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Orthognathic Surgery

Impact of orthognathic surgery on the cheek area using the Barcelona line

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Abstract. A facial appearance of premature aging due to poor bone support of the soft tissues is frequently found in patients with midface hypoplasia. This study was performed to evaluate the changes in the soft tissues of the cheek area in patients subjected to bimaxillary orthognathic surgery. The cheek line angle and length of 27 consecutive patients who underwent bimaxillary surgery, were measured on cone beam computed tomography scans obtained before surgery and at 1 and 12 months after surgery using 3D software. Changes between time-points were analyzed. Bimaxillary surgery was virtually planned in all patients using the Barcelona line protocol. The results showed a mean decrease in cheek angle of 5 ± 5° ($P < 0.001$). This decrease was reflected in a more anterior-projected cheek and was related to forward movement of the upper and lower incisors (x-axis) ($r = -0.469$, $P = 0.014$ and $r = -0.440$, $P = 0.021$, respectively). There was 3D stability of the hard and soft tissue changes at the 1-year postoperative follow-up. The results indicate that bimaxillary surgery performed following the Barcelona line as a planning reference could improve midfacial soft tissue support by means of a more anterior-projected cheek.

Keywords: Orthognathic surgical procedures; Three-dimensional imaging; Minimally invasive surgical procedures; Esthetics; Cheek; Premature aging.

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Aesthetically, young cheeks are prominent, voluminous, and anteriorly curved, as represented by a descendent and uninterrupted line[1–4]. The midfacial skeleton comprises the zygoma and maxillary bones surrounded by periosteum, over which the zygomatic cutaneous ligament is inserted, acting as a soft tissue stabilizer that extends to the dermis. Part of the facial expression muscles (zygomaticus major, zygomaticus minor, and levator labii superioris) are found between the ligaments[5–7], and in conjunction with the superficial subcutaneous facial fat compartments (nasolabial, medial cheek, middle cheek, and inferior jowl) they support the anterior silhouette projection of the cheek[8].

During aging, lesser volumes and/or ptosis of the infraorbital, medial, and lateral cheek fat have been reported, and some pseudo-herniation of the buccal fat may occur, modifying the cheek volume distribution[9,10]. Hence, in patients with midfacial hypoplasia presenting flat cheekbones, an appearance of premature aging may be seen[11]. In the same context, a flat appearance of the cheek line (defined as the line joining the following soft tissue reference points: cheekbone, orbital rim, subpupillary projection, and nasal base) is usually associated with dentofacial deformities[12]. In such cases,

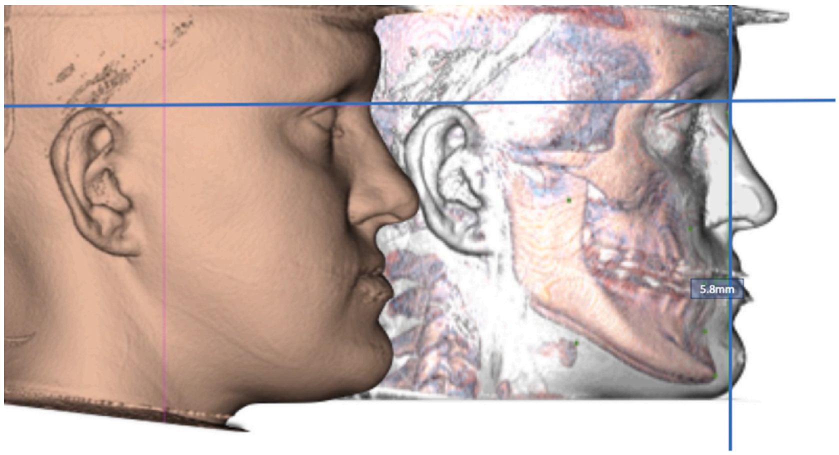

Fig. 1. Natural head orientation superimposition for Barcelona line (BL) demarcation. In this clinical case, the BL protocol indicated that the patient presented a Class III dentofacial deformity in which the upper incisor was positioned behind the reference by 5.8 mm; the soft tissue pogonion point was appropriately positioned in front of the BL. Maxillary forward positioning ahead of the BL was indicated.

orthognathic surgery may be considered as a treatment option[13]. Although the Le Fort I osteotomy is performed below the cheek, it has been demonstrated that proper maxillary advancement and clockwise rotation have an impact upon the cheek line and its volume morphology[14–22].

