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Sequencing of bimaxillary surgery in the correction of vertical maxillary excess: retrospective study

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Abstract. The aim of this study was to evaluate the precision of bimaxillary surgery performed to correct vertical maxillary excess, when the procedure is sequenced with mandibular surgery first or maxillary surgery first. Thirty-two patients, divided into two groups, were included in this retrospective study. Group 1 comprised patients who received bimaxillary surgery following the classical sequence with repositioning of the maxilla first. Patients in group 2 received bimaxillary surgery, but the mandible was operated on first. The precision of the maxillomandibular repositioning was determined by comparison of the digital prediction and postoperative tracings superimposed on the cranial base. The data were tabulated and analyzed statistically. In this sample, both surgical sequences provided adequate clinical accuracy. The classical sequence, repositioning the maxilla first, resulted in greater accuracy for A-point and the upper incisor edge vertical position. Repositioning the mandible first allowed greater precision in the vertical position of pogonion. In conclusion, although both surgical sequences may be used, repositioning the mandible first will result in greater imprecision in relation to the predictive tracing than repositioning the maxilla first. The classical sequence resulted in greater accuracy in the vertical position of the maxilla, which is key for aesthetics.

Key words: orthognathic surgery; Le Fort I osteotomy; sagittal split ramus osteotomy; surgical sequence.

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Technological advances have resulted in changes to orthognathic surgery at a speed that could not even have been imagined when the biological basis for such procedures was first established[1]. Biological knowledge resulted in a safe procedure. Following this, treatment was no longer limited to mandibular repositioning. Maxillary osteotomies and bimaxillary surgery then became popular and have since been performed routinely. With the development of new techniques, instruments, and materials for osteosynthesis, surgical repositioning such as counterclockwise rotation of the occlusal plane, which was considered extremely unstable, has become a useful tool for the surgeon[2].

Among the factors associated with the success of orthognathic surgery are correct diagnosis, adequate treatment planning, accurate reproduction of the treatment plan during surgery, and postoperative stability of the results[3,4].

Initially, because osteosynthesis was done with wires, the traditional operative sequence was required when performing bimaxillary surgery. Thus, it was necessary to reposition the maxilla first and then reposition the mandible, as guided by the maxilla, which was held in place with wires. Internal stable fixation using plates and screws made it possible to invert the operative sequence, allowing the mandible to be repositioned first[5]. Although this is considered a fairly recent technique, it was first described in 1978 as a mandibular osteotomy fixated with screws[6].

The sequencing most used for bimaxillary surgery is repositioning of the maxilla first. This is due in part to the fact that most surgeons have been trained using this sequence. However, operating on the mandible first as the treatment choice has increased significantly, especially in the last decade.

Supporters of the classical surgical sequence justify that preference because they think that the maxillary position will be more accurate, especially when vertical repositioning is to be performed. On the other hand, those who prefer to initiate the procedure by repositioning the mandible feel that this allows compensation for errors in condylar positioning. Other specific reasons are used to justify the use of each one of the surgical sequences[7,8].

At this time, the choice concerning the sequence used is largely made according to surgeon preference and the literature on the subject is somewhat scarce. This study evaluated the accuracy of bimaxillary procedures used for the correction of vertical maxillary excess with surgery initiated by mandibular or maxillary repositioning.

Materials and methods

This retrospective study compared the postoperative results of patients submitted to bimaxillary orthognathic surgery that included maxillary superior repositioning as part of the treatment plan. The sample comprised 32 patients from the Oral Face Care Clinics (Santos, SP, Brazil), operated on by the same surgeon during the period from March 2007 to January 2014. All patients signed a consent form for the use of their medical records. The study was approved by the Ethics Committee of Araraquara Dental School, São Paulo State University – UNESP, Brazil.

All patients underwent pre-surgical orthodontic preparation. Radiographic control was obtained at a maximum of 30 days after surgery and included frontal and lateral cephalometric and panoramic radiographs. Orthodontic treatment was resumed after that control.

