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Symmetry restoration at rest after masseter-to-facial nerve transfer: Is it as efficient as smile reanimation?

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Abstract

Background: Masseter-to-facial nerve transfer is a highly efficient technique for reanimating paralyzed muscle and has been reported to restore facial symmetry at rest. However, no systematic studies have been performed, and the effects of preoperative droop oral commissure on postoperative symmetry at rest have rarely been reported.

Methods: The authors retrospectively analyzed 35 patients with masseteric-facial nerve anastomosis and assessed the quality and quantity of the dynamic recovery and the oral commissure symmetry at rest. The dynamic and static effects were then compared.

Results: All of the patients' Terzis scores were increased post-operatively, and over half of the patients presented restored symmetrical smiles (Terzis scores of 4 or 5). The postoperative symmetry scale of oral commissure at rest improved in 18 of 35 patients. Both the mean postoperative AD-OCE (altitude difference of oral commissure excursion) and the postoperative AD-OCP (altitude difference of bilateral oral commissure position) were decreased compared to preoperative values. The preoperative symmetry had a significant effect on the postoperative AD-OCP. The effects of the dynamic and static symmetry improvements were transformed to a comparable factor "α". The dynamic α was significantly greater than static α.

Conclusions: Masseter-to-facial nerve transfer is a reliable technique for smile reanimation. However, it has only a limited effect on the improvement of symmetry at rest. Assessing the preoperative symmetry of oral commissure at rest can be used to predict postoperative outcomes, and patients with severely droop oral commissure (symmetry scale III or IV) should receive static suspension.

Unilateral facial paralysis is a pathological condition that involves the asymmetry of the face at rest, and it is worsened by activation of the facial musculature while smiling and during facial expression.[1]Dynamic strategies tend to have a greater potential to successfully reconstruct the natural and symmetric expression of resting and animated faces.[2]In short-standing facial paralysis (3 months-2 years), the facial musculature is still available, and nerve transpositions are the best treatment option.[3] Various nerves have been used for transposition, including the spinal acessory, phrenic, and hypoglossal nerves as well as the masseteric nerve.[4-7]Our previous studies found that masseter-to-facial nerve transfer is a highly efficient technique for reanimating paralyzed muscle.[7,8]The advantages of utilizing the masseteric nerve include its location near native facial nerve branches, the relative ease of dissection, its possible length, the high number of motor axons, the fast reinnervation times, and the low morbidity to chewing function. Masseteric-facial nerve anastomosis can recover facial mimetic function with low donorsite morbidity, and it is gaining widespread acceptance for use in an expanding number of clinical scenarios.[7-9]

Unilateral facial paralysis patients could recover minimal asymmetry of their smiles after masseter-to-facial nerve transfer, although symmetry at rest is frequently not satisfactory. Although reports have mentioned that this technique can restore facial symmetry at rest,[10,11]systematic studies have not been performed to determine whether masseter-to-facial nerve transfer restoration of symmetry at rest is as efficient as reanimating the smile. The effect of preoperative oral commissure droop on postoperative symmetry at rest has been rarely reported. To evaluate the effectiveness of the masseteric-facial nerve transfer in symmetry restoration at rest and during smile reanimation and to analyze the effect of preoperative oral commissure droop on postoperative symmetry at rest, we retrospectively analyzed 35 patients with masseteric-facial nerve anastomosis performed from 2010 to 2014. This investigation assessed the quality and quantity of the dynamic recovery and the oral commissure symmetry at rest and compared both the dynamic and static effects.

Methods

Patients

To quantify the effectiveness of masseteric-facial nerve anastomosis, 35 patients (26 female, 9 male) from 22 to 56 (32.31±8.91) years were analyzed. All of the patients had complete unilateral facial paralysis and denervation times ranging from 2 to 25 months (12.09±5.38), and they were candidates for surgical masseteric to facial nerve anastomosis. The causes of facial palsy included acoustic neuroma (n=34) and trauma (n=1).

