Vertical Skeletal and Facial Profile Changes after Surgical Correction of Mandibular Prognathism

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Background: Mandibular prognathism is often corrected by surgical orthodontics. Correction of the sagittal facial profile has received wide attention. However, vertical changes remained undefined and thus, were investigated.

Methods: Subjects included 18 patients with mandibular prognathism who had surgical correction (S group, mean age: 20.1 ± 3.2 years) and 18 patients with Class I malocclusion (C group, mean age: 21.2 ± 3.6 years). Cephalograms were taken at the initial visit (T1) for both the groups and one year after surgery (T2) for the S group and analyzed by standard protocols. The vertical differences between the S and C groups at T1 and within the S group at T1 and T2 were compared. Additionally, the C group at T1 and the S group at T2 were compared.

Results: Comparison between groups at T1 revealed no difference in the anterior and posterior upper facial heights (58 mm and 50 mm, respectively). However, the S group exhibited a longer anterior lower facial height and a shorter posterior lower facial height. Accordingly, any vertical measurements and comparisons related to the mandible revealed significant difference between groups. Surgical correction did not change the vertical chin position. Contrarily, the posterior ramus heights were reduced (from 54 to 50 mm). The vertical measurements and comparisons for soft tissues reflected those for hard tissues.

Conclusions: The results indicate that through surgical correction of mandibular prognathism, vertical facial heights can be maintained within normal physiological function.

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Key words: facial profile, surgical correction, mandibular prognathism, Class III malocclusion

Mandibular prognathism normally is the result of an imbalance between the nasomaxillary complex and a prominent mandible. The accompanying dental condition reveals a Class III malocclusion with an anterior cross bite. A compensated inter-dental relationship can be found with labial tipping of the maxillary anterior teeth in conjunction with lingual tipping of the mandibular anterior teeth. However, the vertical dental relationship with either over or open bite conditions varies among patients

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with mandibular prognathism. Overall, the discrepancies can easily be noticed in the sagittal dental and facial appearance with the prominent vertical feature of greater lower anterior facial height.(1-5)

The facial profile of patients with mandibular prognathism is primarily corrected by a combination of surgical and orthodontic treatment to reach a harmonious facial profile and a balanced occlusion. For example, in cases of mandibular setback surgery alone, facial profile changes include increases in the facial convexity, straightening and lengthening of the upper lip, and reduction of lower lip protrusion.(6-27) However, to reduce vertical and horizontal excess, the recommended surgical protocols are proposed to included maxillary superior impaction and mandibular setback.(28,29) The skeletal and soft tissue facial profiles are straightened and the lip posture is improved; soft tissue responses to two-jaw surgery are similar to those found in mandibular setback surgery alone, except for changes in the nasal tip and the upper lip area.(30-32) Moreover, genioplasty has been added to the protocol to achieve better facial esthetics. Although studies on the soft tissue response to genioplasty are diverse because of the wide variety of genioplastic procedures/materials, the ratios of soft-tissue to hard-tissue changes are quite predictable.(33,34)

As facial profile changes in patients with mandibular prognasthism are often related to dramatic sagittal improvements after surgical correction, vertical facial profiles may be altered simultaneously. However, most studies have investigated surgically-treated facial profile changes by focusing on the sagittal correction,(6-27,30-34) and little information is available on vertical profile correction. Thus, we analyzed the vertical skeletal and soft-tissue facial profile changes after surgical correction, and then compared the structural differences between surgically treated patients and patients with normal profiles. We found that the prognathic mandible per se was the main difference in these patients despite surgical efforts to correct both the sagittal and vertical components of the facial profile.

METHODS

Eighteen patients who had surgical correction (11 females and 7 males, mean age 20.1 ± 3.2 years ranging from 16.3 to 26 years) of dental and skeletal Class III malocclusion and madibular prognathism were included as the surgical (S) group. Eighteen patients (9 females and 9 males with mean age of 21.2 ± 3.6 years ranging from 17.3 to 25.6 years) with Class I malocclusion having an acceptable lip profile within the esthetic line were included as the control (C) group. All patients with mandibular prognathism received combined orthodontic treatment at the Department of Orthodontics, and surgical correction at the Craniofacial Center, Chang Gung Memorial Hospital, from 2001 to 2005. Inclusion criteria consisted of no craniofacial anomalies, no previous orthodontic treatment, an initial proganthic mandible (for the S group) and physical maturity.