The Barcelona line (BL) has been described as a suitable diagnostic and treatment tool for adequate maxilla–mandible sagittal positioning; the BL is a true vertical line that crosses the nasion soft tissue (Fig. 1)[23]. This study was performed to evaluate the three-dimensional (3D) cheek line changes after orthognathic surgery based on the BL protocol.

Materials and methods

Sample selection

The study sample consisted of consecutive patients with dentofacial deformities who were admitted to the Maxillofacial Institute, Teknon Medical Center, Barcelona, Spain in 2019 and underwent bimaxillary orthognathic surgery based on the BL protocol. The study by Jensen et al.[24] was used as the reference for the sample size calculation, which was based on the standard deviation estimates. The size of the difference considered for the changes was 1.1 mm for the 'upper labrale' variable, 0.4 mm for 'inferior nasal tip', 1.85 mm for 'inferior stomion', and 1.9 mm for 'lower lip stomion'. These differences, in relation to the standard deviation, correspond to the medium effect sizes (Cohen's d = 0.5). The calculations were conducted for a one-tailed t-test. The sample size calculation estimated that a total of 27 patients were required in order to reach a statistical power of 80% with a 95% confidence interval (CI).

The inclusion criteria were patients requiring bimaxillary orthognathic surgery, age ≥18 years, and 1-year follow-up records available. The exclusion criteria were dentofacial deformities related to syndromic malformations, a history of chemotherapy, radiotherapy, or medication that could affect bone healing or soft tissue quality, and previous facial aesthetic treatments (both medical and surgical).

Data acquisition and surgical protocol

A cone beam computed tomography (CBCT) scan (i-CAT; Imaging Sciences International, Hatfield, PA, USA) was performed at three timepoints: preoperatively (T0), 1 month after surgery (T1), and 12 months after surgery (T2). All patients were instructed to breathe calmly, sitting in natural head orientation, with the tongue relaxed and the mandible in centric relation[25].

Dolphin Imaging software version 11.9 (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) was used for the surgical planning according to the BL protocol[23]. All surgical splints were printed in-house[26]. In all patients, surgery was performed under general anesthesia by the same surgeon (F.H.A.). The mandible was operated first and was fixed with a hybrid technique[27]. Likewise, Le Fort I osteotomy with or without segmentation was performed through a minimally invasive approach, using the 'twist technique'[28]. Then, after maxillary repositioning and fixation, modified alar cinch suturing and V–Y closure were performed[29]. During the postoperative period, all patients wore a closed-circuit cold mask at 17 °C until discharge. They were discharged 24 h after surgery with standard medications and instructions on functional training with light guiding elastics and a soft diet.

Evaluation

Three-dimensional voxel-based superimposition was applied to evaluate the 3D cheek changes, ensuring that the CBCT scans for analysis (T0–T2) were in the same position[30]. Two consecutive measurements (performed by J.S.V.C.) were compared with a third measurement (performed by A.V.O.) after a 2-week interval to ensure the reliability of the measurements, which was evaluated through the intra-class correlation coefficient (ICC) and inter-examiner correlation.

Two changes over the cheek line were measured: the cheek angle and the cheek line length. To study the 3D changes over the cheek line projection, the cheek angle was measured in degrees (°) and the cheek line length in millimeters (mm) (Fig. 2).

In addition, 3D maxillomandibular skeletal angular and linear measurements were obtained to correlate orthognathic surgery with the cheek angle and length changes (Figs. 3–5). Both measurements were quantified at different time intervals with the aim of evaluating the magnitude of the movements but also their stability. The time intervals were: T0–T1 (3D vectoral change from preoperative to 1 month after surgery), T1–T2 (postoperative 3D vectoral relapse or stability between 1 month after surgery and at least 12 months after surgery), T0–T2 (global 3D vectoral change between preoperative and at least 12 months after surgery). The T0–T2 duration was a mean 16.1 months (standard deviation 5.3 months), median 16.3 months, range 12–24 months.

The cheek line soft tissue changes were correlated with patient age, sex, and dental class (I–III).

