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# Soft and hard tissue changes in skeletal Class III patients treated with double-jaw orthognathic surgery—maxillary advancement and mandibular setback

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*Abstract.* The soft tissues of the facial profile may change after skeletal movement in orthognathic surgery. The aim of this study was to evaluate and compare the differences and correlation between hard and soft tissues after double-jaw surgery in skeletal Class III subjects. Radiographs from the following time points were assessed using Dolphin Imaging software: preoperative (T0), 2–4 months postoperative (T1), and 6–12 months postoperative (T2). Eleven hard and soft tissue points of the facial profile were evaluated. The Student's *t*-test was used to assess the significance of differences between the time intervals; Pearson's correlation coefficient was used to assess the significance of correlation existing between these points; significance was set at $P < 0.05$. In the sample of 58 subjects, the correlation between hard and soft tissues in the mandible was greater than in the maxilla. Similarly, the correlations only between hard tissues and only between soft tissues presented a greater correlation in the mandible. The results are similar to those found in studies on single-jaw surgery for both the maxilla and the mandible. The influence of movements in hard tissues was restricted to the soft tissues of the same jaw, although there were exceptions.

Key words: face; facial bones; orthognathic surgery; maxillofacial surgery..

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Every treatment plan for orthognathic surgery should take into consideration the functional and aesthetic results and also psychological aspects of the patient. Facial aesthetics has an increasingly relevant role in modern society, and the patient's perception of their facial profile may influence their submission or not to the surgical procedure.[1–5]

In 1993, Arnett and Bergman[6] presented a three-dimensional organized

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analysis of the facial structures, which would later be related to the cephalometry of the soft tissues for diagnosis and treatment planning.

Soft tissue cephalometry enables an evaluation of relationships between objective measurements of important structures. It comprises a method for quantifying facial disharmony and identifying its causes.[7] The true vertical line (TVL) is a vertical line passing through the point subnasale, perpendicular to the horizontal plane of the natural head position (NHP; natural head position assumed when the patient is standing with arms relaxed along the body and looking at the horizon). According to Arnett and Gunson,[7] when landmarks in the skull base are used as a reference line for measuring the profile, erroneous findings may be generated, as the landmarks in the skull base may vary as much as the facial and dental structures measured through it. Thus the TVL is used for assessing the profile because it demonstrates a greater accuracy in relation to intracranial references.

The aim of orthognathic surgery is often aesthetic, in addition to the facial improvement of the occlusion. Therefore, predicting changes in the facial soft tissues after orthognathic surgery is extremely important.[8,9] Changes in the facial profile in hard and soft tissues have been reported in the literature,[8,10–15] and studies assessing these changes in double-jaw surgery are scarcer than those assessing only maxillary or only mandibular surgery. The use of proportions of movement between hard and soft tissues instead of absolute measures is frequent and eliminates the effect of height differences between men and women.[16] However, as Joss et al.[17] remark in their systematic review on the relationship between soft and hard tissues in mandibular setback, many studies have presented the proportion of movement between hard and soft tissues, but are lacking in the exact identification of which hard tissue points are actually correlated to which soft tissue points.

The purpose of this study was to evaluate the changes in the facial profile after skeletal movements in skeletal Class III subjects who underwent double-jaw surgery (maxillary advancement and mandibular setback). The hypothesis of the present study was that skeletal changes (changes in hard tissue points) may affect and are correlated to changes in the soft tissues of the facial profile at different points. The specific aims of this study were as follows: (1) to evaluate the significance of differences between the preoperative and postoperative periods and between two different postoperative periods for each measurement analyzed; (2) to evaluate the significance of the correlation and proportion of movements between hard tissue points and soft tissue points in the short and medium term; and (3) to evaluate the significance of correlation and proportion of movements only between hard tissue points, and (4) only between soft tissue points in the short and medium term.

## Materials and methods

This study was conducted in a similar manner to the study of Becker et al.,[18] in which radiographs taken 1 week before surgery, between 2 and 4 months after surgery, and between 6 and 12 months after surgery (T0, T1, and T2, respectively) were evaluated. These were cephalometric radiographs of a sample of nonconsecutive skeletal Class III subjects who underwent maxillary advancement and mandibular setback. All patients selected were treated in the same way with regard to preoperative, perioperative, and postoperative care. Under general anaesthesia, a Le Fort I osteotomy was performed to allow maxillary movement, and a bilateral sagittal osteotomy of the mandibular ramus was performed to allow mandibular movement. Rigid internal fixation was performed with titanium plates from the same manufacturer; four 'L' miniplates were used in the maxilla and one miniplate and one bicortical screw on each side of the mandible of the 2.0 Neoface System miniplate (Neoortho, Curitiba, Paraná, Brazil). The movements of the double-jaw orthognathic surgery were mainly horizontal. The vertical movements were smaller than 3 mm in all cases.