Presurgical orthodontic preparation included dental decompensation; post-surgical treatment included orthodontic finishing, dental alignment, consolidation and coordination of the maxillary and mandibular arches. All surgical corrections for mandibular prognathism involved the Le Fort I maxillary osteotomy and mandibular bilateral sagittal split osteotomy (BSSO). Whenever required, genioplasty and maxillary superior impaction were performed. Rigid fixations were used to immobilize the bony segments for both jaws.

Cephalometric assessment

Lateral cephalograms were taken at the initial visit (T1) for both groups, and one year after surgery (T2) for the S group when the split bony regions were healed and remodeled (Fig. 1). During cephalography, patients were asked to position the maxilla and mandible with teeth in centric occlusion and with the lips in repose. Cephalometric landmarks (Figs. 2 and 3) were constructed according to the studies by Burstone and colleagues,(35,36) Scheideman et al.,(37) and Gjorup and Athanasiou.(21) Cephalometric analyses were performed by following standard protocol.(35-39) A reference line for vertical linear measurement, namely FH (N) was constructed with a line parallel to the Frankfort horizontal plane (FH) registered at the nasion (N) point.(40) A plane (HP), through the nasion upward 7° from the anterior cranial base plane (S-N), was also constructed as a reference according to Burstone and colleagues.(35,36) The vertical measurements for craniofacial configurations (Fig. 2) and soft tissue facial profiles (Fig. 3) are illustrated.

The vertical differences between the S and C

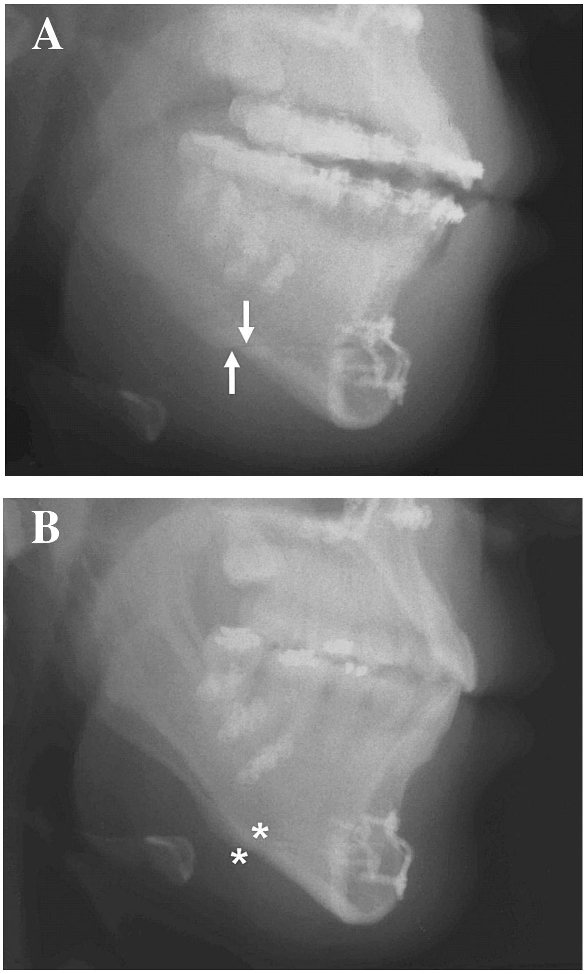

Fig. 1 Radiographic demonstration of bone remodeling along the border of the mandibular corpus. (A) The arrows show the mandibular split area 1 week after surgery. (B) The asterisks show healing of the bone along the split area 1 year after surgery.