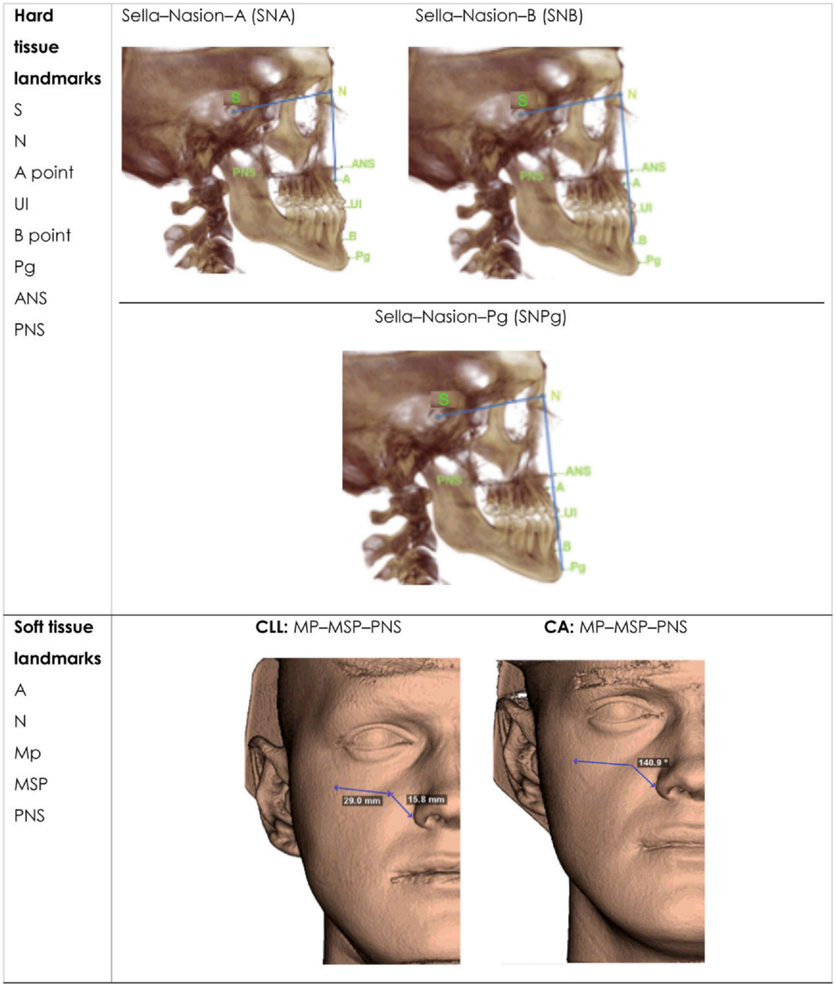

Fig. 2. Hard tissue and soft tissue reference points on the 3D CBCT reconstructions. Abbreviations: S, sella; N, nasion; UI, upper incisor; Pg, pogonion; ANS, anterior nasal spine; PNS, posterior nasal spine; A′, soft tissue A point; N′, soft tissue nasion; CLL, cheek line length; CA, cheek angle. Mp = malar prominence anterior, defined as a point lateral to a vertical line descending from the external eye canthus. MSP = maximum subpupillary projection, which is the most anterior cheek projection below and medial to the pupils, located between the orbital rim and nasal base. PNS = soft tissue in the paranasal areas.

Statistical analysis

The data analysis was performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). A descriptive analysis was performed, with calculation of the mean, standard deviation (SD), minimum and maximum, and median for continuous variables, and absolute and relative frequencies (percentages) for qualitative variables. Absolute displacement of the X, Y, and Z parameters in space was calculated using the formula:

$$\Delta VARIABLE(T2 - T1) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

The inferential analysis to assess cheek line projection included the following: (1) repeated measures analysis of variance (ANOVA) to compare changes in cheek line over time, with the Bonferroni test for evaluating soft tissue changes over the short term (T0–T1), relapse (T1–T2), and the global long-term movement (T0–T2); (2) Pearson correlation to determine the relationship between the skeletal movements and the soft tissue changes; and (3) the independent t-test and one-way ANOVA to assess the skeletal and soft tissue changes according to the specific movements of the jaw and the facial profile of the patient.

Results

The study sample consisted of 27 patients, 18 female (66.7%) and nine male (33.3%), with a mean age of 32.5 ± 11.2 years (range 18–57 years). A Class III dentofacial deformity was present in 14 patients (51.9%) and Class II in 13 patients (48.1%). The surgery-late protocol was performed in 15 patients (55.6%), surgery-early in seven (25.9%), and surgery-first in five (18.5%).

