Musculoskeletal Changes as a Sequel to Advancement Genioplasty: A Long-Term Cephalometric Prospective Study

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Abstract

Aims The aim of this study was to evaluate cephalometrically the stability of hard tissues and soft tissue changes of advancement genioplasty 2 years after surgery.

Methods A prospective study was conducted which comprised of 25 patients, who underwent advancement genioplasty alone with no other orthognathic surgical procedures. Immediate pre-operative, 6 months postoperative, and 2 years postoperative lateral cephalograms were compiled and assessed.

Results The mean surgical advancement planned was around 8 mm. Six months post-surgery, the relapse rate was 15% of the surgical advancement which was considerably reduced in the following 18 months to 7%. The ratio of soft tissue to bony advancement at pogonion was 0.9:1. There are significant alterations in the soft tissue profile in terms of decrease in the soft tissue thickness, facial convexity angle, deepened mentolabial sulcus and minimal increase in the lower lip height.

Conclusion Advancement genioplasty was considered as a relatively stable procedure, if adequate muscular pedicle and internal rigid fixation were maintained. The present study was of 2 years, and we can expect further changes in the hard and soft tissues, which are clinically irrelevant.

Keywords Cephalometric · Genioplasty · Orthognathic · Facial convexity · Mentolabial

Introduction

Facial appearance has a major role in a person's psychological well-being and social acceptance; perhaps, it is most important in regulating social interaction. Humans are characterized with a prominent chin, and its position is definitely an imperative attribute to facial harmony. Several corrective procedures are available for treating an unusually positioned chin. The most favored approach for the correction of skeletal chin deformity is the horizontal osteotomy of the inferior border of the mandible, commonly termed genioplasty [1].

Genioplasty allows three-dimensional alterations of chin position and contour, resulting in significant improvements in facial esthetics. Among all possible directions for repositioning the chin, advancement genioplasty to correct a receding chin is probably the most common procedure. This osteotomy with minor variations can be used to improve almost every possible skeletal abnormality of the chin.

Pre-analyzing the postoperative skeletal position and the soft tissue response to skeletal movement aids in optimal treatment planning. Cephalometric tracings play an important role in evaluation of treatment, progress and surgical outcomes in the orthognathic surgeries. Several studies have addressed outcomes after advancement genioplasty using cephalometrics [2–7]. In a quest to assess changes on long-term basis we conducted this study with an aim to assess skeletal changes after advancement genioplasty so that it can be related to net changes in the soft tissue profile.

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Materials and Methods

This study was carried out in 25 healthy individuals who required advancement genioplasty as esthetic surgery. Pre-operative (T1), 6 months postoperative (T2) and 2 years postoperative (T3) standard lateral cephalograms of 25 patients subjected to advancement genioplasty with or without vertical reduction and no concurrent mandibular procedure were obtained from Department of Oral and Maxillofacial Surgery, Sri Sai College of Dental Surgery, Vikarabad. Approval of college ethical committee was taken. Written informed consent was obtained from each patient. Non-growing adults who have to undergo a genioplasty alone with no concurrent mandibular procedures and without any concomitant systemic problems were included in the study.

Surgical procedure was performed by the same two surgeons in all the patients. All patients were operated on under general anesthesia via nasoendotracheal intubation. Oblique sagittal split sliding genioplasty procedure was followed in all the patients [8]. After sectioning, the genial segment was advanced (8–10 mm) to the planned position and the repositioned segment was stabilized with rigid fixation. The wound was closed in layers, and a pressure dressing was applied externally and maintained in position for 48 h.

All lateral cephalograms taken under standardized conditions were hand-traced on acetate paper with a 0.3-mm lead pencil by the same examiner. In the present study an x – y cranial base coordinate system constructed through sella with the x -axis drawn 7° to the sella nasion line. The y -axis was constructed passing through sella perpendicular to the x -axis. To determine the position of the anterior and posterior genioplasty points (AGP and PGP) at T1, the pre-operative radiographs were superimposed on the T2 cephalograms. During superimposition, particular attention was given so that the areas that undergo minimal remodeling (cribriform plate and the anterior wall of sella turcica) were perfectly coincided. All the linear measurements were considered from the X – Y planes.