Operative technique

The same surgeon (W.W.) performed all of the procedures, which involved transfer of the descending branch of the masseter nerve to the distal Buccal branch of the facial nerve to innervate the paretic mimetic muscle. All patients started intensive biofeedback physical training in front of a mirror at 8 weeks postoperatively. A detailed description of these techniques is presented in previous publications.[7]

Evaluation

The patients were recorded while performing a set of standardized facial movements preoperatively and postoperatively. The patients were followed up for at least 12 months, ranging from 12 to 26 months (14.23±3.84). An independent observer separately graded video recordings of the patients using the Terzis Facial Grading System (See Table, Supplemental Digital Content 1, which shows the Terzis Facial Grading System, INSERT LINK) to evaluate the smile function,[12] and they used the symmetry scale of oral commissure at rest (Table 1 , Fig.1) to evaluate symmetry at rest.

Moreover, to quantitatively and objectively assess the effectiveness of facial nerve reanimation and symmetry at rest, we used a straightforward Java-based software program, Facial Assessment by Computer Evaluation (FACE-gram), designed by Hadlock et al. This program is a highly quantitative facial function clinical measuring tool for zonal facial movement analyses from standard patient photographs.[13-16] FACE-gram was used to assess the symmetry of the oral commissure for a broad smile and at rest. Then, the level of oral commissure symmetry at rest and during smiling was calculated (See Figure, Supplemental Digital Content 2, which shows standard patient photographs were analyzed using the FACE-gram program. Note that the "a-score" is the measurement from the oral commissure perpendicular to the horizontal line at the bottom edge of the lower lip (a-line). Healthy side is on the left, paralytic side on the right, IINSERT LINK). FACE-gram software scaled each photograph based on the size of the iris (approximately 11.8 mm).[14]To compare the dynamic and static effects, we calculated the improvement factor α, which represents the effectiveness of facial nerve reanimation or symmetry at rest (Formula 1).When the value of α is larger, the improvement effectiveness is more efficient; when the value is closer to 1, the postoperative symmetry of oral commissure is better.

Statistical analysis

All of the data are expressed as the mean±SD. To analyze the effects of facial nerve reanimation and symmetry at rest in patients who underwent masseter-to-facial nerve anastomosis, the observers' scores or grades at these successive time points were compared using the Wilcoxon signed rank test. A paired t-test was used to compare differences in the data, including the altitude difference in the oral commissure, dynamic and static α, etc. A one-way ANOVA was used to compare the means of the three groups. The statistical analyses were performed using SPSS version 16.0. (SPSS, Inc., Chicago, IL, USA). The significance level was set at 0.05.

Results

Effects on facial nerve reanimation and smile symmetry

All of the patients had complete unilateral facial paralysis (Terzis score 1) except one patient (Terzis score 2). The Terzis Facial Grading System was used for the evaluation of postoperative smile function (Fig. 2), and 16 patients were ranked as 3 (45.7%), 13 as 4 (37.1%) and 6 as 5 (17.1%). Therefore, over half of the patients had restored symmetrical smiles (Terzis score4 or 5). All of the patients' Terzis scores were increased postoperatively (Wilcoxon signed rank test, $P<0.001$ compared with the preoperative scores), and the patients' smile symmetries were significantly improved.

FACE-gram was used to quantitatively and objectively assess the altitude difference of the oral commissure excursion (AD-OCE), and the results indicated that the mean postoperative AD-OCE (2.24±1.99 mm) was significantly decreased compared with the preoperative value (9.08±2.13 mm, paired-sample t-test, $P<0.001$, Fig. 3a).

Effects of facial nerve reanimation and symmetry at rest

All of the patients were evaluated using the symmetry scale of oral commissure at rest (Fig. 4), and the results are summarized in Table 2. The postoperative grades were improved in 18 out of 35 patients compared with the preoperative grade (Wilcoxon signed rank test, $P<0.001$).