Patients previously treated for maxillofacial deformities by other types of orthognathic surgery (single-jaw surgery, other types of fixation, vertical movement greater than 3 mm) were excluded from the sample, as well as patients who suffered facial trauma or who had other systemic diseases or syndromes. Some patients had incomplete records or X-ray records outside the time ranges necessary for this study. These patients were also excluded from the sample.

Radiographs were taken with a standard length marker of 50.0 mm using a PM 2002 CC Proline panoramic imaging unit (Planmeca, Helsinki, Finland). They were digitalized using an HP ScanJet G4050 scanner (Hewlett-Packard Co., Palo Alto, CA, USA) and afterwards imported into Dolphin Imaging 3D v. 11.5 software (Dolphin Imaging Software, Canoga Park, CA, USA). Cephalometric tracings and measurements of the distances between specific cephalometric points were done with images totally calibrated by Dolphin Imaging 11.5. At this time, the top-most and the bottom-most graduation points were marked on the head-holder nosepiece ruler.

Based on the cephalometric soft tissue points described by Arnett et al.,[19] a customized cephalometric analysis was created and then selected in the software for evaluation of the desired measurements. Eleven points (in both hard and soft tissue) were assessed in relation to the TVL, which is a line perpendicular to the horizontal plane of the NHP passing through the subnasale area (Fig. 1). The distance between the TVL and the head-holder nosepiece ruler image set at T0 was established to be the same at T1 and T2 for every subject, and checked by superimposition to ensure that the TVL did not move if the subnasale area changed after surgery.

SPSS v. 18.0 statistical software (SPSS Inc., Chicago, IL, USA) run on the Microsoft Windows operational system was used for the processing and analysis of data.

The level of significance was set at 5%, in which the values of $P < 0.05$ reject the null hypothesis that there is no difference or significant correlation for each measurement analyzed between the preoperative and postoperative periods and between the two postoperative periods.

The Student's *t*-test for paired samples was used in order to assess the presence of significant differences between the preoperative and postoperative periods (T0 with T1, and T0 with T2) and, to evaluate relapse, the differences between the two postoperative periods (T1 with T2).

Pearson's correlation coefficient was used to assess the existing significant correlation in changes in hard tissue and soft tissue points between the preoperative and postoperative time intervals (T1–T0 and T2–T0), and between the two postoperative time intervals (T2–T1). These tests were used for every measurement.

A single examiner performed all the tracings. Ten percent of tracings were repeated after 2 months by the same examiner and by a more experienced examiner (gold standard). The intraclass correlation coefficient was used to evaluate the intra- and inter-examiner agreements, and the non-parametric Kolmogorov–Smirnov test was used to assess the normality of data.

## Results

A strong intra- and inter-examiner agreement was found (intraclass correlation

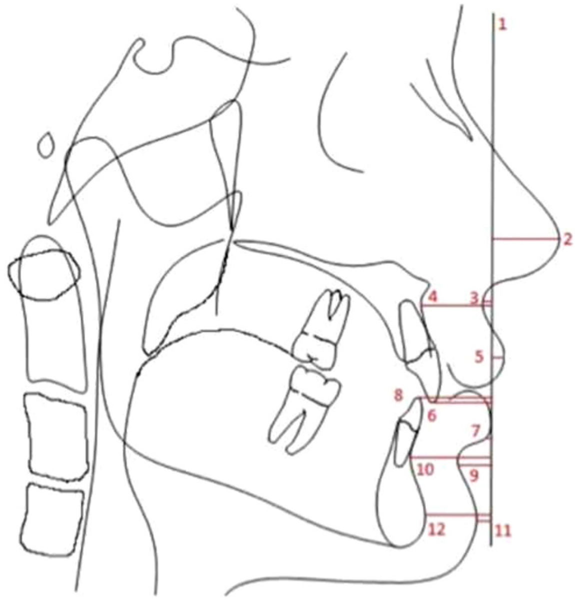


*Fig. 1.* Cephalometric points of hard and soft tissues and distances to be measured between them and the true vertical line (TVL): 1, TVL; 2, nasal projection (nasal point); 3, A′ (point A of soft tissue); 4, A (point A of hard tissue); 5, upper lip (most anterior point of upper lip); 6, upper incisor (most incisal point of the upper incisor crown); 7, lower lip (most anterior point of the lower lip); 8, lower incisor (most incisal point of the lower incisor crown); 9, B′ (point B of soft tissue); 10, B (point B of hard tissue); 11, Pog′ (soft pogonion); 12, Pog (hard pogonion).

coefficient over 0.900 for both situations for every point assessed).