In this study we compiled parameters from the Shaughnessy et al.'s analysis, Burstone's analysis, Park et al.'s analysis without using MePL and OPL and Steiner's analysis to integrate all the anatomical structures and assess the changes with utmost possibilities [1, 2, 9].

The skeletal and soft tissue landmarks and the reference lines that were used are shown in Fig. 1. The pre-surgical, 6 months post-surgical and long-term post-surgical values of the various parameters obtained from the study were compiled and tabulated, and statistical analysis was performed.

Statistical Analysis

All the analysis was performed using SPSS, version 14. A p value of <0.05 was considered statistically significant. Comparison of mean values at T1, T2 and T3 was made using repeated-measures ANOVA with post hoc Bonferroni test.

Results

The study includes 25 healthy individuals (6 males and 19 females) who required advancement genioplasty as esthetic surgery. The age of the patients ranged from 16 to 28 years with a mean of 19.1 years. No cases of malunion, non-union, infection or loss of osteosynthesis occurred.

Horizontal Hard Tissue Parameters

There was no significant difference in the mean of A to y -axis and B to y -axis when compared from T1–T3 and T1–T2, respectively, but the point B– Y -axis is increased from T1 to T3. The mean (SD) pre-surgical (T1), 6 months post-surgical (T2) and long-term post-surgical Pg– Y -axis values are 61.16 (8.33), 67.96 (7.56) and 67.88 (7.38), respectively. Post hoc test showed that the mean at T1 was significantly lower than at T2 and T3 ($p < 0.001$), suggesting that the point Pg– Y -axis is increased from T1 to T3 as shown in Table 1.

Vertical Hard Tissue Parameters

Net inferior relocations of points B, AGP, Pg and Me from T1 to T3 are 0.36, 2.76, 3.48 and 3.56 mm ($p < 0.001$), respectively. This indicates that the mean at T1 was significantly lower than at T2 and T3 and the points B, AGP, Pg and Me to X -axis are increased from T1 to T3 as shown in Table 1.

The mean of PGP– X -axis at T1 was significantly higher than at T2 and T3, which implies that the point PGP– X -axis is decreased from T1 to T3 ($p < 0.001$). Most of these changes took place during the first 6 months after surgery. Changes thereafter were diminutive.

Horizontal Soft Tissue Parameters

The point Li– Y -axis is decreased from T1 to T3 ($p < 0.001$) with the mean at T1 being significantly higher than at T2 and T3 by 1.20 mm. Post hoc test showed that the mean of Mlf– Y -axis at T3 was lowest followed by T2 with highest being T1 ($p < 0.001$). The mean of Pg'– Y -axis

Fig. 1 Cephalometric landmarks and some measurement definitions. **a** Innermost point on contour of maxilla between anterior nasal spine and incisor. **b** Innermost point on contour of mandible between incisor and bony chin. L1 Incision inferior: midpoint of incisal edge of most prominent mandibular central incisor, Me Menton: most inferior midline point on mandibular symphysis, Pg Pogonion: most anterior point on osseous contour of chin, S Sella: center of sella turcica, G Glabella: most anterior point on forehead near supraorbital ridges, N Nasion: most anterior point of frontonasal suture, Cm Columella point: midpoint of columella of nose, Pn Pronasale: most anterior and prominent point of nose (tip), Sn Subnasale: point at which columella (nasal septum) merges with upper lip in midsagittal plane, Sls Superior labial sulcus: point of greatest concavity in the middle of upper lip between subnasale and labrale superius, Ls Labrale superior: most anterior point of upper lip, Sts Stomion

