaluate the whole size and shape subjectively. As they are usually assessed by most authors, the appearance of scars, symmetry of the ears, and overall satisfaction were also determined. The patients' parents were contacted by telephone within 3 to 6 months after the operation and were asked to score their impressions about the items mentioned above on a 5-point scale (1, very poor; 2, poor; 3, fair; 4, good; 5, excellent).

2.2. Objective measurement

A surface 3-dimensional (3D) scanner (Artec Spider; Artec Group, Luxembourg) was used to capture 3D images of both normal and affected auricles of patients before surgery and 14 days after surgery. The acquired data were processed with Artec Studio version 9.0 software (Artec Group) following a standard surface scan workflow (e.g., rough serial registration, fine registration, global registration, manual alignment, fast fusion). Subsequently, data were exported as stereolithography interface format files and imported into Geomagic Studio 2012 software (3D Systems, Rock Hill, SC). Spikes were removed and holes were filled to match the curvature of the surrounding mesh, and the crease angles were minimized between polygons using the software to obtain excellent 3D models showing the precise size and details of the ears. Finally, data were imported into Mimics Medical 20.0 software (Materialise, Leuven, BE) for analysis.

The values of VHA, transverse diameter of the auricle (TDA), minimum length of the helix (MLH), length of the inner auricle (LIA), and transverse diameter of the inner auricle (TDIA) were calculated in the measurement mode of Mimics software. VHA was defined as the maximum vertical distance from the sup-helix (A_1) to the sublobe (B_1) (Fig. 1A, D). TDA was defined as the maximum transverse distance from the preauricle (C_1) to the postauricle (D_1) (Fig. 1A, D). MLH was the inner arch of the helix as measured between the intersection of the crus of the helix and the tragus (E) and the intersection of the earlobe and the helix (F) (Fig. 1C, F). LIA was defined as the maximum distance of the inner area of the helix measured from the intertragic notch (A_2) to the inner edge of the helix (B_2) (Fig. 1B, E). TDIA was defined as the maximum transverse distance of the inner area of the helix as measured from the intersection of the inferior crus of the antihelix (C_2) to the lateral edge of the helix (D_2) (Fig. 1B, E). Measurement results are listed in Table 2.

2.3. Statistical analysis

All data were imported into Statistical Package for Social Sciences Version 20.0 (SPSS, Inc., Chicago, IL) for analysis. In all statistical analyses, a P value $< .05$ was considered statistically significant. The Wilcoxon matched pairs signed-rank test was used to analyze the data. To prove that the new indices were superior, the differences between postoperative and preoperative values were compared for VHA and LIA and for TDA and TIDA. Postoperative and preoperative values of MLH were also compared for the same purpose. Additionally, all of the aforementioned indices were measured and compared for patients' normal and affected ears to explore the true relationships objectively.

3. Results

All of the patients had good outcomes, and no complications were observed. With respect to individual esthetic units, the folds of the ear, helix, scapha, and conchal cavity had the highest overall median scores, whereas the antihelix crura received the lowest score. The scores for the appearance of scars and symmetry of the ears were not high. All 9 patients gave a score of ≥4 for overall satisfaction (Table 3).

In the evaluation of new indices, the difference in LIA (4.49 ± 2.90 mm) was greater than the difference in VHA (0.7 ± 0.81 mm) and the mean postoperative MLH (62.18 ± 11.86 mm) was greater than the mean preoperative MLH (54.07 ± 15.80 mm).