Inclusion criteria were (1) adult patients, (2) vertical maxillary excess, (3) any type of occlusal pattern, (4) bimaxillary surgery with counterclockwise rotation of the occlusal plane, with or without genioplasty, (5) pre- and postoperative lateral cephalometric radiographs obtained in the same set, and (6) free of any syndrome or craniofacial cleft. Exclusion criteria were (1) history of facial trauma, (2) submitted to temporomandibular joint surgery, (3) previous orthognathic surgery, (4) segmented surgery, (5) facial asymmetry, and (6) incomplete records.

The patients were divided into two groups according to the surgical sequence performed. Group 1 included 16 patients (10 female and six male) with a mean age of 26.96 years (range 18–40 years), who underwent the traditional surgical sequence of repositioning the maxilla first. Group 2 included 16 patients (nine female and seven male) with a mean age of 27.81 years (range 17–51 years). In this group, the surgical sequence was altered and the mandible was repositioned first. For both groups, an external reference was used to reposition the maxilla. This was done with a Kirschner wire positioned at nasion. All patients received stable fixation with four 2.0-mm L- or T-plates in the maxilla and hybrid fixation with one 2.0-mm miniplate associated with a bicortical screw behind the plate in the mandible. No postoperative intermaxillary fixation was used.

The preoperative lateral cephalometric radiograph, obtained in the week prior to the procedure, was digitized using Dolphin software (Dolphin Imaging Management Solutions, Chatsworth, CA, USA). The predictive tracing was then constructed. Model surgery was done using dental models mounted in a semi-adjustable articulator (Arcon Bio-Art, São Carlos, SP, Brazil) and using the Erickson platform (Rocky Mountain Orthodontics, Denver, CO, USA).

The models were mounted in centric relation in the articulator. For each patient, two sets of upper and lower models were mounted. Reference lines were drawn on the models, and the mesiobuccal cusps of the first molars, canine cusps, and incisor edge of the right upper central incisor were marked to allow measurements in the Erickson platform. Model surgery was performed according to the prediction tracing and following the traditional sequence for both groups. Thus, the maxilla was repositioned first and then the mandible was repositioned into the final occlusion. After this, the final splint was made.

For the group of patients who were to receive maxillary surgery first, the second mounted mandibular model, which was intact, was positioned in the articulator and the intermediate splint was constructed. For the group of patients who were to receive mandibular surgery first, the second intact mounted maxillary model was positioned in the articulator and the intermediate splint was made.

The postoperative lateral cephalometric radiograph was obtained after a maximum of 30 days and was also digitized in the same fashion, allowing the postoperative tracing to be constructed. The tracings produced by the software included the frontal and nasal bones, cranial base, ear canal, mandible, maxilla, upper and lower central incisors, upper and lower first molars, orbit, and soft tissue profile.

The cephalometric landmarks considered to verify changes in the position of the maxilla were anterior nasal spine (ANS), posterior nasal spine (PNS), A-point, upper central incisor edge (U1 tip), and upper first molar (6S occlusal). The landmarks used for the mandible were lower central incisor edge (L1 tip), pogonion (Pg), B-point, and lower first molar (6I occlusal)[8]. All landmarks were located by two separate examiners who had previously been calibrated. When discrepancies were greater than 0.5 mm or 0.5°, two new measurements were obtained. The method used the values of the Cartesian coordinates (x horizontal and y vertical) of each point in the predictive and postoperative tracings. The origin was where the Cartesian axes intersected sella (S), represented by the coordinates $x = 0$ and $y = 0$.

To compare the accuracy of the two different surgical sequences, the postoperative tracings were superimposed onto the prediction tracings using the points sella (S) and nasion (N). The vertical and horizontal positions of each point considered were compared to determine whether the treatment planning was accurately reproduced and whether there were differences in the precision obtained by the two different operative sequences. Each point was located twice and measurements were taken in duplicate in order to calculate the method error. Results were tabulated for statistical analysis.