Lateral cephalometric radiographs were evaluated at T0 (1 week before surgery), at T1 (between 2 and 4 months after surgery, with a mean of 2.8 months), and at T2 (between 6 and 12 months after surgery, with a mean of 9.3 months). A total of 58 skeletal Class III patients submitted to maxillary advancement and mandibular setback constituted the sample. Of these, 38 were women and 20 men. The average age was 27.3 years (range 18–48 years). The average maxillary advancement at point A was 1.5 mm, with a standard deviation of 1.0 mm (range 0.2–6.1 mm) and the average mandibular setback at point B was 7.2 mm, with a standard deviation of 4.2 mm (range 0.9–18.1 mm).

Table 1 shows the minimum and maximum values and the mean and standard deviation obtained in millimetres for each of the points evaluated in relation to the TVL for T0, T1, and T2. Positive values indicate a position in front of the TVL and negative values, a posterior position.

Table 2 presents the range of movement and the mean and standard deviation between two periods for every point, for T1–T0, T2–T0, and T2–T1, and the results of the Student's *t*-test for paired samples.

The correlations between movements presented by soft tissue points in relation to the movements presented by hard tissue points between T1 and T0, T2 and T0, and T2 and T1, assessed through the Pearson correlation coefficient, are displayed in Tables 3–5, respectively. For the points in which significance in correlation was observed, the explained variance (indicated by $r^2$) indicates the extent to which the variance of one of the points was explained by the variance of the other point, i.e., the degree in which the movement between the points was explained only through the relationship between themselves, disregarding the influence of other points within these values. The value of the explained variance ($r^2$) was adjusted to estimate the value extrapolated for the population. The proportion of movement of soft tissues in relation to hard tissues was registered for the points that presented a significant correlation.

Correlation was also found in movements presented between only hard tissue points and only soft tissue points, between T1 and T0, T2 and T0, and T2 and T1. These correlations are shown in Table 6.

## Discussion

While significant advances have been made with regard to the predictability of orthognathic surgery in its osseous aspect and in relation to surgical stability, the same does not hold true for soft tissue predictability.[9,20] This study assessed the changes in the facial profile after skeletal movements observed in skeletal Class III subjects who underwent double-jaw surgery (maxillary advancement and mandibular setback). The aim of this study was to evaluate significant differences between preoperative and postoperative periods and between two postoperative periods

*Table 1.* Minimum, maximum, mean, and standard deviation in millimetres of the measures evaluated for T0 (preoperative), T1 (2–4 month postoperative), and T2 (6–12 months postoperative) between the lower points and the true vertical line (TVL).

| | T0 | | T1 | | T2 | |
|---|---|---|---|---|---|---|
| | Min/Max | Mean ± SD | Min/Max | Mean ± SD | Min/Max | Mean ± SD |
| Nasal projection | 10.5/23.3 | 16.5 ± 2.3 | 7.8/20.9 | 15.0 ± 2.3 | 8.9/21.5 | 15.2 ± 2.2 |
| A′ | −8.4/0.6 | −2.3 ± 1.6 | −7.4/2.3 | −1.3 ± 1.6 | −6.9/3.1 | −1.2 ± 1.5 |
| A | −31.6/−12.9 | −18.5 ± 3.2 | −30.4/−12.8 | −17.0 ± 3.1 | −28.4/−12.8 | −16.9 ± 2.9 |
| Upper lip | −4.4/8.2 | 1.6 ± 2.1 | −1.3/9.2 | 2.8 ± 2.0 | −0.7/9.7 | 3.0 ± 2.0 |
| Upper incisor | −23.7/−5.1 | −12.8 ± 4.3 | −21.9/−3.3 | −11.0 ± 4.2 | −20.7/−2.0 | −10.9 ± 4.1 |
| Lower lip | −5.7/27.6 | 6.7 ± 5.1 | −10.0/11.6 | 1.1 ± 4.0 | −10.7/13.7 | 1.5 ± 4.2 |
| Lower incisor | −19.4/10.3 | −7.2 ± 5.6 | −28.0/−6.3 | −14.9 ± 4.7 | −24.2/−4.9 | −14.3 ± 4.5 |
| B′ | −17.4/17.8 | 0.5 ± 6.4 | −20.6/7.8 | −5.8 ± 5.5 | −21.5/7.3 | −5.8 ± 5.4 |
| B | −30.3/3.5 | −11.7 ± 6.8 | −38.1/−7.1 | −18.9 ± 6.2 | −39.3/−8.2 | −18.8 ± 6.2 |
| Pog′ | −16.3/19.7 | 4.5 ± 7.5 | −18.3/9.4 | −2.2 ± 6.6 | −18.5/9.0 | −2.0 ± 6.5 |
| Pog | −29.9/12.3 | −7.9 ± 8.5 | −31.9/−1.0 | −15.6 ± 7.3 | −31.8/−1.5 | −15.3 ± 7.2 |

Min, minimum; Max, maximum; SD, standard deviation; A′, point A of soft tissue; A, point A of hard tissue; B′, point B of soft tissue; B, point B of hard tissue; Pog′, soft pogonion; Pog, hard pogonion.