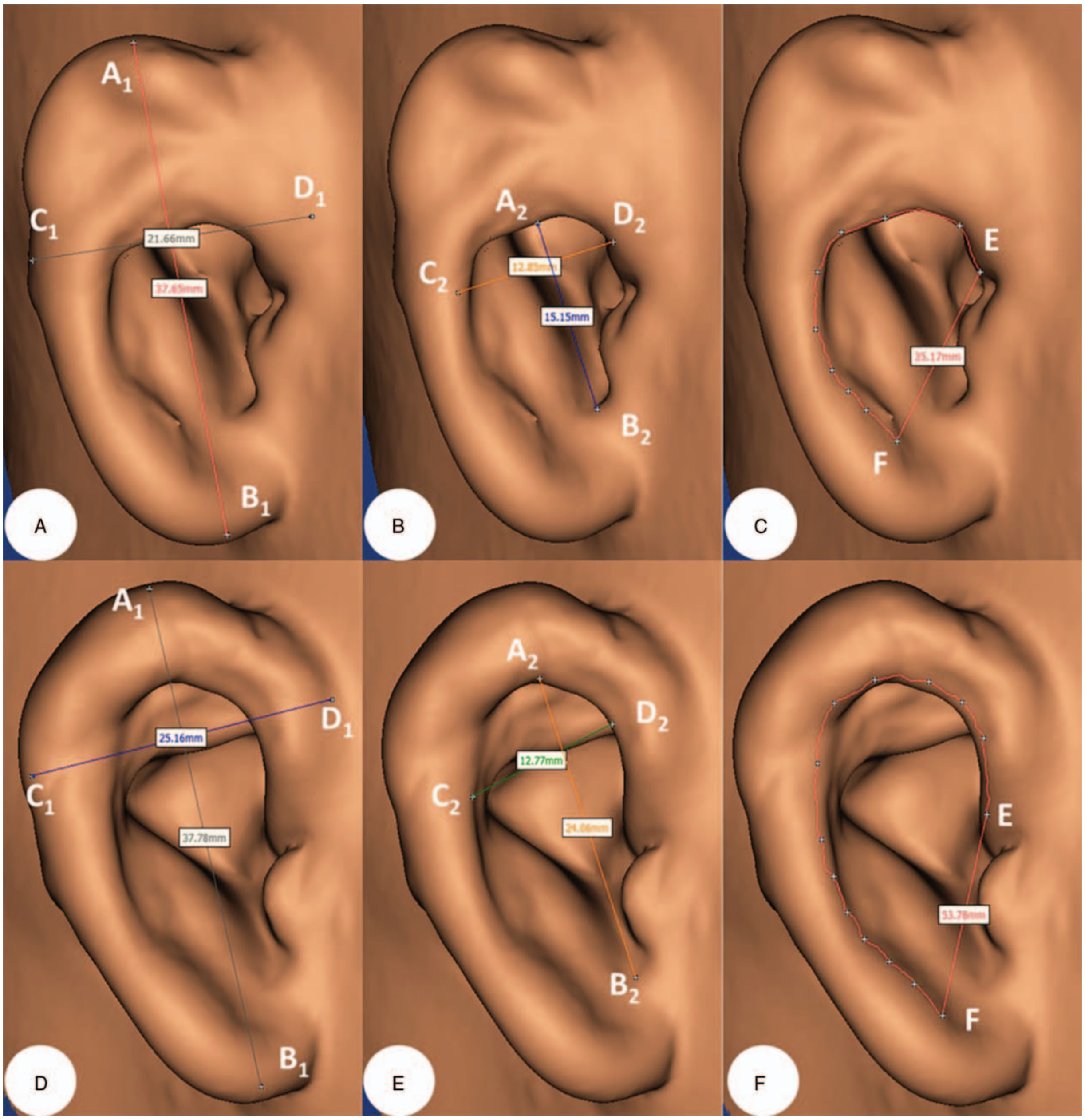

Figure 1. Measurement of the vertical height and transverse diameter of the auricle, the minimum length of the helix, and the length and transverse diameter of the inner auricle in a patient before and after surgery using digitally processed images of the preoperative constricted ear (A–C) and postoperative ear (D–F). A_1, sup-helix; B_1, sublobe; C_1, preauricle; D_1, postauricle; E, the intersection of the crus of the helix and the tragus; F, the intersection of the earlobe and the helix; A_2, the intertragic notch; B_2, the inner edge of the helix; C_2, the intersection of the inferior crus of the antihelix; D_2, the lateral edge of the helix.

The difference in TDA was slightly greater than the difference in TDIA, and negative values were found in both measurements when the preoperative transverse distance was subtracted from the postoperative transverse distance. There were statistically significant differences between the difference in LIA and the difference in VHA and between preoperative and postoperative MLH values ($P < .05$). However, there was no statistically significant difference between the difference in TDA and the difference in TDIA ($P > .05$) (Table 4).

The results of the comparison of the 5 indices between normal and preoperative constricted ears are listed in Table 5. The mean VHA, LIA, TDA, TDIA, and MLH values were greater for the normal ear than the preoperative constricted ear, and statistically significant differences were found in all 5 comparison groups ($P < .05$).

4. Discussion

This study reported a new specialized subjective scale and objective indices for the assessment of treatment outcomes for constricted ears. These new methods and indices will serve as superior options to the current methods, which are not specific, comprehensive, or precise.