Reproducibility of the method was evaluated using 32 radiographs chosen at random and digitized twice by the same examiner with a 30-day interval between measurements. Casual error was calculated using the Dahlberg formula. The intraclass correlation coefficient was used to determine intra-examiner reliability. Descriptive statistics are presented as the mean, standard deviation, median, minimum, and maximum values. The Shapiro–Wilk test and the analysis of skewness and kurtosis were used to determine the normality of the data. Characteristics of the sample were assessed using the *t*-test for continuous quantitative variables and the Chi-square test for categorical variables. Differences in measurements between predictive tracings and postoperative tracings were evaluated with the Student *t*-test for paired samples and the Wilcoxon test for data with a non-normal distribution. Differences between groups were determined by Student *t*-test and Mann–Whitney tests for variables with a non-parametric distribution. The statistical software package used was SPSS version 16.0 (SPSS Inc., Chicago, IL, USA), considering a significance level of 5%.

Results

No statistically significant differences were found between the two groups with regard to the sample age ($t = 0.79$, $P = 0.433$) or the sample sex ($\chi^2 = 0.130$, $P = 0.719$). Comparisons of some of the cephalometric measurements assessed pre-surgically and post-surgically are given in Table 1.

The planned surgical movement for the maxilla was advancement, superior repositioning, and counterclockwise rotation. The anatomical landmarks ANS and PNS were used to compare surgical repositioning between the groups. There was no statistically significant difference regarding the planned surgical repositioning. The mean planned advancement of ANS was 2.80 ± 1.38 mm in group 1 and 2.11 ± 1.83 mm in group 2 ($P = 0.236$). The desired superior repositioning of ANS was 3.13 ±1.27 mm in group 1 and 2.68 ± 1.02 mm in group 2, with no difference between the groups ($P = 0.271$). For PNS, the predicted superior repositioning was 0.34 ± 1.72 mm in group 1, whereas PNS was inferiorly repositioned 0.94 ± 1.49 mm in group 2 ($P = 0.032$). These values show that there was a counterclockwise rotation in both groups (Table 2). The *t*-test was applied to show the differences between the movements of ANS and PNS in both groups (group 1: $t = -5.21$, $P < 0.001$; group 2: $t = -8.02$, $P < 0.001$), thus confirming the counterclockwise rotation. Independent of the surgical sequence, the mandible would follow that repositioning.

The results showed that the casual error was 0.46 mm to 1.68 mm for the horizontal axis measurements and 0.20 mm to 1.26 mm for the vertical axis measurements. Intra-examiner reproducibility was very high, varying from 0.927 to 0.998. There were no significant differences between groups 1 and 2 regarding the values determined for the prediction tracings. There were significant differences in the horizontal and vertical measurements in the values obtained for PNS in the postoperative tracings.

The difference between the values achieved and the values determined in the prediction tracings for group 1 was statistically significant for 6S and 6I, showing a larger horizontal anterior movement than desired. Vertically, there were statistically significant differences for the lower central incisor edge (L1 tip) and PNS. L1 tip rotated upwards a mean of 1.13 mm less than desired, while PNS was superiorly repositioned an average of 1.68 mm more than desired (Table 3).

In group 2, significant differences between horizontal values desired and achieved were significant for B-point, Pg, and U1 tip, with an average of 1.70 mm, 2.23 mm, and 0.81 mm less than desired, respectively. However, the greatest differences observed for this group were found for the vertical values, with A-point, ANS, B-point, L1 tip, 6I, and U1 tip (average of 2.12 mm, 1.28 mm, 1.67 mm, 1.92 mm, 0.98 mm, and 1.03 mm, respectively) being superiorly repositioned less than was desired. The exception was PNS, which was more superiorly repositioned than desired, 1.01 mm on average (Table 4).

Table 5 presents the comparison of the mean values for groups 1 and 2. The differences between the values achieved and desired for the vertical measurements were significant for A-point, 6I, Pg, and U1 tip. The inaccuracy in reproducing the

Table 1. Comparison of cephalometric measurements of groups 1 and 2 for the pre-surgical and post-surgical tracings[a].