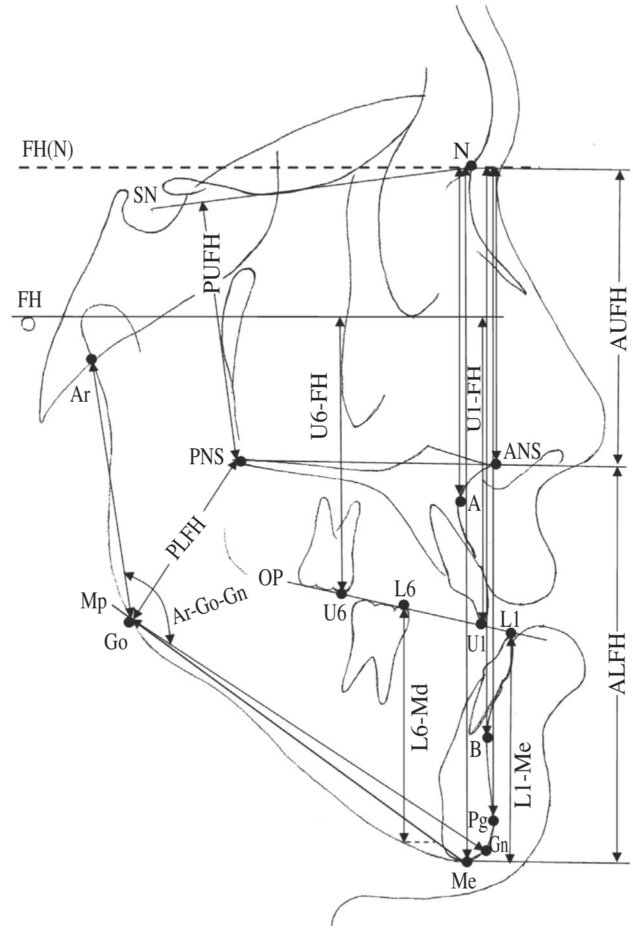

Fig. 2 Vertical measurements of dentoskeletal components. The cephalometric landmarks were mentioned as in the methods section. AUFH (anterior upper facial height): Distance from N to A. ALFH (anterior lower facial height): Distance from ANS to Me. PUFH (posterior upper facial height): Distance from PNS to the SN plane. PLFH (posterior lower facial height): Distance from PNS to the MP plane. ∠ SN-MP: Angle formed by SN and MP. ∠ FH-MP: Angle formed by FH and MP. ∠ Ar-Go-Gn: Angle of Ar-Go-Gn. Ar-Go: Distance from Ar to Go. ANS-FH(N): Distance from ANS to the FH(N) plane. A-FH(N): Distance from A to the FH(N) plane. B-FH(N): Distance from B to the FH(N) plane. Pg-FH(N): Distance from Pg to the FH(N) plane. Me-FH(N): Distance from Me to the FH(N) plane. U1-FH: Distance from U1 to the FH plane. U6-FH: Distance from U6 to the FH plane. L1-Me: Distance from L1 to Me, parallel to the FH plane. L6-Md: Distance from L6 to the mandible border, parallel to the FH plane. ∠ FH-OP: Angle formed by FH and OP.

groups at T1 and within the S group at T1 and T2 were compared. Moreover, comparisons were made between the C group at T1 and the S group at T2.

Error of the methods

Eighteen cephalographs, with 26 randomly chosen variables, were traced twice one month apart by the same investigator. Duplication error was assessed by Dahlberg's method ($ME = \sqrt{\Sigma d^2/2n}$); d is the difference between these pairs and n is the number of them.[41] The mean method error was 0.48 mm for linear and 0.75° for angular measurements. The