All patients underwent bimaxillary surgery performed with the upper incisor positioned anterior to the BL reference by 1–4 mm. Table 1 reports the direction (no movement, forward, backward, upward, downward, centering, non-centering, clockwise and counterclockwise rotations) and mean magnitude of the surgical movements at the different landmarks assessed by CBCT at time-points T0–T2.

The intra-examiner reliability of measurements (by J.S.V.C.) based on the ICC for consecutive measurements was 0.96, while the inter-examiner reliability of measurements (by J.S.V.C. and A.V.O.) was 0.93. Analyses were conducted to compare the cheek changes between different subgroups (including by age, sex, types of maxillary and mandibular movements). The most notable cheek changes occurred in the younger age group, female patients, and the Class III group (Supplementary Material Table S1). Regarding the treatments applied, maxillary segmentation, counterclockwise rotation, and forward movements were associated with a longer and defined cheek line and also with the most notable cheek angle reduction (Supplementary Material Tables S1 and S2).

A significant decrease in cheek angle was recorded from preoperative to 1

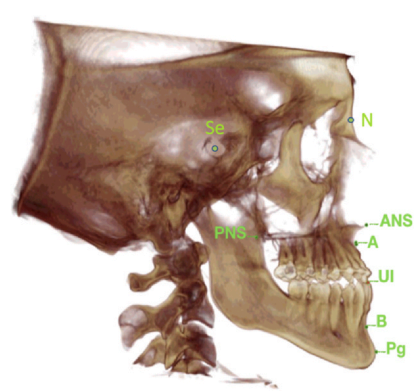

Fig. 3. Bone landmarks from the 3D CBCT reconstructions. Abbreviations: Se, sella; N, nasion; ANS, anterior nasal spine; A, A point; UI, most anterior upper incisor point; B, B point; Pg, pogonion; PNS, posterior nasal spine.

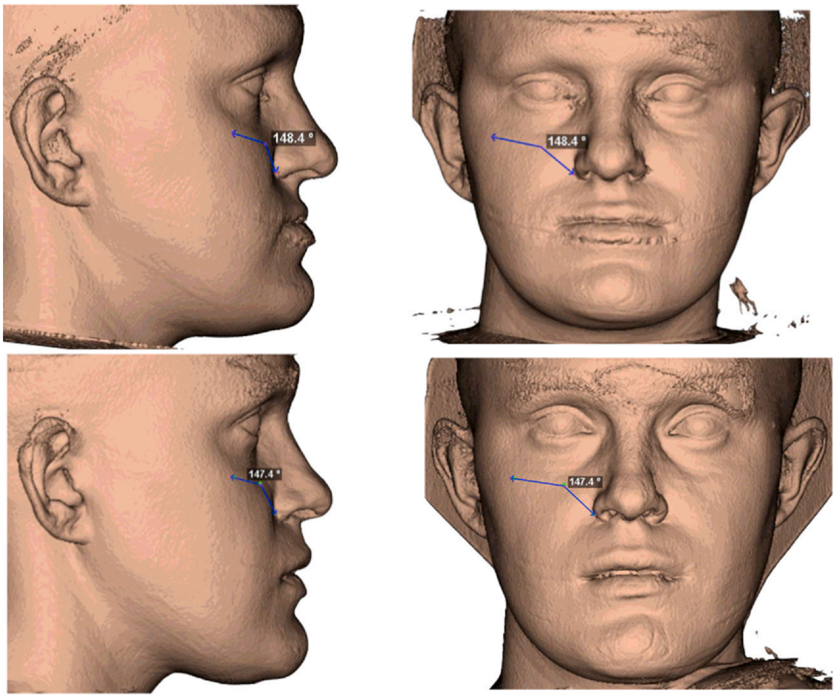

Fig. 4. Clinical case, showing soft tissue cheek angle measurements on the 3D soft tissue reconstruction at time-points T0 and T2. The pre- and postoperative cheek angle measurements are expressed in degrees. Even though the decrease in cheek angle was small in this clinical case (only 1°), the aesthetic effect is easily appreciated following the soft tissue reorganization.