superior: lowermost point on vermillion of upper lip, Sti Stomion inferior: uppermost point on vermillion of lower lip, Li Labrale inferior: most anterior point of lower lip, Mlf Mentolabial fold: point of greatest concavity in midline of lower lip between labrale inferior and soft tissue pogonion, Pg' Soft tissue pogonion: most prominent or anterior point on chin in midsagittal plane, Me' Soft tissue menton: lowest point on contour of soft tissue chin, Nasolabial angle: Angle made by points Cm–Sn–Ls, Mlf depth Mentolabial fold depth: distance from point Mlf to line connecting Li and Pg', Facial convexity Angle made by points G–Sn–Pg', AGP Anterior genioplasty point: point on chin contour between B point and pogonion, which represents anterior limit of genioplasty osteotomy, PGP Posterior genioplasty point: mid-planned point on lower border of mandible representing posteroinferior limit of genioplasty osteotomy, E-line Esthetic line: line connecting Pn and Pg'

was increased from T1 to T2 by 6.4 mm and decreased from T2 to T3 0.28 mm ($p < 0.001$) as shown in Table 2.

Vertical Soft Tissue Parameters

Net vertical reductions in the height from Sti and Li to X-axis are 1.44 and 2 mm, respectively. These changes are clinically evident. Changes found at mentolabial fold 2 years postoperatively are not clinically appreciable. The lower components of the mandible represented diverse

features. They showed momentous net vertical increase in the height from Pg' and Me' to X-axis by 3.04 and 3.12 mm, respectively, as shown in Table 2.

Dimensional Parameters

The distance from labrale superius to E-line and from labrale inferius to E-line decreased significantly by 0.54 and 3.04 mm ($p < 0.001$), respectively. The mentolabial fold demonstrated a net deepening of 2.92 mm ($p < 0.001$)

Table 1 Hard tissue parameters

	Mean	SD	<i>p</i> value	Post hoc test
<i>Horizontal hard tissue parameters</i>				
A to y-axis				
T1	72.92	3.34	0.122; NS	–
T2	72.36	3.05		
T3	72.44	3.24		
B to y-axis				
T1	61.80	6.43	0.015; Sig	T1 < T3
T2	61.80	6.68		
T3	62.12	6.51		
AGP to y-axis				
T1	60.80	7.44	<0.001; Sig	T2, T3 > T1
T2	64.84	7.43		
T3	65.00	7.33		
Pg to y-axis				
T1	61.16	8.33	<0.001; Sig	T2, T3 > T1
T2	67.96	7.56		
T3	67.88	7.38		
PGP to y-axis				
T1	31.40	7.83	<0.001; Sig	T2, T3 > T1
T2	33.80	7.86		
T3	34.16	7.67		
<i>Vertical hard tissue parameters</i>				
A to X-axis				
T1	50.6	2.81	0.375	–
T2	50.56	2.83		
T3	50.56	2.83		
B to X-axis				
T1	96.96	4.11	0.009; Sig	T2 > T1
T2	97.40	4.00		
T3	97.32	4.08		
AGP to X-axis				
T1	100.84	6.91	<0.001; Sig	T2, T3 > T1
T2	103.52	6.56		
T3	103.60	6.45		
Pg to X-axis				
T1	106.36	5.94	<0.001; Sig	T2, T3 > T1
T2	110.12	5.08		
T3	109.84	5.16		
Me to X-axis				
T1	114.76	7.62	<0.001; Sig	T2, T3 > T1
T2	118.24	6.57		
T3	118.32	6.31		
PGP to X-axis				
T1	105.52	8.15	<0.001; Sig	T1 > T2, T3
T2	103.84	8.36		
T3	104.00	8.36		

Repeated-measures ANOVA with post hoc Bonferroni test

T1: pre-operative values, T2: 6 months postoperative values, T3: 2 years postoperative values

Sig significant, NS nonsignificant

as a result of treatment. Significant net changes in soft tissue thickness, at Pg to Pg' and point B to the mento-labial fold, could be observed from T1 to T3. The ratio of Pg to Pg' was 1:0.91 which was in harmony with the available literature. The mean of Stms–Stmi at T1 was significantly higher than at T2 and T3, which implies that Stms–Stmi is decreased from T1 to T3 ($p < 0.001$) as shown in Table 3.