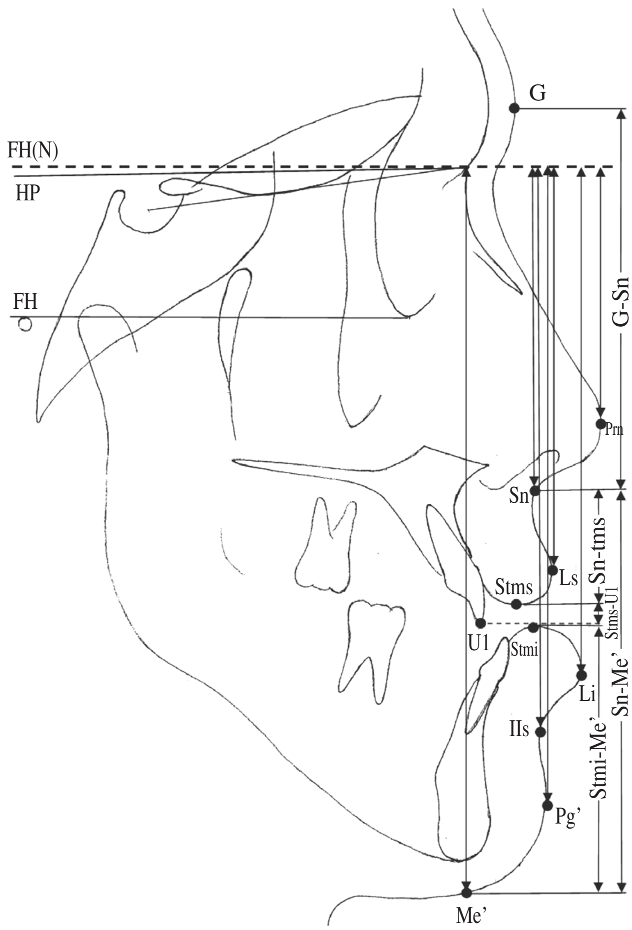

Fig. 3 Vertical measurements of soft-tissue components. The cephalometric landmarks were mentioned as in the methods section. [G-Sn/Sn-Me'(HP+)]: Vertical height ratio. [Sn-Stms/Stmi-Me'(HP)]: Vertical lip-chin ratio. Sn-Stms: Upper lip length. Stms-U1: Maxillary incisor exposure. Stmi-Me': Lower lip length. Prn-FH(N): Distance from Prn to the FH(N) plane. Sn-FH(N): Distance from Sn to the FH(N) plane. Ls-FH(N): Distance from Ls to the FH(N) plane. Li-FH(N): Distance from Li to the FH(N) plane. Ils-FH(N): Distance from Ils to the FH(N) plane. Pg'-FH(N): Distance from Pg' to the FH(N) plane. Me'-FH(N): Distance from Me' to the FH(N) plane.

overall method error of the various measurements was less than 0.7 mm and 0.8°. Thus, no significant differences were found between the two investigations.

Statistical analysis

Statistical analysis was performed using SPSS 13.0 (Statistical Package for Social Sciences, Chicago, Ill). Significant differences between the control and surgical group pre- and post- surgery (T1 and T2) were assessed by the Mann-Whitney U-test; the changes between T1 and T2 were evaluated using the Wilcoxon signed rank test. To avoid enlarging a type I error, a p value less than 0.017 in the multiple comparisons was considered statistically significant.

RESULTS

In most studies dealing with surgical correction to improve the facial profile, the pre- and post-treatment results are compared. Sagittal correction in patients with a prognathic mandible turns patients a normal skeletal Class I pattern with a harmonious facial appearance. Dental occlusion is also corrected to a normal Class I occlusion. However, it remains unclear how facial skeletal and soft tissue are reconstructed. Thus, in this study, we included patients with normal Class I malocclusion and a facial profile within the esthetic line as a control group for comparison. Unless mentioned otherwise, the landmarks and measurements were referred to the figure legends in Figs. 2 and 3.

Vertical structural features between groups at T1

Interestingly, the upper facial heights (UFH) for both groups were quite consistent for each measurement and near the same value of 58 mm and 50 mm for anterior upper facial height (AUFH) and posterior upper facial height (PUFH), respectively. Thus, no differences were found in these heights between groups (Table 1, columns 2, 3 and 5). Similarly, within UFH, the vertical height ANS-FH(N) presented constant values of 58 - 59 mm. On the contrary, there were significantly different findings in the measurements of ∠SN-MP, ∠FH-MP and ∠Ar-Go-Gn between groups. The S group had a shorter posterior lower facial height (PLFH) and a longer anterior lower facial height (ALFH) than the C group. Nevertheless, the Ar-Go measurements were similar for both groups at T1. Dental vertical measurements between groups remained constant except for increased L1-Me in the S than C group (47 vs. 42 mm). Occlusal plane angulation revealed subtle differences between groups (7.6 vs. 8.2 degrees).

Table 1. Vertical Measurements of Dentoskeletal Components: C, S (T1) and S (T2)