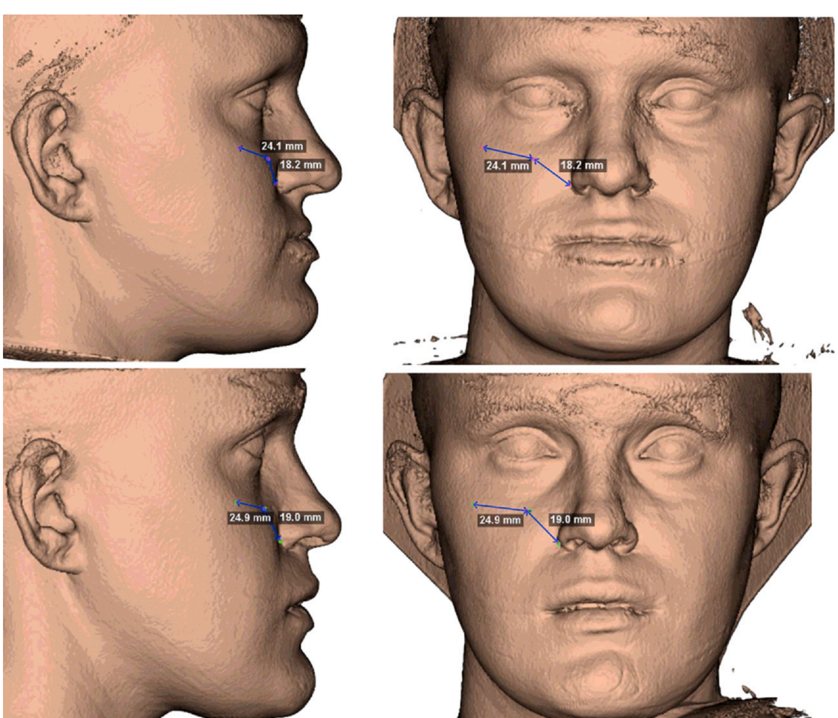

Fig. 5. Clinical case, showing soft tissue cheek line length measurements on the 3D soft tissue reconstruction at time-points T0 and T2. The pre- and postoperative cheek line length measurements are expressed in millimeters. In this case, 1.6 mm of cheek line lengthening was gained at stability, at the 1-year follow-up.

month after surgery ($-5 \pm 4°$, $P < 0.001$) (Fig. 6), without any further change between T1 (immediately after surgery) and T2 (12 months of follow-up) ($-0.01 \pm 2°$, $P = 1.000$). Therefore, a significant long-term global decrease was observed ($-5 \pm 5°$, $P < 0.001$) (Table 2). Overall, the more the upper incisor moved towards an anterior position (x-axis), the narrower the resulting cheek angle was found to be ($r = -0.469$, $P = 0.014$) (Fig. 7); similarly, the more the inferior incisor advanced with the mandibular movement (x-axis), the narrower the resulting cheek angle ($r = -0.440$, $P = 0.021$). Analyses of cheek angle measurements according to the different related variables are shown in Supplementary Material Table S3.

A non-significant mean cheek line lengthening of 2 ± 5 mm ($P = 0.116$) was recorded postoperative. There was no significant lengthening over the long term (T0–T2, 1 ± 4 mm; $P = 0.309$) (Fig. 8, Table 3). Analyses of cheek line length measurements according to the different related variables are shown in Supplementary Material Table S4. Cheek line lengthening was correlated with A point advancement ($r = 0.535$, $P = 0.004$), an increased sella–nasion–A point (SNA) angle after the surgery ($r = 0.483$, $P = 0.011$), and posterior nasal spine (PNS) advancement and downwards movement ($r = 0.425$, $P = 0.027$ and $r = 0.387$, $P = 0.046$, respectively) .

Discussion

The results of this study suggest that bimaxillary surgery with proper repositioning of the maxillomandibular complex is associated with a reduction in cheek angle (−3.5%; $P < 0.001$). Clinically, surgery resulted in a more projected and convex cheek, since the maximum subpupillary projection (MSP) and paranasal soft tissue (PNST) points were moved upwards and forwards, which is consistent with the patterns of facial beauty and youthfulness. Thus, it can be concluded that protruded positioning with the BL protocol induces a midface push-effect[23,31], in line with the published literature on the protrusive pattern regarded as aesthetically acceptable after using different planning protocols that assess the impact of orthognathic surgery upon the cheek area[14–22,31,32].

Table 1. Angular skeletal measurements at the study time-points and changes in linear and angular skeletal measurements between time-points.