Cephalometric measurement	Pre-surgical[b]		*P*-value	Post-surgical[b]		*P*-value	Pre-surgical—post-surgical[c]		*P*-value
	Group 1	Group 2		Group 1	Group 2		Group 1	Group 2	
Skeletal pattern									
Facial convexity (A–NPg) (mm)	5.1 ± 4.0	0.5 ± 5.2	0.008	5.2 ± 2.1	1.2 ± 2.9	0.001	0.1 ± 0.8	0.7 ± 0.9	0.604
Maxillary depth (FH–NA) (°)	91.9 ± 2.8	89.8 ± 5.4	0.174	96.3 ± 3.5	93.2 ± 5.0	0.044	4.4 ± 0.5	3.4 ± 0.9	0.321
Facial axis (NBa–PtGn) (°)	85.6 ± 6.6	88.9 ± 6.0	0.146	90.2 ± 3.3	91.0 ± 3.6	0.542	4.6 ± 1.2	2.1 ± 1.1	0.124
Facial taper (MP–NPg) (°)	61.9 ± 6.7	58.9 ± 5.9	0.197	62.1 ± 4.5	60.1 ± 4.6	0.217	0.2 ± 0.9	1.2 ± 0.7	0.460
FMA (MP–FH) (°)	31.3 ± 6.6	31.6 ± 7.9	0.893	26.9 ± 4.7	28.0 ± 8.1	0.651	−4.4 ± 0.8	−3.6 ± 0.5	0.444
Palatal plane (PP–FH) (°)	2.6 ± 3.7	2.7 ± 4.5	0.950	2.8 ± 2.8	4.2 ± 4.8	0.312	0.2 ± 0.9	1.5 ± 0.8	0.304
Dental pattern									
U1 protrusion (U1–APg) (mm)	8.3 ± 3.3	5.7 ± 3.7	0.046	6.7 ± 1.7	5.6 ± 1.8	0.085	−1.6 ± 0.9	−0.1 ± 0.7	0.215
L1 protrusion (L1–APg) (mm)	5.4 ± 3.9	4.8 ± 3.8	0.716	3.9 ± 1.6	3.1 ± 1.6	0.129	−1.5 ± 0.8	−1.7 ± 0.8	0.732
Inter-incisal angle (U1–L1) (°)	121.6 ± 8.7	128.0 ± 7.9	0.035	124.0 ± 6.6	128.3 ± 6.4	0.072	2.3 ± 0.8	0.3 ± 1.4	0.205
U1 inclination (U1–APg) (°)	31.7 ± 8.6	24.4 ± 6.6	0.011	28.6 ± 4.2	26.6 ± 4.1	0.179	−3.1 ± 2.1	2.2 ± 1.4	0.050
L1 inclination (L1–APg) (°)	26.6 ± 5.6	27.6 ± 4.8	0.635	27.3 ± 5.3	25.0 ± 4.2	0.189	0.7 ± 1.8	−2.6 ± 1.5	0.185
Occlusal plane to FH (°)	8.9 ± 3.9	9.1 ± 4.2	0.892	6.6 ± 3.6	5.0 ± 6.6	0.418	−2.3 ± 0.8	−4.1 ± 0.9	0.160

A, A-point; N, nasion; Pg, pogonion; FH, Frankfort horizontal plane; Ba, basion; Pt, pterygomaxillary point; Gn, gnathion; MP, mandibular plane; PP, palatal plane; U1, upper incisor; L1, lower incisor.

[a] Group 1: patients received bimaxillary surgery with repositioning of the maxilla first; group 2: patients received bimaxillary surgery with the mandible operated on first. Statistical significance tested with the Student *t*-test.

[b] Mean ± standard deviation values.

[c] Mean ± standard error values.

Table 2. Comparison of horizontal and vertical planned movement of anterior nasal spine (ANS) and posterior nasal spine (PNS) for groups 1 and 2[a].