Tanzer categorized constricted ears into 3 forms, each representing different extents of reduction in the size of the ear, particularly vertical height.[1] However, in patients with

Table 2

Measurement results.

	VHA, mm			LIA, mm			TDA, mm			TDIA, mm			MLH, mm		
No.	Pre	Post	Nor	Pre	Post	Nor	Pre	Post	Nor	Pre	Post	Nor	Pre	Post	Nor
1	49.26	50.50	50.31	29.59	31.31	35.24	31.68	32.38	30.01	19.19	22.52	18.24	63.94	66.79	74.70
2	37.73	37.99	42.58	15.23	24.15	28.07	21.29	23.59	26.79	13.38	13.67	16.71	29.74	46.91	56.44
3	43.31	44.02	47.70	23.19	28.23	33.45	20.32	20.42	28.74	11.23	12.13	21.73	50.28	54.58	76.53
4	47.79	47.94	49.97	29.35	31.21	23.56	15.54	22.03	23.56	7.92	14.50	17.49	43.11	61.07	77.59
5	36.01	36.02	42.80	15.48	21.81	31.01	21.35	22.03	29.06	14.42	13.35	23.21	39.53	47.60	80.02
6	44.50	46.26	47.04	23.56	31.99	35.69	28.68	25.64	32.70	22.04	21.50	24.81	57.24	70.79	79.33
7	42.34	44.44	48.17	25.21	28.28	34.62	24.87	26.91	30.87	17.52	19.12	23.43	56.12	60.55	79.81
8	45.94	45.98	53.24	27.72	28.89	41.38	23.17	25.61	31.42	17.24	16.61	23.04	63.27	66.74	88.71
9	60.93	60.95	57.83	37.62	41.50	37.34	28.31	31.44	33.41	24.06	24.14	22.56	83.44	84.58	88.13

LIA = length of the inner auricle, MLH = minimum length of the helix, Nor = normal ear, Post = postoperative ear, Pre = preoperative constricted ear, TDA = transverse diameter of auricle, TDIA = transverse diameter of the inner auricle, VHA = vertical height of the auricle.

unilateral constricted ears, the affected ear can be wider, narrower, or unchanged compared with the normal side in terms of severity. In some mild cases, the superior rims of the helices fold or flatten and reduction is mainly manifested in vertical height, with width remaining normal. In some moderate cases, the superior antihelical crura fails to fold and the antihelical bodies flatten, with hood-like broad rolling and protrusion, resulting in the widening of the conchal cavity and an even width of the auricle. In severe cases, the overall size of the ear decreases and the width of the auricle narrows. In such a condition, the use of width as an index for evaluating the outcomes of therapy should be investigated in different forms and cases.

For the correction of mild and moderate constricted ears, we recommend ear molding in the neonatal period in line with some authors.[11] In this study, the patients were older than 1 year and could not undergo ear molding alone. Hence, the technique of Pan et al of tumbling CF and free auricular composite grafting was applied.[6] Previous research has shown that ear size fully matures after 12 years of age.[12] As most patients included were between 1 and 2 years old and could undergo tumbling CF, one of the surgical aims was to relieve the restriction due to the folding of the helix and other part of the ear. After several years, the size of the ear tended to stabilize and the patients could undergo free auricular composite grafting to correct size asymmetry if necessary.

A crucial purpose of the treatment of exterior deformations of the ear is to improve the appearance of the ears. Hence, patients' subjective impressions are important in the evaluation of outcomes, with satisfaction in appearance and symmetry being the most often assessed.[5,8] Braun et al[13,14] and Marone et al[13,14] utilized the Glasgow Benefit Inventory, a comprehensive measurement of the benefits of otorhinolaryngology involving motion, physical health, learning, vitality, and other psychosocial factors, to detect changes in the health status of patients. Woo et al[4] reported a quantized measurement of procedural pain, degree of improvement, and overall satisfaction survey. In the research of Pan et al,[6] successful reconstruction of the antihelix, supra-crus, and scapha was considered as an index for evaluating surgical outcomes. Akter et al[15] introduced comprehensive tools for the measurement of the results of microtia reconstruction in evaluating satisfaction with ear surgery, individual esthetic units, and psychosocial behavior. In the present study, on the basis of the methods of Akter et al and Pan et al and the clinical features of constricted ears, we established a personalized scale for the subjective evaluation of constricted ears. As mentioned above, the helix, antihelix, superior crus of the antihelix, scapha, and conchal cavity were the most often affected units of the ears; thus, we chose indices related to these units to appraise the outcomes of surgery, which would be beneficial in improving surgical skills and focus surgeons' attention to the reconstruction of the esthetic unit. The subjective scale presented in this study is the first of its kind and was specifically designed for assessing ears with this deformity on the basis of clinical features. As shown in Table 3, the median

Table 3

Satisfaction with ear surgery and individual esthetic units.