Variables	C	S (T1)	S (T2)	S (T1) vs. C	S (T2) vs. C	S (T2) vs. S (T1)
	Mean ± SD			*p* value		
Skeletal						
AUFH (mm)	58.47 ± 3.85	58.83 ± 3.35	58.14 ± 3.21	0.845	0.737	0.079
ALFH (mm)	71.72 ± 4.99	77.36 ± 7.66	78.36 ± 6.95	0.021	0.004†	0.149
PUFH (mm)	50.75 ± 3.54	50.53 ± 3.44	50.56 ± 3.36	0.736	0.736	0.892
PLFH (mm)	50.50 ± 4.11	43.33 ± 5.81	43.50 ± 6.27	0.000‡	0.000‡	0.649
SN-MP (deg)	31.36 ± 5.26	38.17 ± 6	41.06 ± 6.3	0.002†	0.000‡	0.006†
FH-MP (deg)	25.19 ± 5.11	30.97 ± 5.66	33.81 ± 6.18	0.007†	0.000‡	0.009†
Ar-Go-Gn (deg)	117.83 ± 4.87	130.08 ± 5.84	128.28 ± 6.43	0.000‡	0.000‡	0.319
Ar-Go (mm)	53.17 ± 4.87	53.78 ± 5.28	49.89 ± 6.55	0.713	0.067	0.001†
ANS-FH(N) (mm)	58.25 ± 4.15	59.03 ± 3.31	58.11 ± 3.03	0.578	0.944	0.009†
A-FH(N) (mm)	64.25 ± 4.36	66.58 ± 3.55	65.58 ± 3.21	0.053	0.303	0.005†
B-FH(N) (mm)	106.14 ± 5.97	112.81 ± 7.72	111.17 ± 7.19	0.006†	0.041	0.024
Pg-FH(N) (mm)	121.61 ± 7.18	128.44 ± 9.68	128.39 ± 8.75	0.025	0.022	0.997
Me-FH(N) (mm)	129.36 ± 7.7	136.11 ± 9.28	136.08 ± 9.16	0.017	0.024	1
Dental						
U1-FH (mm)	60.61 ± 4.42	61.19 ± 5.47	60.72 ± 4.98	0.796	0.97	0.535
U6-FH (mm)	55.33 ± 3.31	56.06 ± 4.67	56.78 ± 3.83	0.515	0.274	0.026
L1-Me (mm)	42.31 ± 3.44	46.89 ± 5.76	48.36 ± 5.85	0.008†	0.000‡	0.081
L6-Md (mm)	42.69 ± 2.92	43.11 ± 6.08	45.06 ± 6.28	0.736	0.342	0.007†
FH-OP (deg)	7.64 ± 4.15	8.17 ± 3.63	7.72 ± 4.97	0.621	0.956	0.807

Abbreviations: C: control group; S(T1): surgical group at T1; S(T2): surgical group at T2; *: $p < 0.017$; †: $p < 0.01$; ‡: $p < 0.001$. For definitions of the cephalometric landmarks and measurements, reter to the legends in Fig. 2.

Overall results indicated that the craniofacial discrepancy for patients with mandibular prognathism was in the mandible- associated lower facial height variables.

Vertical changes within the S group at T1 and T2

There were significant increase in the ∠SN-MP and ∠FH-MP angles, and vertical shortening of Ar-Go in the S group at T2 (Table 1, columns 3, 4 and 7). Moreover, surgical correction affected the L6-Md height at T2. However, the ALFH and PLFH remained constant at T1 and T2. The results suggest that surgical correction mostly affected the mandibular vertical measurements of the skeletal and dental components closer to the sagittal split osteotomy sites.

Comparison of the S group at T2 and the C group

To examine whether surgically corrected vertical components can conform to the normal standard, the S group at T2 and the C group were compared (Table 1, columns 2, 3 and 6). Significant changes were noted in the angular and linear measurements related to the mandible, the findings of which were similar to those in the comparison of the S group at T1 and the C group. In other words, in spite of the surgical efforts to achieve a sagittally balanced facial profile, we concluded that the vertical correction failed to return the skeletal components to the normal standard.

Analysis of the soft tissue facial profiles

Significant differences in Stmi-Me' measurements among groups C, S(T1) and S(T2) were identified (Table 2, columns 2, 3, 4, 5 and 6), suggesting that the lower lip length was longer in the S than the C group. The other significant finding was the Ls-FH(N) difference in length between S(T1) and S(T2) of 79 mm and 81 mm, respectively (Table 2, column 3, 4 and 7), indicating dropping of the Ls point of the upper lip after surgery. However, the upper lip length remained constant as indicated by the Sn-Stms measurement among C, S(T1) and S(T2). Also, the measurements of the total vertical facial profiles such as Me'-FH(N) and Pg'-FH(N) did not show any differences. On the other hand, interesting findings were noted with respect to the vertical height ratio G-Sn/Sn-Me', ranging from 1.0 for S(T1) and 1.03 for S(T2) to 1.02 for C; and of the vertical lip-chin ratio, ranging from 0.42 for S(T1) and 0.45 for S(T2) to 0.48 for C. The results suggest that for the patients with surgical correction, the vertical facial profile tended to reach balanced proportions as revealed by the standard C group ratios (Table 2, columns 2, 3 and 4).