	Group 1 Mean ± SD	Group 2 Mean ± SD	*P*-value	95% CI	
				Lower bound	Upper bound
Horizontal					
ANS	2.80 ± 1.38	2.11 ± 1.83	0.236	−0.48	1.86
PNS	3.03 ± 1.39	2.40 ± 1.61	0.245	−0.45	1.72
Vertical					
ANS	−3.13 ± 1.27	−2.68 ± 1.02	0.271	−1.28	0.37
PNS	−0.34 ± 1.72	0.94 ± 1.49	0.032	−2.45	−0.12

CI, confidence interval; SD, standard deviation.

[a] Group 1: patients received bimaxillary surgery with repositioning of the maxilla first; group 2: patients received bimaxillary surgery with the mandible operated on first.

treatment plan regarding the variables A-point, 6I, and U1 tip was greater for group 2 than for group 1. The error for Pg was smaller in group 2. There were no statistically significant differences between the groups for the horizontal measurements.

Discussion

The traditional operative sequence for bimaxillary surgery consists of maxilla repositioning first, as guided by the unoperated mandible. This was the only possible sequence when osteosynthesis was done with wires, because the mandible was not stable enough to be used to guide the maxilla into its postoperative position.

With the development of methods of functionally stable osteosynthesis by means of plates and screws, the inverted surgical sequence became possible. In this technique the mandible is repositioned first, guided by the unoperated maxilla[5]. When this sequence is chosen, the surgeon has to be experienced enough to treat possible complications, such as a bad split[7]. Advancements made in the materials and techniques of stable fixation have allowed the method to become increasingly more frequently applied[3,9].

Table 3. Difference between achieved and desired horizontal and vertical values in group 1 ($n = 16$).

Axis, variable	Achieved–desired[a] Mean ± SE	95% CI		*P*-value[b]
		Lower bound	Upper bound	
Horizontal				
A-point	1.04 ± 0.56	−0.15	2.23	0.082
ANS	0.48 ± 0.80	−1.23	2.19	0.558
B-point	−0.69 ± 0.39	−1.52	0.14	0.096
L1 tip	0.10 ± 0.28	−0.51	0.70	0.746
6I occlusal	1.75 ± 0.46	0.77	2.74	0.002*
PNS	−0.12 ± 0.67	−1.54	1.30	0.861
Pg	−0.96 ± 0.59	−2.22	0.30	0.125
U1 tip	−0.34 ± 0.25	−0.89	0.21	0.203
6S occlusal	1.48 ± 0.44	0.53	2.43	0.005*
Vertical				
A-point	−0.25 ± 0.57	−1.46	0.96	0.665
ANS	−1.00 ± 0.52	−2.11	0.11	0.075
B-point	−0.57 ± 0.67	−2.00	0.85	0.365[c]
L1 tip	−1.13 ± 0.32	−1.81	−0.45	0.003*
6I occlusal	0.12 ± 0.27	−0.46	0.69	0.532[c]
PNS	1.68 ± 0.48	0.65	2.71	0.003*
Pg	2.44 ± 1.15	−0.01	4.89	0.051
U1 tip	0.08 ± 0.33	−0.62	0.78	0.823
6S occlusal	0.20 ± 0.28	−0.39	0.80	0.473

6I occlusal, lower first molar; 6S occlusal, upper first molar; ANS, anterior nasal spine; CI, confidence interval; L1 tip, lower central incisor edge; Pg, pogonion; PNS, posterior nasal spine; SE, standard error; U1 tip, upper central incisor edge.

[a] Achieved–desired = difference between achieved values and desired values. In the horizontal axis, positive values indicate advancement. In the vertical axis, positive values indicate superior repositioning.

[b] Student *t*-test; $*P < 0.05$.

[c] Non-parametric Wilcoxon test; $*P < 0.05$.