Angular Parameters

The points S–N–Pog and S–N–Pg' are increased from T1 to T3 ($p < 0.001$). The mean of Sn–Gn'–C at T1 was significantly higher than at T2 and T3, which implies that angle Sn–Gn'–C is decreased from T1 to T3 ($p < 0.001$) as shown in Table 3.

Discussion

Dentofacial deformities are usually allied with excessive protrusion or retrusion of the chin [10]. For ages several corrective procedures have been established for treating an unusually positioned chin. Genioplasty allocates three-dimensional organization of chin position, resulting in significant improvement in facial esthetics whether performed independently or in association with other orthognathic procedures.

The success of orthognathic surgery relies on long-term skeletal and soft tissue stability. The process of predicting orthognathic treatment outcomes has advanced from manual tracings to computerized assessment of digital lateral cephalograms. Whatever may be the method for establishing these predictions, the precision of the prediction relies on the ratios used to characterize the response of soft tissue to the bony alterations [11]. Many studies have formulated ratios based on soft tissue responses to hard tissue changes following orthognathic surgeries, and predictions have been done based on these ratios [2, 11–13]. The soft to hard tissue movement can vary appreciably in each individual, and prediction tracings may aid in such scenario.

Variable aspects which can alter prediction outcome are type of surgery, accuracy of surgery, methods of fixation, amount of soft tissue stripping, pre-surgical soft tissue thickness, extent of relapse, accuracy and reproducibility of tracing including difficulty in identifying some landmarks [14].

In the present study all the patients underwent minimal soft tissue stripping with broad attachment of lingual soft tissue. The pedicled advancement genioplasty was considered as the standard method as the amount of bone

Table 2 Soft tissue parameters

	Mean	SD	<i>p</i> value	Post hoc test
<i>Horizontal soft tissue parameters</i>				
Sn to y-axis				
T1	90.44	5.45	0.122; NS	–
T2	90.44	5.41		
T3	90.36	5.50		
Sls to y-axis				
T1	89.16	5.22	0.015; Sig	T1 < T3
T2	89.12	5.21		
T3	89.28	5.16		
Ls to y-axis				
T1	92.92	5.40	<0.001; sig	T2, T3 > T1
T2	92.72	5.31		
T3	92.64	5.42		
Li to y-axis				
T1	85.60	5.18	<0.001; Sig	T2, T3 > T1
T2	84.24	5.61		
T3	84.24	5.28		
Mlf to y-axis				
T1	77.28	5.03	<0.001; Sig	T2, T3 > T1
T2	75.80	4.66		
T3	75.28	4.82		
Pg' to y-axis				
T1	72.32	8.12	<0.001; Sig	T2, T3 > T1
T2	78.72	7.61		
T3	78.44	7.68		
<i>Vertical soft tissue parameters</i>				
Sn to x-axis				
T1	49.16	3.34	0.173	–
T2	48.88	3.17		
T3	49.04	3.37		
Sls to x-axis				
T1	53.72	4.08	0.548	–
T2	53.60	3.89		
T3	53.76	4.03		
Ls to x-axis				
T1	60.72	4.45	0.009; Sig	T2, T3 > T1
T2	60.96	4.45		
T3	60.96	4.50		
Sts to x-axis				
T1	70.12	3.77	0.725	–
T2	70.24	3.82		
T3	70.12	3.94		
Sti to x-axis				
T1	75.56	3.75	<0.001; Sig	T1 > T2, T3
T2	74.16	3.50		
T3	74.12	3.50		