DISCUSSION

Patient with mandibular prognathism often reveal sagittal and vertical discrepancies giving an impression of a long lower facial height. Consequently, intra oral condition presents a Class III malocclusion with an anterior cross-bite. Surgical correction turns a facial discrepancy into a balanced

Table 2. Vertical Measurements of Soft-tissue Components: C, S (T1) and S (T2)

Variables	C	S (T1)	S (T2)	S (T1) vs. C	S (T2) vs. C	S (T2) vs. S (T1)
	Mean ± SD			*p* value		
Vertical height ratio [G-Sn/Sn-Me'(HP+)]	1.02	1	1.03	–	–	–
Vertical lip-chin ratio [Sn-Stms/Stmi-Me'(HP+)]	0.48	0.42	0.45	–	–	–
Sn-Stms (mm)	24.61 ± 2.15	23.64 ± 2.49	24.39 ± 3.08	0.318	0.76	0.211
Stms-U1 (mm)	1.92 ± 1.31	3.06 ± 2.22	1.94 ± 0.82	0.037	0.769	0.024
Stmi-Me' (mm)	49.86 ± 4.13	55.97 ± 4.59	53.97 ± 4.44	0.000‡	0.007†	0.048
Prn-FH(N) (mm)	52.39 ± 4.37	51.33 ± 3.7	51.53 ± 3.87	0.366	0.485	0.125
Sn-FH(N) (mm)	63.78 ± 4.47	64.19 ± 3.66	64.56 ± 3.74	0.894	0.772	0.094
Ls-FH(N) (mm)	80.11 ± 5.79	79.72 ± 5.65	81.14 ± 5.67	0.845	0.667	0.000‡
Li-FH(N) (mm)	97.75 ± 6.64	98.03 ± 6.06	98.64 ± 8.72	0.919	0.568	0.57
Ils-FH(N) (mm)	105.83 ± 7.71	110.64 ± 9.06	109.03 ± 8.26	0.095	0.289	0.042
Pg'-FH(N) (mm)	121.56 ± 8.44	126.44 ± 9.81	126.39 ± 8.82	0.149	0.149	0.985
Me'-FH(N) (mm)	136.83 ± 8.59	143.11 ± 9.27	143.08 ± 9.34	0.044	0.062	0.902

Abbreviations: C: control group; S(T1): surgical group at T1; S(T2): surgical group at T2; *: $p < 0.017$; †: $p < 0.01$; ‡: $p < 0.001$. For definitions of the cephalometric landmarks and measurements, reter to the legends in Fig. 3.

facial profile (i.e., lips within the esthetic line). In addition, it improves the oral condition with a Class I occlusion with normal overbite and overjet. However, questions as to how the vertical surgical condition can be improved or maintained without jeopardizing normal physiological function remain undefined.

To unravel these questions, we studied and compared two groups of patients, one with a Class I occlusion having nose-lip relationship within the esthetic line (control group) and another with mandibular prognathism. We found that the measurements of the vertical facial height for both groups maintained the same nasomaxillary complex. The differences were noted in the vertical components of the mandible with a longer mandibular body in the S group. The shorter posterior and longer anterior lower facial height in the S group than the C group led to the impression of a deeper inclination of the mandibular plane toward the facial profile. This notion was further supported by findings of more obtuse mandibular plane angles including ∠SN-MP, ∠FH-MP and ∠Ar-Go-Gn in the S group, in agreement with previous reports.[1,2,4,5]

Despite the difference in the mandible- associated lower facial height, the surgical outcome of the vertical correction was not normalized to the pattern of the C group, as in case of the sagittal correction to return the face to a balanced profile in the C group (data not shown). Nevertheless, the surgical correction maintained the same lower facial height[42] in the anterior and posterior components, a point which needs to be addressed.