When bimaxillary surgery includes maxillary segmentation, repositioning the mandible first reduces the conventional model surgery time because only one splint is needed, since the maxilla can be repositioned directly over the operated mandible without a final splint, provided that the occlusion is stable. This allows more precise occlusal intercuspation and eliminates the risk of dislocating the maxillary segments during separation and osteosynthesis of the mandibular osteotomies[5]. Although the authors state that a final splint is not necessary, this is not the consensus and many surgeons prefer to use either a conventional or a lingual splint in such cases.

Patients who underwent correction of a vertical maxillary excess as part of their treatment plan were selected for this study, because for most purely anteroposterior movements one would expect the surgical sequence to be of less importance, except in very large discrepancies or bimaxillary advancements.

In this study, all patients were operated on using an intermediate and a final splint. A review of the literature identified only one study that reported that an intermediate splint is not necessary when the maxilla is repositioned first[10]. The ability of the surgeon to reproduce the treatment plan during surgery is very important. Precision is fundamental, independent of which jaw is repositioned first, because it will become the reference for the other jaw. Thus, a properly constructed intermediate splint is important. Care should be taken to avoid introducing bite and articulator mounting errors into the splint[9].

Precision in the conventional superimposition of tracings depends to a great extent on the precise identification of cephalometric landmarks and structures[11]. S–N superimposition is widely used and no other method has been shown to offer better precision. With the software used in this study, attempting to superimpose the anatomical tracings on sella turcica and the frontonasal region would be very inaccurate, because they correspond to a drawing made by the software. Thus, points S and N were used and the software applied a coordinate x and y system, with the axes intersecting with the origin at S.

Comparison of the predictive tracings from both study groups showed that there was no significant difference in the planned surgical repositioning between the groups. For both groups, the correspondence between the planned and postoperative repositioning was also within acceptable limits. The groups were thus homogeneous and comparable. All studies

Table 4. Difference between achieved and desired horizontal and vertical values in group 2 (*n* = 16).

Axis, variable	Achieved–desired[a] Mean ± SE	95% CI Lower bound	95% CI Upper bound	*P*-value[b]
Horizontal				
A-point	0.03 ± 0.63	−1.31	1.37	0.756[c]
ANS	0.46 ± 1.19	−2.08	2.99	0.485[c]
B-point	−1.70 ± 0.41	−2.56	−0.83	0.001*
L1 tip	−0.52 ± 0.29	−1.14	0.10	0.096
6I occlusal	0.73 ± 0.55	−0.45	1.91	0.209
PNS	−0.20 ± 0.62	−1.53	1.13	0.753
Pg	−2.23 ± 0.53	−3.36	−1.09	0.001*
U1 tip	−0.81 ± 0.19	−1.21	−0.39	0.001*
6S occlusal	0.47 ± 0.54	−0.69	1.64	0.398
Vertical				
A-point	−2.12 ± 0.46	−3.10	−1.14	<0.001*
ANS	−1.28 ± 0.43	−2.19	−0.37	0.009*
B-point	−1.67 ± 0.56	−2.85	−0.48	0.010[c]*
L1 tip	−1.92 ± 0.36	−2.70	−1.14	<0.001*
6I occlusal	−0.98 ± 0.30	−1.63	−0.33	0.006*
PNS	1.01 ± 0.42	0.12	1.90	0.029*
Pg	−0.62 ± 0.95	−2.65	1.41	0.526
U1 tip	−1.03 ± 0.34	−1.76	−0.32	0.008*
6S occlusal	−0.53 ± 0.29	−1.16	0.09	0.091

6I occlusal, lower first molar; 6S occlusal, upper first molar; ANS, anterior nasal spine; CI, confidence interval; L1 tip, lower central incisor edge; Pg, pogonion; PNS, posterior nasal spine; SE, standard error; U1 tip, upper central incisor edge.

[a] Achieved–desired = difference between achieved values and desired values. In the horizontal axis, positive values indicate advancement. In the vertical axis, positive values indicate superior repositioning.

[b] Student *t*-test; *$P < 0.05$.