FACE-gram was used to quantitatively and objectively assess the altitude difference of the bilateral oral commissure position (AD-OCP) at rest, and the results indicated that the postoperative AD-OCP (2.88±1.58 mm) was significantly decreased compared with the preoperative AD-OCP (4.69±1.66 mm; paired-sample t-test, $t=7.69$, $P<0.001$, Fig. 3b). We grouped patients according to their preoperative grade of symmetry scale of oral commissure at rest. Because grade III & IV patients had droop oral commissure with or without sagging skin and only one patient was scored IV, the patients with scores of IV and III were merged into one group (Group III&IV). In Group I, the postoperative AD-OCP (1.28±0.75 mm) decreased compared with the preoperative value (2.12±0.59 mm), although the difference was not statistically significant (paired-sample t-test, $t=1.87$, $P=0.158$, Fig. 3c). In Group II, however, there was a significant decrease in the postoperative AD-OCP (2.39±1.14 mm) compared with their preoperative value (4.00±1.16 mm; paired-sample t-test, $t=3.45$, $P=0.013<0.05$, Fig. 3c). The same decrease was also found in Group III&IV (AD-OCP 3.29±1.61 mm postoperatively vs. 5.32±1.41 mm preoperatively; paired-sample t-test, $t=6.79$, $P<0.001$, Fig. 3c). To further analyze the effect of preoperative symmetry on postoperative outcome, a one-way ANOVA was used to compare the postoperative AD-OCP among the three groups ($F=3.687$, $P=0.036<0.05$). The results showed that the preoperative symmetry had a significant effect on the postoperative AD-OCP. An LSD (Least Significant Difference) test was used to compare the postoperative AD-OCP among the three groups, and the results showed that the postoperative AD-OCP of Group III&IV was significantly higher than that of Group I ($P=0.016<0.05$, Fig. 3c). Significant differences were not observed among the other groups (Fig. 3c).

Comparing the dynamic and static improvement effectiveness

The improvement factor α represents dynamic/static improvement effectiveness. A comparison of the dynamic and static α showed that the dynamic α (0.76±0.25) was significantly higher than the static α (0.38±0.26; paired-sample t-test, $t=5.88$, $P<0.001$, Fig. 3d).

Discussion

Numerous techniques for facial reanimation have been developed in recent decades, and their ultimate goal is to restore or minimize impairments in facial expressions, such as an asymmetrical smile or drooping at the corner of the mouth.[17]In short-standing facial paralysis, the ipsilateral facial muscles remain viable, and reinnervation of the facial nerve is the principal goal. Apart from direct coaptation of the transected nerve ends, one of the critical factors of reinnervation is the selection of a motor nerve. Among the different nerves required for innervation, the cross-facial nerve,[18,19] extra-facial nerve(hypoglossalor masseter-to-facial nerve),[20-23]and their combined application have been widely used and described[24,25]and present varying degrees of facial nerve reinnervation.

Spira first reported the use of the masseteric nerve as a new axonal source for the cervicofacial branch of the impaired facial nerve in 1978,[26] and this technique has been used to reanimate both recent and long-standing facial paralyses.[27,28] The masseteric nerve has been successfully used for rehabilitation of the paralyzed face for the past two decades and presents good functional and aesthetic results.[29]

In our retrospective study, we analyzed patients with the Terzis Facial Grading of smile function and found that all patients showed significant improvements in smile symmetry. Over half of the patients had restored symmetrical smiles after the masseter-to-facial nerve transfer, and the other patients had moderately restored symmetrical smiles. Not surprisingly, a considerable number of studies with similar results have been published. And, there are some studies assessing massteric-facial nerve transfers and other nerve anastomosis techniques. For instance, comparing with hemihypoglossal-to -facial neurorrhaphy, masseter-to-facial nerve transfers are effective and reliable techniques for facial reanimation, requiring no bone dissection, less time-consuming procedure, and less prone to facial synkinesis. [30]

In addition, the FACE-gram program was used to quantitatively assess the AD-OCE, which creates accurate measurements of facial landmarks and facial movements.[14,16] We found that the masseter-to-facial nerve transfer led to significantly decreased postoperative AD-OCE, and the mean was approximately 2 mm. The results of the measurements objectively showed that masseter-to-facial nerve transfer is a highly efficient technique for reanimating paralyzed muscle and restoring a symmetrical smile. The positive effect of the masseter-to-facial nerve transfer on dynamic recovery has gained widespread acceptance. A data analysis performed in this retrospective study obtained the same results. This behavior is likely caused by the high axonal load that can be delivered with this nerve relative to that of other nerves, such as hypoglossal nerves and cross-facial nerve grafting.[11] Moreover, the use of the masseteric nerve does not require nerve grafts; therefore, the nerve impulse only has to pass across one nerve coaptation and traverse a relatively short distance to the muscle. Thus, the masseteric nerve itself may transmit stronger impulses than other nerves. Thus, masseter-to-facial nerve transfer could provide adequate oral commissure excursion and restore a symmetrical smile.