Table 2 continued

	Mean	SD	<i>p</i> value	Post hoc test
Li to <i>x</i> -axis				
T1	88.44	7.51	<0.001; Sig	T1 > T2, T3
T2	86.44	7.56		
T3	86.44	7.83		
Mlf to <i>x</i> -axis				
T1	92.16	4.75	0.861	–
T2	92.12	4.62		
T3	92.24	4.50		
Pg' to <i>x</i> -axis				
T1	104.80	4.73	<0.001; Sig	T2, T3 > T1
T2	108.24	4.42		
T3	107.84	4.52		
Me' to <i>x</i> -axis				
T1	120.60	7.09	<0.001; Sig	T2, T3 > T1
T2	124.00	6.39		
T3	123.72	6.77		

Repeated-measures ANOVA with post hoc Bonferroni test

T1: pre-operative values, T2: 6 months postoperative values, T3: 2 years postoperative values

Sig significant, NS nonsignificant

resorption is less and has trimmed down postoperative infection [15]. There was no incidence of postoperative sepsis in any patient. Mild transient mental nerve paresthesia was noticed in eight patients, which was due to retraction and was resolved during follow-up. Lingual hematoma was noticed in ten patients and subsided within a week. Postoperative healing was uneventful and satisfactory.

Advancement genioplasty appears to be a reasonably stable procedure. Two years after surgery, the mean relapse at Pg was 1% of the surgical advancement out of which 70% was in the first 6 months. Part of this change is most likely due to bone remodeling. Postoperatively bone resorption was seen at the sharp superior edge of the osseous segment as a result of osteotomy. The bone deposition zones are anterior surface of the mandible above the osteotomy and posterior–inferior aspect of the genial segment without apparent effects on soft tissue pogonion. The angles and sharp edges were remodeled. The remodeling patterns of the advanced segment did not show any evidence of inferior rotation or bodily displacement during the postoperative evaluation, which correlates with the previous studies [16].

Internal fixation has influenced positively the stability of surgeries, thereby reducing the relapse potential. Type and position of fixation also contributed to the stability in our

Table 3 Dimensional and angular parameters

	Mean	SD	<i>p</i> value	Post hoc test
<i>Dimensional parameters</i>				
Li–L1				
T1	14.64	4.70	<0.001; Sig	T1 > T2, T3
T2	12.64	4.34		
T3	12.60	4.32		
Mlf to B				
T1	15.12	3.89	<0.001; Sig	T1 > T2 > T3
T2	13.24	3.57		
T3	12.72	3.65		
Mlf depth				
T1	4.64	1.47	<0.001; Sig	T2, T3 > T1
T2	7.68	1.22		
T3	7.56	1.23		
Pg to Pg'				
T1	12.20	2.16	<0.001; Sig	T1 > T2, T3
T2	10.20	2.18		
T3	10.12	2.13		
Ls to E-line				
T1	−0.20	2.43	<0.001; Sig	T1 > T2, T3
T2	−1.36	3.17		
T3	−1.44	2.93		
Li to E-line				
T1	4.52	3.90	<0.001; Sig	T1 > T3 > T2
T2	1.00	3.63		
T3	1.48	3.73		
Stm _s –stm _i				
T1	6.08	2.87	<0.001; Sig	T1 > T2, T3
T2	4.48	2.43		
T3	4.32	2.38		
Stm _s –U1				
T1	6.24	2.39	<0.001; Sig	T1 > T3 > T2
T2	5.56	2.36		
T3	5.96	2.65		
<i>Angular parameters</i>				
Cm–Sn–Ls				
T1	100.92	11.01	0.135	–
T2	100.84	11.03		
T3	100.92	11.01		
S–N–Pog				
T1	78.04	3.88	<0.001; Sig	T2, T3 > T1
T2	81.52	4.01		
T3	81.48	4.04		
S–N–Pog'				
T1	83.80	4.05	<0.001; Sig	T2, T3 > T1
T2	86.76	4.21		
T3	86.76	4.13		