Post-treatment score	C1	C2	C3	C4	C5	C6	C7	C8	C9	Median	IQR
Height of ear	4	4	4	5	4	4	4	3	5	4	(4–4)
Width of ear	4	4	4	5	3	3	4	4	4	4	(4–4)
Size of ear	4	4	4	5	4	4	4	4	4	4	(4–4)
Folds of ear	4	5	5	5	5	5	4	4	5	5	(4–5)
Helix	5	4	5	5	5	4	5	4	4	5	(4–5)
Antihelix	5	4	4	3	5	4	5	5	4	4	(4–5)
Antihelix crura	4	3	3	3	3	5	4	5	3	3	(3–4)
Scapha	5	5	5	5	4	5	4	5	4	5	(4–5)
Conchal cavity	5	5	5	5	4	4	4	5	4	5	(4–5)
Appearance of scar	4	3	3	4	5	5	5	4	3	4	(3–5)
Symmetry of ears	4	4	3	4	3	4	4	3	3	4	(3–4)
Overall satisfaction	4	4	4	5	4	4	4	4	4	4	(4–4)

C1–C9 represents cases 1 to 9, respectively.
IQR = interquartile range.

Table 4

Evaluation of new indices.

Case	1	2	3	4	5	6	7	8	9	Mean	Z	*P*
Postoperation and preoperation differences between VHA and LIA, mm												
dVHA	1.24	0.26	0.71	0.15	0.01	1.76	2.10	0.04	0.02	0.7±0.81	−2.666	.008
dLIA	1.72	8.92	5.04	1.86	6.33	8.43	3.07	1.17	3.88	4.49±2.90		
Postoperation and preoperation differences between TDA and TIDA, mm												
dTDA	0.70	2.30	0.10	6.49	0.68	−3.04	2.04	2.44	3.13	1.65±2.58	−0.652	.515
dTDIA	3.33	0.29	0.90	6.58	−1.07	−0.54	1.60	−0.63	0.08	1.17±2.43		
Difference of MLH between postoperation and preoperation (mm)												
Post	66.79	46.91	54.58	61.07	47.60	70.79	60.55	66.74	84.58	62.18±11.86	−2.666	.008
Pre	63.94	29.74	50.28	43.11	39.53	57.24	56.12	63.27	83.44	54.07±15.80		

The differences in VHA (dVHA), LIA (dLIA), TDA (dTDA), and TDIA (dTDIA) were calculated by subtracting the preoperative value from the postoperative value.
LIA=length of the inner auricle, MLH=minimum length of the helix, Post=postoperation; Pre=preoperation, TDA=transverse diameter of the auricle, TDIA=transverse diameter of the inner auricle, VHA=vertical height of the auricle.

score of the helices and folds of the ears was 5, which shows that the surgical purpose of unfolding the hood-like broad roll of the helix was achieved and accepted by patients. The conchal cavity also had the highest overall median score, which showed that the inner parts of the helices were deemed to be expanded by patients. Thus, overall satisfaction was high. In tumbling CF surgery, ear symmetry and reconstruction of the antihelix crura cannot be completely achieved in some severe cases. Hence, the scores of these indices were low, especially in group IIB (Tanzer classification).