Symmetry at rest is as important as symmetry during smiling for facial paralysis patients. Drooping at the corner of the mouth results in asymmetry and gives the appearance of sadness, which can cause significant aesthetic and psychological impairment. Previous studies did not systematically analyze the effect of masseter-to-facial nerve transfer according to the oral commissure symmetry at rest. To analyze the symmetry at rest, we established asymmetry scale of oral commissure at rest. The symmetry of a smile represents a dynamic recovery, and the symmetry of oral commissure at rest also represents the recovery of static symmetry to a certain extent.

We analyzed patients using the symmetry scale of oral commissure at rest and found that more than half of the patients' symmetry scales were improved. In addition to the semi-quantitative symmetry scale, we quantitatively assessed the AD-OCP by using FACE-gram and found that the masseter-to-facial nerve transfer significantly decreased the AD-OCP. We grouped patients according to their preoperative grades to further analyze the effect of the masseter-to-facial nerve transfer on postoperative symmetry at rest. When the patients' preoperative symmetry scales were I, the difference between the preoperative and postoperative AD-OCP was not significant, which means that the masseter-to-facial nerve transfer did not have a negative effect. When the patients' preoperative symmetry scales were II, III or IV, the postoperative AD-OCP significantly decreased compared with preoperative AD-OCP. In these cases, the masseter-to-facial nerve transfer can improve symmetry at rest. Upon further analysis of the data, we found that the preoperative symmetry had a significant effect on the postoperative AD-OCP. When the preoperative symmetry scale was higher, the postoperative AD-OCP was larger. Thus, oral commissure at rest was more asymmetric. In particular, in patients with droop oral commissure with or without sagging skin (symmetry scale III or IV), the postoperative AD-OCP was significantly greater than that in patients with symmetric oral commissure (symmetry scale I). These patients, whose preoperative symmetry scales are III or IV, are not always satisfied with their symmetry at rest, and a number of these patients experience static suspension during the second stage operation. Static suspension effectively improved symmetry at rest. Thus, the preoperative symmetry of the oral commissure at rest contributes to the estimation of postoperative outcomes. In addition, in patients with droop oral commissure (symmetry scale III or IV), masseter-to-facial nerve transfer should be combined with static suspension in one stage or in a second stage operation. And a study of masseter-to-facial nerve transfer combined with static suspension is being carrying out in our clinic.

A systematic analysis of the effect of masseter-to-facial nerve transfer on oral commissure symmetry at rest showed that the technique could improve symmetry at rest. However, the effect of static symmetry improvement is not as favorable as the effect of improved dynamic symmetry. The effects of masseter-to-facial nerve transfer on the recovery of dynamic and static symmetry were first compared with the improvement factor in our study. We transformed the effects of the dynamic and static symmetry improvements to a comparable factor, and a comparison of the dynamic and static symmetry improvement factor α showed that the dynamic α was significantly higher than the static α and had a value closer to 1. Therefore, the dynamic symmetry of oral commissure showed greater improvements than the static symmetry.

Why did the masseter-to-facial nerve transfer have different effects on the recovery of dynamic and static symmetry? The main reason maybe that masseter-to-facial nerve transfer cannot completely recover denervated facial muscles. Muscle fibers can be broken down into two main types[31, 32]: slow twitch muscle fibers (Type I) and fast twitch muscle fibers (Type II, which can subsequently be broken down into two types: Type IIA and Type IIX). Type I fibers are characterized by low force/power/speed production and high endurance, Type IIX fibers are characterized by high force/power/speed production and low endurance, and Type IIA fibers fall in between the previous two. Skeletal muscle is composed of a variety of fiber types with different functional and histologic characteristics. Postural muscles are composed mostly of Type I fibers (fatigue resistant, slow contracting), which are identified by slow contraction times and a high resistance to fatigue. However, the muscles used in rapid locomotion have higher proportions of Type II fibers (fast contracting, relatively fatigable).[33, 34] In humans, the quadriceps muscles contain ~52% Type I fibers, whereas the soleus is ~80% Type I. In facial muscles, the orbicularis oculi muscle of the eye is only ~15% Type I fibers,[35] whereas the frontalis muscle is ~50% Type I.[36]A previous study using an animal model found that muscular atrophy was more serious in Type II fibers than in Type I fibers when the trigeminus nerve and facial nerve were simultaneously severed relative to the atrophy that occurred when only the facial nerve was severed,[37] and these results indicate that the trigeminus nerve plays an important role in maintaining the function of Type II fibers rather than Type I. Because the Masseter nerve is a motor branch from the anterior division of the mandibular branch of the trigeminal nerve, masseter-to-facial nerve transfer may allow for the improved recovery of Type II fibers of denervated facial muscles relative to that of Type I fibers.