Skeletal measurements	Normal	T0	T1	T2	T0–T1	T1–T2	T0–T2
SNA	82 ± 2	81 ± 3	86 ± 4	86 ± 4	5 ± 3 $P < 0.001$*	1 ± 1 $P = 0.025$*	5 ± 3 $P < 0.001$*
SNB	80 ± 2	79 ± 7	85 ± 4	85 ± 3	6 ± 4 $P < 0.001$*	−0.1 ± 0.9 $P = 1.000$	6 ± 4 $P < 0.001$*
A point					5 ± 2 $P < 0.001$*	1 ± 0.7 $P < 0.001$*	5 ± 2 $P < 0.001$*
UI					7 ± 3 $P < 0.001$*	2 ± 1.4 $P < 0.001$*	7 ± 3 $P < 0.001$*
PNS					6 ± 3 $P < 0.001$*	1 ± 1 $P < 0.001$*	6 ± 3 $P < 0.001$*
B point					11 ± 8 $P < 0.001$*	2 ± 2 $P = 0.105$	11 ± 7 $P < 0.001$*
Pg					14 ± 10 $P < 0.001$*	1.4 ± 1 $P < 0.001$*	14 ± 9 $P < 0.001$*
NA–OP		80 ± 5	85 ± 4	85 ± 4	5 ± 5 $P < 0.001$*	0.1 ± 1 $P = 1.000$	6 ± 6 $P < 0.001$ *

NA–OP, Nasion-A / Oclussal plane; Pg, pogonion; PNS, posterior nasal spine; SNA, sella–nasion–A point angle; SNB, sella–nasion–B point angle; UI, upper incisor. Values are presented as the mean ± standard deviation. A, B, Pg, PNS, and UI distances are given in millimeters; SNA, SNB, SNPg, and NA–OP angles are given in degrees. All points were correlated with the quantity and direction of movements (advancement, setback, upward, downward, centering, no centering, clockwise and counterclockwise rotation).

*Significant change.

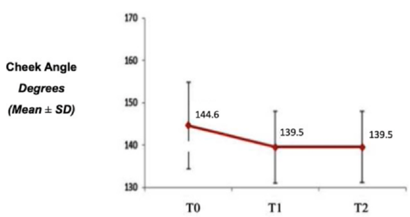

Fig. 6. Mean cheek angle (± standard deviation) measured preoperatively and at 1 month and 12 months of follow-up. The angle decreased markedly from T0 to T1, and remained stable at the 1-year follow-up. The global decrease (T0–T2) proved significant ($P < 0.001$).

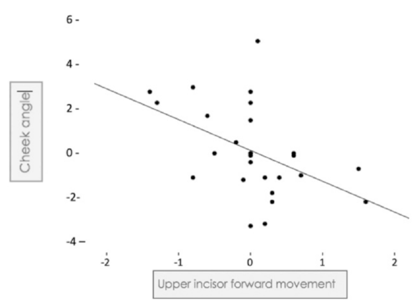

Fig. 7. Correlation of cheek angle and upper incisor forward movement. A strong correlation is observed ($r = -0.469$, $P = 0.014$), indicating that the greater the sagittal (‘x’) displacement of the upper incisor, the greater the resulting narrowing of the cheek angle. Greater cheek prominence is thus obtained.

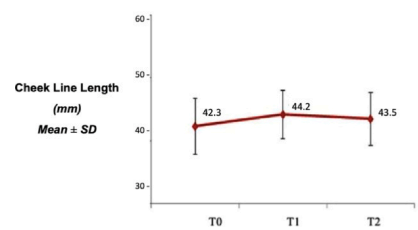

Fig. 8. Mean cheek line length (± standard deviation) measured preoperatively and at 1 month and 12 months of follow-up. This distance tended to increase over the short term, but this was not statistically significant ($P = 0.116$), and the global change (T0–T2) was minimal ($P = 0.309$).

Regarding the surgical technique, and apart from affording adequate facial proportions, it is important to highlight the need for a minimally invasive approach, taking care not to damage the perinasal muscles and ligaments, and thus preserve the medial base support for the cheek and upper lip[27,33–35]. Also, alar cinch suturing to maintain the perinasal structures improves repositioning of the soft tissue of the cheek after orthognathic surgery[29].

When specifically evaluating the impact of each type of surgical movement upon the cheek angle, maxillary advancement, segmentation with lateral expansion, and counterclockwise rotation resulted in a comparatively greater decrease in cheek angle (Supplementary Material Table S2). On the other hand,

Table 2. Cheek angle measurements at time-points T0, T1, and T2, and changes between time-points. Values are presented as the mean ± standard deviation, in degrees.