It should be noted that subjective evaluation alone is not sufficient. Accurate and comprehensive measurement methods will help clinicians monitor changes before and after surgery and allow precise evaluation of the outcomes.[16] Noninvasive magnetic resonance (MR) and computed tomography (CT) scans have been widely used for data collection in the past and have been shown to be appropriate for diagnosis, surgery selection, and outcome assessment.[17,18] However, MR scans are time-consuming and costly, and exposure to radiation cannot be avoided when performing CT scans. In this study, a 3D surface scanner with no radiation was used. This method revealed the precise details of the auricle to facilitate surgical design or pre/postoperative evaluation. This method is both economical and effective. Previous authors used vertical height as the only objective index.[19,20] Park et al[21] utilized vertical and horizontal expansion of the ear after surgery, which led us to believe that changes in the length and width of the inner helix might be greater after therapy and that these indices would be more meaningful. In the first operation, which involved unfolding the crimped cartilage of the helix as seen from the front of the ears, the vertical height of some ears did not improve significantly. However, the inner part of the helix expanded and the appearance was much improved. After measuring the new indices, we discovered that the improvement in LIA (4.49±2.90 mm) was greater than that in VHA (0.7±0.81 mm). The improvement in postoperative MLH was also obvious. It is worth noting that in cases 5 and 9, the difference in VHA was 0.01 and 0.02 mm, respectively, and remained almost unchanged. However, the differences in LIA in the same ear for these patients were 6.33 and 3.88 mm, respectively. This seemed to verify the assumption that the inner part of the helix expands more obviously. In accordance with the typical changes seen in constricted ears after surgery, we drafted new indices. A highly accurate assessment was achieved using 3D digital tools. The data obtained proved that the new indices and new objective assessment method are better than the traditional indices and objective methods for the evaluation of constricted ears. This is also the first objective evaluation method specifically designed for this deformity.

It is interesting that negative values were found when we measured TDA and TDIA when the preoperative transverse

Table 5

Difference in size between normal and constricted ears.

Case	1	2	3	4	5	6	7	8	9	Mean	Z	*P*
Difference of VHA between normal ear and preoperation, mm												
Nor	50.31	42.58	47.70	49.97	42.80	47.04	48.17	53.24	57.83	48.85±4.80	−2.192	.028
Pre	49.26	37.73	43.31	47.79	36.01	44.50	42.34	45.94	60.93	45.31±7.28		
Difference of LIA between normal ear and preoperation, mm												
Nor	35.24	28.07	33.45	23.56	31.01	35.69	34.62	41.38	37.34	33.37±5.25	−2.192	.028
Pre	29.59	15.23	23.19	29.35	15.48	23.56	25.21	27.72	37.62	25.22±7.05		
Difference of TDA between normal ear and preoperation, mm												
Nor	30.01	26.79	28.74	23.56	29.06	32.70	30.87	31.42	33.41	29.62±3.05	−2.547	.011
Pre	31.68	21.29	20.32	15.54	21.35	28.68	24.87	23.17	28.31	23.91±5.00		
Difference of TDIA between normal ear and preoperation, mm												
Nor	18.24	16.71	21.73	17.49	23.21	24.81	23.43	23.04	22.56	77.92±9.38	−2.31	.021
Pre	19.19	13.38	11.23	7.92	14.42	22.04	17.52	17.24	24.06	54.07±15.80		
Difference of MLH between normal ear and preoperation, mm												
Nor	74.70	56.44	76.53	77.59	80.02	79.33	79.81	88.71	88.13	77.92±9.38	−2.666	.008
Pre	63.94	29.74	50.28	43.11	39.53	57.24	56.12	63.27	83.44	54.07±15.80		

LIA=length of the inner auricle, MLH=minimum length of the helix, Nor=normal ear, Pre=preoperation, TDA=transverse diameter of the auricle, TDIA=transverse diameter of the inner auricle, VHA=vertical height of the auricle.

distance was subtracted from the postoperative transverse distance. In the comparison of TDA and TDIA between normal and preoperative ears, all the values were greater in the normal ears than in the preoperative constricted ears, except in case 1. This reveals that the differences in transverse distance among normal, preoperative, and postoperative ears may be irrelevant. This finding may be inconsistent with the viewpoint of Tanzer,[1] who believed that the conchal cavity was wider in group II constricted ears. However, the comparison of VHA, LIA, and MLH between normal and preoperative constricted ears revealed that the length of the ears and the arch length of the helix truly decreased in the affected auricles, which is consistent with the report of Tanzer.

It is worth noting that this study included a small number of patients and involved a short follow-up period, making it impossible to verify therapeutic effects. However, the purpose of this study was to introduce new evaluation methods. We feel that this purpose has been fulfilled. Using the new personalized subjective scale introduced in this study, surgeons will be able to gain better insights into which esthetic aspects of the constricted ear are most relevant to the patient. This could help in providing more comprehensive and targeted ear reconstruction and improve outcomes, particularly in staged surgeries. The items of the subjective scale can be used as criteria for ear reconstruction. Further, the new indices and objective evaluation methods can allow more precise and effective assessment of the ear. If composite tissue transplantation, which requires highly precise design with respect to the size of the transplanted tissue, is needed for a patient in the future, this method will undoubtedly provide information for improving the symmetry and overall appearance of the ears.