Conclusions

The results presented here indicate that masseter-to-facial nerve transfer is a reliable technique for smile reanimation, and it can also improve symmetry at rest. However, this technique only has a limited effect on symmetry at rest. Assessing the preoperative symmetry of oral commissure at rest increases the estimation accuracy of postoperative outcomes. Patients with droop oral commissure (symmetry scale III or IV) should also receive static suspension

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Legend

Fig.1. Demonstrations of the symmetry scaling of oral commissure at rest. Unilateral facial paralysis patients were evaluated using the symmetry scale of oral commissure at rest. The grades are I to IV from left to right.

Fig.2. Preoperative (above) and postoperative (below) evaluations using the Terzis Facial Grading System. Significant improvement in smile symmetry was found 12 month after the procecure.

Fig.3. Statistical graphs. **a** Quantitative analysis of the preoperative and postoperative AD-OCE assessed with FACE-gram. Error bars indicate SD (paired-sample t-test, *** $P<0.001$). The AD-OCE was significantly decreased after the procecure. **b** Quantitative analysis of the preoperative and postoperative AD-OCP assessed with FACE-gram. Error bars indicate the SD (Paired-sample t-test, *** $P<0.001$). The postoperative AD-OCP was significantly decreased after the procecure. **c** Patients were grouped according to their preoperative grade from the symmetry scale of oral commissure at rest, quantitative analyses of the preoperative and postoperative AD-OCE assessed with FACE-gram. Error bars indicate the SD (Paired-sample t-test, * $P<0.05$, *** $P<0.001$). In Group II and Group III&IV, The postoperative AD-OCP was significantly decreased after the procecure. Further analysis of the effect of preoperative symmetry on postoperative outcome was performed (one-way ANOVA, $P<0.05$). There was a significant difference in the postoperative AD-OCP value among the three groups, suggesting that the preoperative symmetry could possible affect the postoperative outcome. **d** Quantitative analysis of the improvement factor α. Error bars indicate the SD (Paired-sample t-test, *** $P<0.001$). The dynamic α was significantly higher than the static α.

Fig.4. Preoperative (above) and postoperative (below) evaluations according to the symmetry scaling of oral commissure at rest. The postoperative grades were improved in partial patients with preoperative grade II & III. The pre and postoperative grades remained the same in all patients with preoperative grade I & IV.

Supplemental Digital Content 1. See Table which shows the Terzis Facial Grading System, INSERT LINK.

Supplemental Digital Content 2. See Figure which shows standard patient photographs were analyzed using the FACE-gram program. Note that the "a-score" is the measurement from the oral commissure perpendicular to the horizontal line at the bottom edge of the lower lip (a-line). Healthy side is on the left, paralytic side on the right, IINSERT LINK.

Table 1. Symmetry scale of oral commissure at rest

Description	Grade
Droop oral commissure with sagging skin	IV
Droop oral commissure without sagging skin	III
Minimal asymmetry of oral commissure	II
Symmetric oral commissure	I

Table 2. Details of 35 patients' preoperative and postoperative grades from the symmetry scale of oral commissure at rest

Preoperative	n	Postoperative	n′	Percent(n′/n)
I	4	I	4	100%
II	7	I	2	28.57%
		II	5	71.43%
III	23	II	16	69.57%
		III	7	30.43%
IV	1	IV	1	100%
Total	35		35	

$$\alpha = \frac{(\mathrm{Ha}-\mathrm{Pa})-(\mathrm{Ha}'-\mathrm{Pa}')}{\mathrm{Ha}-\mathrm{Pa}} = 1-\frac{\mathrm{Ha}'-\mathrm{Pa}'}{\mathrm{Ha}-\mathrm{Pa}}$$

Formula 1. α, improvement factor; Ha, preoperative a-score of the healthy side; Pa, preoperative a-score of the paralytic side; Ha', postoperative a-score of the healthy side; Pa', postoperative a-score of the paralytic side.