In dealing with a prognathic mandible, a bilateral sagittal split osteotomy (BSSO) is used to set back the mandible. The mandibular body is more or less shaped like an imaginary triangle, with occlusal and mandibular planes intersecting toward the posterior portion of the face. Setting back the mandible by BSSO only lengthens the posterior components of the mandibular body at the osteotomy site. The lengthening is even worse in cases where an anterior open bite needs to be closed by pivoting the distal portion of the bony segments at the osteotomy site. Thus, biomechanical stretching in the lengthening of the mandible inadvertently increases the burden on the nearby functioning muscles, including the masseter, medial pterygoid, and pterygo-masseteric sling,[39] inviting potential relapse.[29,43] Accordingly, resolution needs to be sought by reduction of the total length by superior impaction of the maxilla. Under these conditions, a Le Fort I maxillary osteotomy in conjunction with superior impaction is necessary to fit the facial complex within normal physiological function.

Similarly, in patients with mandibular prognathism presenting with a gummy smile characterized by a long incision-stomion (i.e., incisor display with lips in repose), a maxillary superior impaction is carried out to minimize display of the teeth.[43,48] With a BSSO procedure the mandible will not lengthen the complex due to autorotation of the mandible. This was the rationale in adopting bimaxillary surgery in our patients with mandibular prognathism. These efforts were rewarded by findings of well-maintained anterior and posterior lower facial heights in this study. Normal physiological function was not violated by bimaxillary surgical correction in patients with mandibular prognathism, producing a stable surgical correction.[29,43]

In our study, not all surgery patients received maxillary superior impaction. This was supported by the results of subtle changes in the occlusal plane to the standard after surgery.[45,46] The segmented (i.e., two or three pieces) Le Fort I osteotomy was applied to accommodate the transverse dimension of the mandibular dental arch. In doing so the dental alignment after surgery simplified post-surgical orthodontic mechanics and care.

The differential vertical proportions of the face are what make the face appealing. Accordingly, we divided and analyzed the vertical facial height ratio between the upper and lower parts of the face and the vertical lip-chin ratio between the upper and lower lips.[36] The soft tissue analysis pointed out that the surgical correction tended to return disproportion to the standard proportion of the face and lips.

To sum up, patients with mandible prognathism were treated with combined orthodontics and orthognathic surgery. Even though discrepancies were noted in the mandible- associated lower facial height, the surgical resolution needed to be confined within the context of normal neuromuscular physiology. Thus, the protocol for bimaxillary surgery was recommended and implemented. It is the different proportions of the face normalized to standard after surgical correction that presents a pleasing facial appearance.

Conclusions

1. Craniofacial discrepancy in patients with mandibular prognathism was in the mandible- associated lower facial heights.

2. Surgical correction mostly affected the mandibular measurements of the skeletal and dental components closer to the sagittal split osteotomy sites.

3. Surgical correction of the vertical skeletal components did not normalize to the control standard.

4. The vertical facial profile tended to resume a standard balanced proportion after surgery.

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下顎骨前突之手術矯正後骨骼與顏面輪廓垂直向的變化

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背 景： 下顎骨前突的患者常需要藉由正顎手術的矯正治療來改正。顏面輪廓水平面向的手術矯正已有廣泛的探討，但垂直面向的變化則未有定論，因此本研究即針對此部分作相關的調查。

方 法： 研究樣本選自 18 位下顎骨前突接受手術性矯正的病人 (S 組，平均年齡：20.1 ± 3.2 歲)，對照組則選定 18 位第一級異常咬合的患者 (C 組，平均年齡：21.2 ± 3.6 歲)。選取 C 組及 S 組開始矯正前 (T1) 及 S 組手術後約一年矯正完成 (T2) 的測顱X 光片，透過標準測顱分析法來評估。C 組及 S 組於 T1 的垂直面向差異，以及 S 組本身在 T1 與 T2 的垂直面向變化作相互的比較。此外 C 組於 T1 再與 S 組於 T2 垂直面向之數值進行交互比較。

結 果： C 組及 S 組於 T1 之測顱分析比較顯示，前上及後上顏面高度並無顯著差異。然而 S 組則呈現略長的前下顏面高度及較短的後下顏面高度 (58 mm 及 50 mm)。因此，在 C 組及 S 組間任何與下顎相關的垂直向測量值與比較均有顯著之差異。手術後下巴垂直向的位置並未改變。相反的，後下顎枝高度有縮短 (從 54 減到 50 mm)。軟組織垂直面向的測量值及比較結果也反映出軟組織相對於硬組織改變後的變化。

結 論： 由研究結果顯示手術矯正對下顎骨突出患者的垂直顏面高度可維持在正常生理功能。

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關鍵詞：顏面輪廓，手術矯正，下顎前突，三級異常咬合

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