[c] Non-parametric Wilcoxon test; *$P < 0.05$.

that have used the mandible to reposition the maxilla and have reported the use of an external reference, have described a vertical inaccuracy ranging from 0.5 mm to 1.0 mm on average. For the horizontal axis, an imprecision of 2.0 mm is described. This is attributed to differences in relation to the true centre of mandibular rotation or to the condylar position, which guides the postoperative position of the maxilla[9].

Table 5. Prediction discrepancies between groups 1 and 2.

Axis, variable	Difference between group 1 and group 2 Mean ± SE	95% CI Lower bound	95% CI Upper bound	*P*-value[a]
Horizontal				
A-point	1.01 ± 0.84	−0.71	2.73	0.097[b]
ANS	0.02 ± 1.43	−2.90	2.96	0.970[b]
B-point	1.01 ± 0.56	−0.14	2.15	0.084
L1 tip	0.61 ± 0.40	−0.22	1.44	0.143
6I occlusal	1.02 ± 0.72	−0.45	2.50	0.167
PNS	0.08 ± 0.91	−1.78	1.94	0.930
Pg	1.27 ± 0.80	−0.36	2.89	0.122
U1 tip	0.46 ± 0.32	−0.19	1.12	0.161
6S occlusal	1.00 ± 0.70	−0.43	2.44	0.164
Vertical				
A-point	1.87 ± 0.73	0.38	3.36	0.016*
ANS	0.28 ± 0.67	−1.09	1.65	0.679
B-point	1.10 ± 0.87	−0.68	2.88	0.181[b]
L1 tip	0.79 ± 0.48	−0.20	1.78	0.113
6I occlusal	1.10 ± 0.41	0.27	1.93	0.015[b]*
PNS	0.67 ± 0.64	−0.64	1.97	0.304
Pg	3.06 ± 1.49	0.01	6.11	0.049*
U1 tip	1.11 ± 0.47	0.15	2.07	0.025*
6S occlusal	0.74 ± 0.40	−0.09	1.56	0.079

6I occlusal, lower first molar; 6S occlusal, upper first molar; ANS, anterior nasal spine; CI, confidence interval; L1 tip, lower central incisor edge; Pg, pogonion; PNS, posterior nasal spine; SE, standard error; U1 tip, upper central incisor edge.

[a] Student *t*-test; *$P < 0.05$.

[b] Non-parametric Mann–Whitney test; *$P < 0.05$.

The number of cephalometric landmarks that presented statistically significant differences between the prediction tracing and the actual result was greater when surgery was performed by operating on the mandible first. It should be pointed out that in group 1, pogonion was more posteriorly positioned than planned. In group 2, ANS, A-point, and U1 tip were more inferiorly positioned than planned. PNS presented a more superior position than planned in both groups.

When the groups were compared, the difference in relation to the treatment plan was greater when surgery was initiated by mandible repositioning (group 2) for A-point and the upper incisor edge (U1 tip). When the procedure was initiated by maxillary repositioning (group 1), the difference was greater in relation to the vertical position of Pg. Since several patients in both groups had a genioplasty, this may have influenced this result.

In this sample, an external reference was used during surgery in both groups of patients. This enhances the accuracy of the vertical maxillary repositioning[12]. Some inaccuracy may occur during the mounting of models, model surgery, or due to an inability to reproduce the treatment plan during surgery. However, the external reference provides greater precision for vertical repositioning of the maxilla than intraoral references, and it is an important tool for both surgical sequences. From the aesthetic standpoint, accurate vertical repositioning of the maxilla is essential. The external reference allows the compensation of small errors in vertical planning or repositioning.

The vertical position of the posterior maxilla is theoretically determined by the seating of the mandibular condyles in the articular fossa, with occlusion guided by the intermediate or final splint, according to the surgical sequence. This is less precise than the external reference for repositioning the anterior maxilla. Independent of the planning, the vertical position of the upper incisors is the most important feature, because it defines aesthetics with regard to repose and smile. From this standpoint, repositioning the maxilla first reproduced the treatment plan for incisor exposure more accurately in the studied sample.