Figure 1

Figure 2

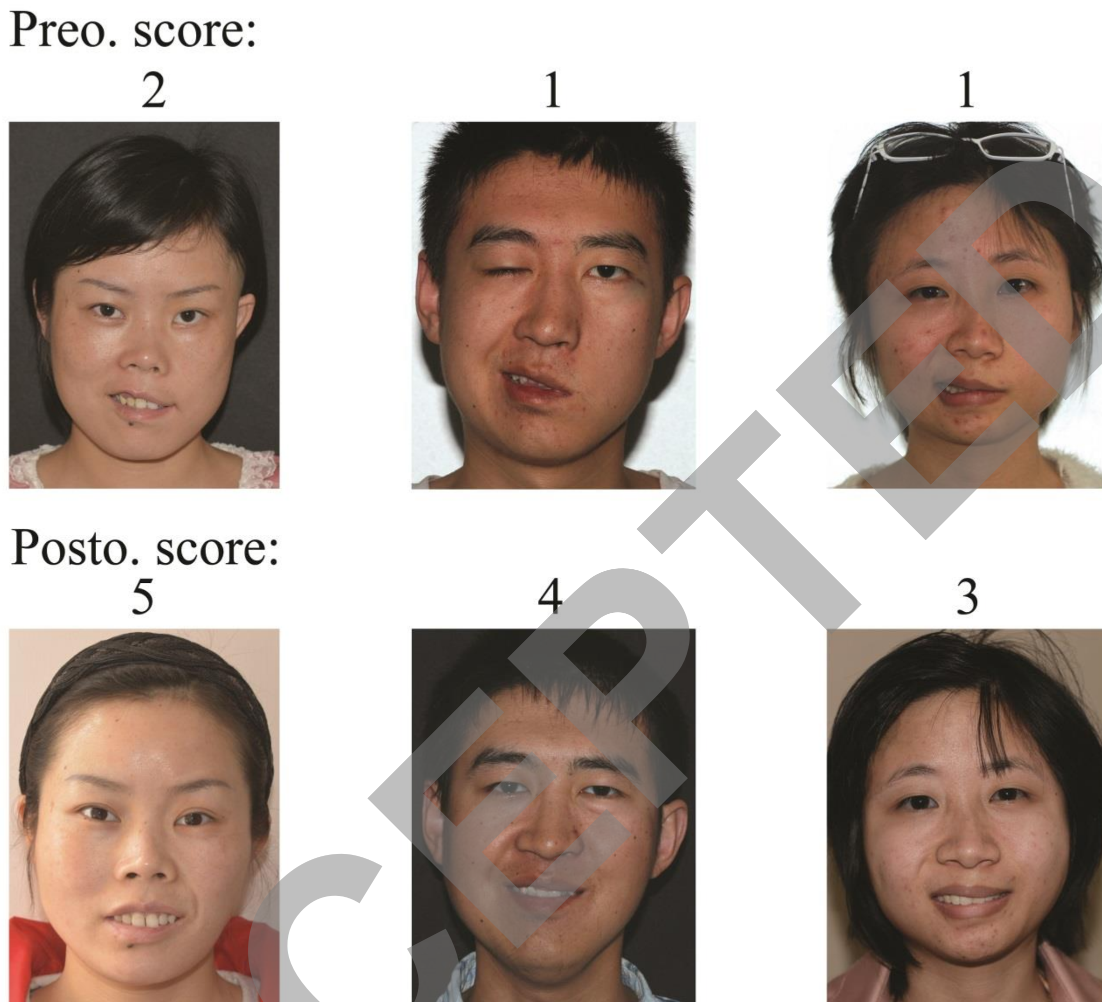