Table 3 continued

	Mean	SD	<i>p</i> value	Post hoc test
Sn–Gn'–C				
T1	122.68	14.39	<0.001; Sig	T1 > T2, T3
T2	114.24	7.38		
T3	114.32	7.32		

Repeated-measures ANOVA with post hoc Bonferroni test

T1: pre-operative values, T2: 6 months postoperative values, T3: 2 years postoperative values

Sig significant, NS nonsignificant

study, and we standardize our internal fixation by using single T-shaped miniplate and five screws in midline. This finding is in accordance with the study done by Shaughnessy et al. and Reyneke et al. and is in contravention of the study done by Polido, Regis and Bell, where they noticed a relapse rate around 24% 2 years post-surgically [2, 3, 17].

The sloppy bone architecture and gonial angle of the mandible led to the significant increase in lower facial height though it was not planned. Van Sickel et al. and Sridhar Reddy et al. also found 0.78 and 0.21 mm of mean vertical movement, respectively [16, 18]. Though the amount of resorption was not significant, it was considerably more in vertical direction than in horizontal direction. The horizontal movement in our study reflects changes both in stability and resorption. The vertical changes most likely represent the direction of advancement.

The greatest amount of change in the soft tissue occurred at the soft tissue pogonion with fewer changes at mentolabial sulcus and least at labrale inferior. The soft tissue of the chin tracked the bony movement in a ratio of 0.9:1. The relapse we noticed was clinically nonsignificant, and it cannot be distinguished clearly by the lay population. This is attributed to the remodeling that takes place at the surgical site but is not due to the instability of the surgical procedure. Mentolabial fold depth increased as shown in Fig. 2. All the changes are pictorially represented in Fig. 3.

All the parameters in relation to upper lip and lower lip showed significant changes following the procedure resulting in the reduced interlabial gap, increasing the lip competency. Mild inward rotation of the lower lip has been elicited, thus resulting in minimal disclosure of vermillion. The mentalis muscle is the sole elevator and provides the major vertical hold up of the lower lip. Subsequently, if this muscle is not precisely repositioned during surgery, it may result in extremely unesthetic chin known as “witch’s chin” and possible lip incompetence due to chin ptosis [19].

Fig. 2 Pre-operative and 2 years postoperative patient profile

Conclusion

Cephalometric analysis continuously plays an important role in assessing the osseous and soft tissue changes following orthognathic surgeries. The analysis we pursued integrates all the anatomical structures, even in maxilla,

and helps in assessing the hard and soft tissue changes following most of the orthognathic surgeries with utmost possibilities.

We can expect further changes in the hard and soft tissues with time. These post-surgical changes could be due to remodeling changes, relapse or the normal aging

Fig. 3 Pictorial representation of changes following advancement genioplasty. Me, pre-operative hard tissue menton; Pg, pre-operative hard tissue pogonion; Me^s, pre-operative soft tissue menton; Pg^s, pre-operative soft tissue pogonion; Me², hard tissue menton 2 years postoperatively; Pg², hard tissue pogonion 2 years postoperatively;

Me^{s2}, soft tissue menton 2 years postoperatively; Pg^{s2}, soft tissue pogonion 2 years postoperatively; Li, pre-operative labrale inferioris; Li², labrale inferioris 2 years postoperatively; Mls, pre-operative mentolabial sulcus; Mls², mentolabial sulcus 2 years postoperatively

process. Post-surgical relapse was less with rigid internal fixation. The minimum changes seen were almost similar to the average annualized changes seen in the non-surgical group. Therefore, we can rely on these predictions even on long-term basis.

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Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical Standard The study was approved by Institutional Review Committee (IRC) on Ethical Issues, Sri Sai College of Dental Surgery, Vikarabad.

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