Number of patients	27	
Cheek angle (°)		
T0	145 ± 10	
T1	140 ± 8	
T2	140 ± 9	
Change in cheek angle (°)		
T0–T1	−5 ± 4	$P < 0.001$*
T1–T2	−0.01 ± 2	$P = 1.000$
T0–T2	−5 ± 5 (−3.50%) 95% CI −7 to −3	$P < 0.001$*

CI, confidence interval.

*Significant change.

Table 3. Cheek line length measurements at time-points T0–T2, and changes between time-points. Values are presented as the mean ± standard deviation, in millimeters.

Number of patients	27	
Cheek line length (mm)		
T0	42 ± 4	
T1	44 ± 4	
T2	44 ± 4	
Change in cheek line length (mm)		
T0–T1	2 ± 5	$P = 0.116$
T1–T2	−1 ± 4	$P = 1.000$
T0–T2	1 ± 4 (+2.8%) 95% CI 1 to 3	$P = 0.309$

CI, confidence interval.

mandibular and chin advancements resulted in a greater reduction in the cheek angle (Supplementary Material Table S3). It could be postulated that although the mandible and chin are distant structures, their joint forward movement will improve the support of the midfacial soft tissue, although these observations are to be interpreted with caution.

As mentioned previously, there are two causes of deficient midfacial projection that may arise concomitantly: flat cheekbones and the aging process. In those with flat cheekbones, the patients may complain of a premature aging appearance. Therefore, a correct diagnosis is essential in order to choose the appropriate treatment or combination of treatments[36–39]. Different Le Fort osteotomy designs have been developed according to the severity of maxillary hypoplasia. The high Le Fort osteotomy is a functionally stable and surgically predictable procedure in patients with a moderate to severe zygomatic-maxillary midfacial deficiency. However, it must be noted that more surgical complications such as bleeding or neurological disorders have been linked with higher osteotomies[5,40,41]. In cases with flat malar bones, patient-specific implants or soft tissue fillers can be used concomitantly or after orthognathic surgery[42]. On the other hand, focusing on the scenario of premature aging appearance, a midfacial lifting procedure or soft tissue filler use should be considered[42].

The authors would like to highlight that the outcomes obtained showed greater maxillary advancement movements (SNA $5 \pm 3°$, $P < 0.001$) in older people, likely due to the presence of soft tissue atrophy at the level of the upper lip and cheek area, apart from skeletal maxillary hypoplasia, which in turn resulted in an increased reduction in the cheek angle ($-6 \pm 5°$) in this group (Supplementary Material Table S3). Thus, in older patients with soft tissue atrophy and midface hypoplasia, greater maxillary advancements should be indicated to adequately correct both causes of a lack of midface projection simultaneously. Similarly, Class III patients showed a greater reduction in the cheek angle and greater lengthening of the cheek line than Class II patients (Supplementary Material Tables S1 and S2), since Class III patients usually present a greater lack of maxillary projection and thus require greater maxillary advancement.

The limitations of this study include its retrospective and single-center design, with the potential biases involved. In addition, there was heterogeneity in dental class among the patient sample, which could add some bias, and moreover the cheek soft tissue measurements were made on CBCT scans using specific software, thus introducing another potential source of measurement bias[43,44]. Furthermore, patient weight and/or body mass index were not measured, and these parameters could influence the soft tissue volume and quality in the midface compartments. Since the BL was the planning tool used in this study, the outcomes must be interpreted with caution when generalizing them to cases planned with other methodologies. Furthermore, comparative groups to test the advantages of using the BL planning protocol over other protocols in different sexes and races, measuring soft tissue thickness, could be useful for assessing the soft tissue behavior after orthognathic surgery. Lastly, mention should be made of the variability that characterizes any form of reference measurement, and emphasis must be placed on the need for accurate clinical judgment to guide diagnosis and planning in orthognathic surgery.

In conclusion, the results obtained in this study suggest that maxillomandibular surgery performed following the Barcelona line as the planning reference could improve midfacial soft tissue support, showing a more anterior-projected cheek.

Patient consent

Obtained.

Ethical approval

Obtained from the Institutional Review Board of Teknon Medical Center (Ref. 2020/91-MAX-CMT).

Funding

None.

Competing interests

None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijom.2024.11.002.

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