5. Conclusion

The specialized subjective scale for the comprehensive and personalized evaluation of constricted ears introduced in this study will be beneficial for the assessment of patients and could focus the surgeon's attention to each esthetic unit, potentially improving the surgeon's skills and outcomes in the future. The new objective indices presented in this study, MLH and LIA, are more efficient than the traditional method of using VHA in diagnosing and evaluating surgical outcomes. The transverse diameter has no relevance in diagnosis and surgical outcome evaluation. The methods and indices presented in this study will lead to better evaluation of constricted ears, making it easier to assess treatment outcomes and plan future treatments appropriately.

Author contributions

Conceptualization: Di Wang.
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Visualization: Di Wang, Haiyue Jiang.
Writing – original draft: Di Wang.
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References

[1] Tanzer RC. The constricted (cup and lop) ear. Plast Reconstr Surg 1975;55:406–15.
[2] Janz BA, Cole P, Hollier LHJr, et al. Treatment of prominent and constricted ear anomalies. Plast Reconstr Surg 2009;124:27e–37e.
[3] Wang D, Lin L, Pan B, et al. Should constricted ear be treated as auricular malformation or deformity? Ann Plast Surg 2018;81:249.
[4] Woo T, Kim YS, Roh TS, et al. Correction of congenital auricular deformities using the ear-molding technique. Arch Plast Surg 2016; 43:512–7.
[5] Mohammadi AA, Imani MT, Kardeh S, et al. Non-surgical management of congenital auricular deformities. World J Plast Surg 2016;5:139–47.
[6] Pan B, Zhao Y, Zhuang H, et al. Tumbling cartilage flap and free auricular composite tissue transplantation for correcting mild and moderate forms of constricted ear. Arch Facial Plast Surg 2010;12: 241–4.
[7] Xiaogeng H, Hongxing Z, Qinghua Y, et al. Subtotal ear reconstruction for correction of type 3 constricted ears. Aesthetic Plast Surg 2006;30:455–9.
[8] Egemen O, Ozkaya O, Barutca SA, et al. Tanzer group IIB constricted ear repair with helical advancement and superior auricular artery chondrocutaneous flap. J Craniofac Surg 2012;23:728–31.
[9] Holmstrom H, Steenfos H. Two stage correction of the constricted ear. Case report. Scand J Plast Reconstr Surg Hand Surg 1991;25:183–5.
[10] Ohjimi H, Era K, Kinoshita K, et al. Double pennant technique: elongating the helix using rim flaps to correct the constricted ear. Ann Plast Surg 2004;53:465–8.
[11] Schonauer F, La Rusca I, Molea G. Non-surgical correction of deformational auricular anomalies. J Plast Reconstr Aesthet Surg 2009;62:876–83.
[12] Farkas LG, Posnick JC, Hreczko TM. Anthropometric growth study of the ear. Cleft Palate Craniofac J 1992;29:324–9.
[13] Braun T, Hainzinger T, Stelter K, et al. Health-related quality of life, patient benefit, and clinical outcome after otoplasty using suture techniques in 62 children and adults. Plast Reconstr Surg 2010; 126:2115–24.
[14] Marone SA, Linhares Filho TA, Ishie RT, et al. Using ERG inquiry to evaluate otoplasty satisfaction in an otorhinolaryngology medical residency training hospital. Braz J Otorhinolaryngol 2012;78:113–9.
[15] Akter F, Mennie JC, Stewart K, et al. Patient reported outcome measures in microtia surgery. J Plast Reconstr Aesthet Surg 2017;70:416–24.
[16] Abdel Razek A, Mukherji S. Imaging of posttreatment salivary gland tumors. Neuroimaging Clin N Am 2018;28:199–208.
[17] Razek A, Ghonim M, Ashraf B. Computed tomography staging of middle ear cholesteatoma. Pol J Radiol 2015;80:328–33.
[18] Razek A. Assessment of masses of the external ear with diffusion-weighted MR imaging. Otol Neurotol 2018;39:227–31.
[19] Demir Y. Correction of constricted ear deformity with combined V-Y advancement of the crus helicis and perichondrioplasty technique. Plast Reconstr Surg 2005;116:2044–6.
[20] Elsahy NI. Technique for correction of lop ear. Plast Reconstr Surg 1990;85:615–20.
[21] Park C. A new corrective method for the Tanzer's group IIB constricted ear: helical expansion using a free-floating costal cartilage. Plast Reconstr Surg 2009;123:1209–19.