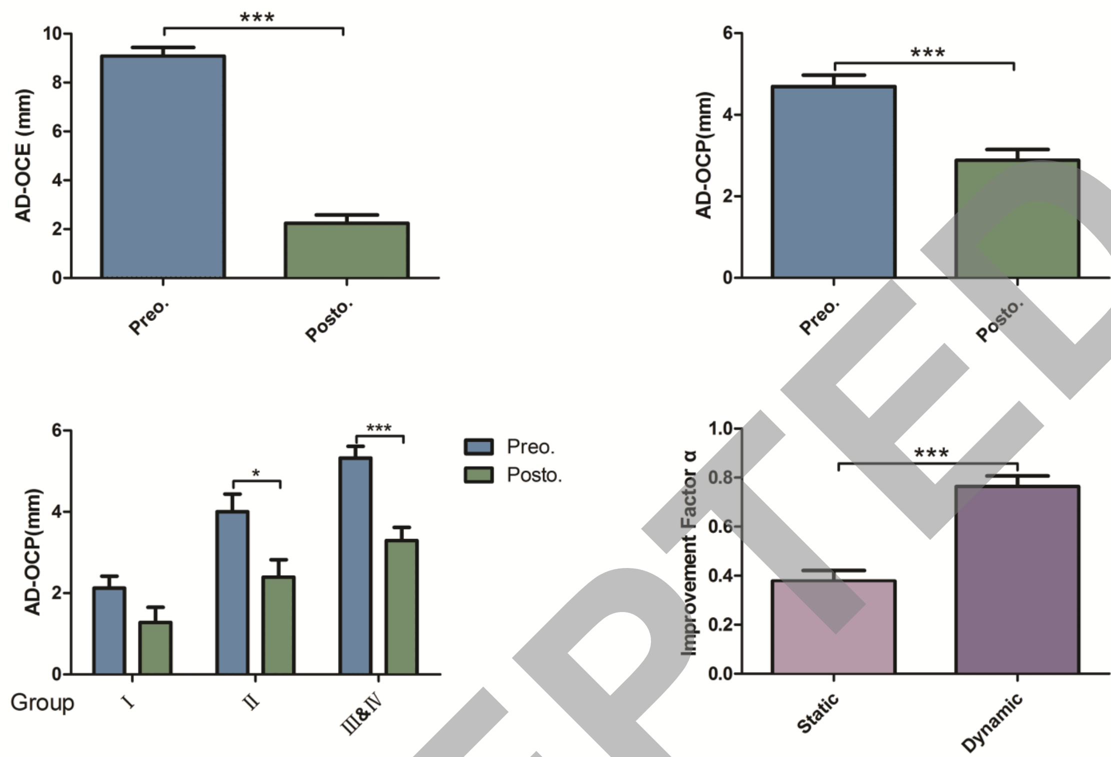
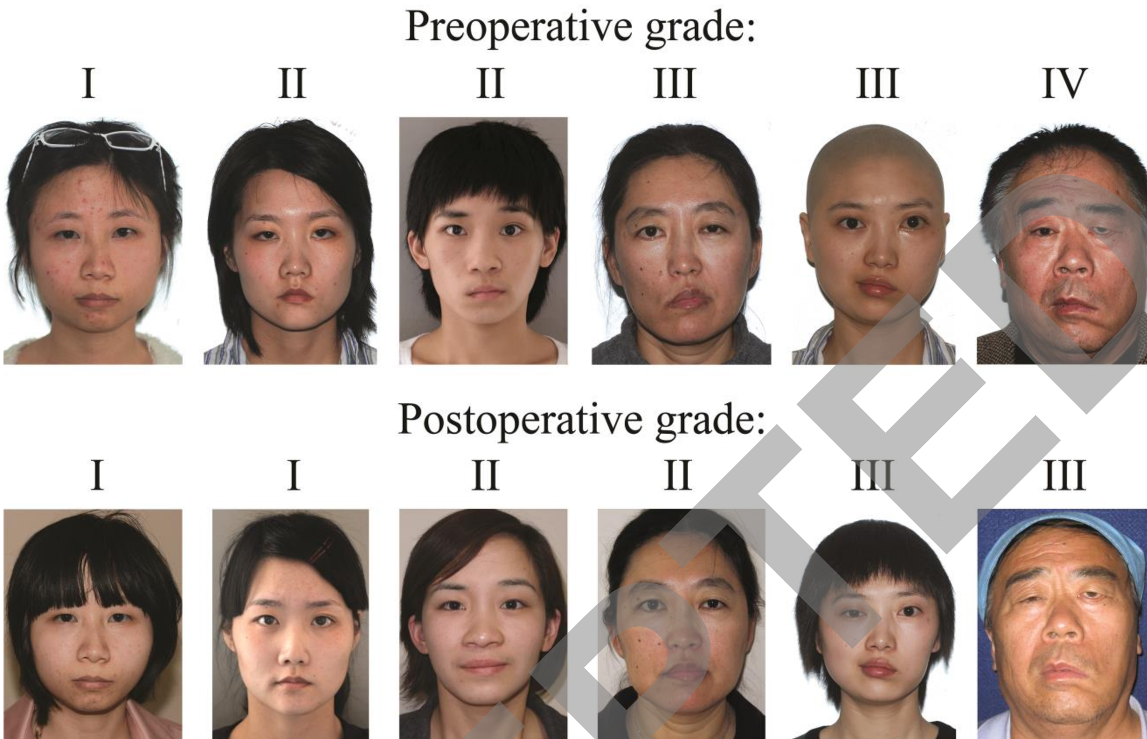