It has been reported previously in the literature that, if the centric occlusion registration is not correct, the patient will slip into a different mandibular position during general anaesthesia. In this case, if the surgery is to be started with maxillary repositioning, there will be errors in the position of the maxilla. If the surgery is initiated with mandibular repositioning, such imprecision may be avoided.

This reveals an important detail. In the case of isolated maxillary procedures, or in bimaxillary procedures, where the maxilla is to be repositioned first, the maxillomandibular relationship should be verified and compared to the articulator. If the mandibular position has changed and duplicate models are available, a new intermediate splint could be produced to invert the surgical sequence and reposition the mandible first. If there are no duplicate models, the procedure may have to be aborted[7]. If the maxilla is mounted in the wrong position, it also cannot be used to position the mandible first. In that case, measurements would have to be transferred directly to the articulator for planning of the new mandibular position[13].

The maxillary repositioning is extremely precise, but the sagittal split osteotomy condylar repositioning is not. According to some authors, initiating the surgery by maxillary repositioning could perpetuate the inherent error of the sagittal osteotomy. On the other hand, if the mandible is operated on first, some imprecision could be compensated for by the maxillary surgery and thus this would be a more logical and preferable sequence[14]. For instance, 1 mm of error in mandibular repositioning can create a malocclusion. However, if the mandible is repositioned first, the error can be compensated for by maxillary surgery to obtain the appropriate occlusion[16]. Small imprecision (1 mm or less), even in the upper incisor region, is not a significant clinical problem, but a 1-mm malocclusion can be problematic[7].

This refers to malocclusions resulting from small errors in condylar position that are imperceptible during surgery and usually fail to be corrected even redoing the osteosynthesis. This line of thought disregards the fact that such small errors can be corrected by postoperative orthodontics. On the other hand, if the compensation through maxillary repositioning creates a 1-mm deviation of the midline, this will be a significant problem. Errors in condylar position may occur in both surgical sequences and result in malocclusion. If that was not the case, isolated maxillary surgery would never present an inadequate postoperative occlusion, which sometimes happens.

Selective manipulation of the occlusal plane is an important tool for functional and mainly for aesthetic enhancement. When the intention is to increase the occlusal plane angle, it is usually easier to reposition the maxilla first, creating a posterior open bite to facilitate mandibular repositioning. When the plan is to reduce the occlusal plane angle by lowering the posterior maxilla, it is easier to reposition the mandible first, creating space to reposition the maxilla. This avoids producing a large anterior open bite and a thick splint after the maxillary repositioning[15].

The decision regarding the surgical sequence depends on the confidence of the surgeon to be able to reposition the maxilla or the mandible with greater precision. It is largely a matter of personal preference[16]. Both sequences produce similar results in the vast majority of cases. The excellent article by Perez and Ellis discusses the situations in which it is advantageous to start the procedure with the mandible: when the posterior maxilla is to be inferiorly repositioned, when there is doubt about the registration of centric occlusion, when the intermediate repositioning makes intermaxillary fixation difficult, if the quality of the osteosynthesis is questionable, and if temporomandibular joint surgery is to be done in the same procedure[7].

A new variable is the possibility of virtual planning, eliminating the use of the articulator. Some error factors are avoided, but the correct occlusal registration is still necessary. Thus, the most rational attitude is to choose the surgical sequence according to the needs of the patient and treatment plan.

In conclusion, the following results were found in this sample of patients: (1) although either surgical sequence can be used, repositioning of the mandible first was less precise than operating on the maxilla first; (2) the classical sequence, repositioning the maxilla first, allowed better accuracy in the vertical position of A-point and the upper incisor edge; and (3) initiating surgery by mandibular repositioning was more accurate in relation to the vertical position of pogonion.

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Competing interests

No conflict of interest.

Ethical approval

This study obtained approval from the Ethics Committee of Araraquara Dental School, São Paulo State University – UNESP.

Patient consent

Informed consent was obtained from each patient to participate in this follow-up study and for the use of their medical records.

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