Figure 3



AD-OCE (mm)
Preo.
Posto.
***
AD-OCP(mm)
Preo.
Posto.
***
AD-OCP(mm)
Group
I
II
III&IV
*
***
Preo.
Posto.
Improvement Factor α
Static
Dynamic
***

Figure 4


Preoperative grade:
I
II
II
III
III
IV
Postoperative grade:
I
I
II
II
III
III

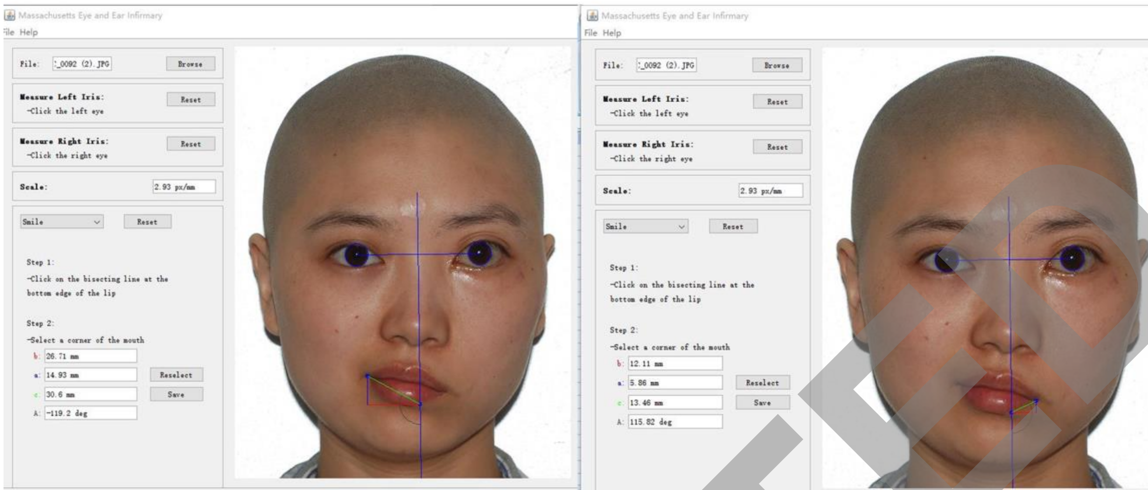
SDC 1 Table

Supplemental Digital Content 1

Supplemental Table. Terzis Facial Grading System

Description	Score
Symmetrical smile with teeth showing, full contraction	5
Symmetry, nearly full contraction	4
Moderate symmetry, moderate contraction, mass movement	3
No symmetry, bulk, minimal contraction	2
Deformity, no contraction	1

SDC 2 Figure



Massachusetts Eye and Ear Infirmary
File Help
File: :_0092 (2).JPG
Browse
Measure Left Iris:
-Click the left eye
Reset
Measure Right Iris:
-Click the right eye
Reset
Scale:
2.93 px/mm
Smile
Reset
Step 1:
-Click on the bisecting line at the bottom edge of the lip
Step 2:
-Select a corner of the mouth
b: 26.71 mm
a: 14.93 mm
Reselect
c: 30.6 mm
Save
A: -119.2 deg
Massachusetts Eye and Ear Infirmary
File Help
File: :_0092 (2).JPG
Browse
Measure Left Iris:
-Click the left eye
Reset
Measure Right Iris:
-Click the right eye
Reset
Scale:
2.93 px/mm
Smile
Reset
Step 1:
-Click on the bisecting line at the bottom edge of the lip
Step 2:
-Select a corner of the mouth
b: 12.11 mm
a: 5.86 mm
Reselect
c: 13.46 mm
Save
A: 115.82 deg