*Table 2*. Range, mean, and standard deviation in millimetres of changes that occurred during the movements between T1 and T0, T2 and T0, and T2 and T1 for lower points evaluated in relation to the true vertical line (TVL).

| | T1–T0 | | T2–T0 | | T2–T1 | |
|---|---|---|---|---|---|---|
| | Range | Mean ± SD | Range | Mean ± SD | Range | Mean ± SD |
| Nasal projection | −4.2/0.4 | −1.5 ± 0.9[c] | −4.7/0.3 | −1.3 ± 0.8[c] | −2.0/1.2 | 0.2 ± 0.6[b] |
| A′ | 0.0/5.9 | 1.1 ± 0.8[c] | 0.0/6.0 | 1.1 ± 0.8[c] | −0.8/0.8 | 0.0 ± 0.4 NS |
| A | 0.1/6.5 | 1.5 ± 1.0[c] | 0.1/6.1 | 1.6 ± 1.1[c] | −1.1/2.0 | 0.1 ± 0.7 NS |
| Upper lip | −0.2/3.7 | 1.2 ± 0.7[c] | 0.0/3.7 | 1.4 ± 0.8[c] | −1.3/1.7 | 0.1 ± 0.6 NS |
| Upper incisor | 0.2/4.1 | 1.8 ± 1.0[c] | 0.0/4.8 | 2.0 ± 1.0[c] | −1.6/3.0 | 0.2 ± 0.8 NS |
| Lower lip | −16.9/−0.2 | −5.6 ± 3.2[c] | −13.9/−0.3 | −5.3 ± 3.0[c] | −1.7/3.0 | 0.4 ± 0.9[b] |
| Lower incisor | −20.5/−0.2 | −7.7 ± 4.2[c] | −16.7/−0.2 | −7.0 ± 3.9[c] | −1.2/3.8 | 0.6 ± 1.0[c] |
| B′ | −16.1/−0.4 | −6.3 ± 3.9[c] | −15.1/−0.5 | −6.3 ± 3.7[c] | −1.6/2.0 | −0.0 ± 0.8 NS |
| B | −18.1/−0.9 | −7.2 ± 4.2[c] | −17.5/−0.5 | −7.2 ± 4.0[c] | −1.7/2.0 | 0.1 ± 0.8 NS |
| Pog′ | −15.7/−0.2 | −6.7 ± 4.1[c] | −16.1/−0.3 | −6.4 ± 4.0[c] | −1.3/3.1 | 0.2 ± 0.8[a] |
| Pog | −19.7/0.8 | −7.7 ± 4.9[c] | −19.7/1.8 | −7.4 ± 4.7[c] | −2.3/2.6 | 0.4 ± 0.9[b] |

SD, standard deviation; NS, non-significant difference; A′, point A of soft tissue; A, point A of hard tissue; B′, point B of soft tissue; B, point B of hard tissue; Pog′, soft pogonion; Pog, hard pogonion.
[a] Significant difference at $P < 0.05$.
[b] Significant difference at $P < 0.01$.
[c] Significant difference at $P < 0.001$.

for each measurement analyzed, to evaluate significant correlations and proportions between hard tissue points and soft tissue points, and also only between hard tissue points and only between soft tissue points (which have not been identified in other works) in the short and medium term.

According to Eggensperger et al.,[21] changes in the hard tissue – soft tissue relationship were first registered by McNeill et al.[22] The difficulty in predicting the postoperative profile is due to differences in changes between hard tissues and facial soft tissues.

The response of the facial soft tissues after orthognathic surgery may be influenced by various factors, such as the degree of deformity, soft tissue thickness, and musculature tonicity.[8,17,23,24] The thicker the soft tissues are, the greater the tendency to absorb the movement created by the hard tissue, i.e., the tissue tends to reflect the movement occurring in the hard tissue less.[17,25,26]

Variations in the proportion of movement between soft and hard tissues have been reported. This variation is understandable when the various presurgical factors (mentioned above) are taken into consideration, as well as the perioperative factors, such as degree of dissection, oedema or haematoma, quantities of osseous reshaping (resection of the nasal spine or osseous graft), and incision suture (V–Y technique), and the postoperative factors, such as a high degree of osseous absorption, relapse, scar formation and tissue contraction, infection, postoperative orthodontia, and surgical stability.[17,26] Presurgical variables cannot be controlled, however some perioperative and postoperative variables may be controlled to obtain more predictable results.[26]

According to Louis et al.,[26] Sforza et al.,[27,28] and Joss et al.,[17] the aesthetic evaluation should be performed at least 6 months after surgery to obtain reliable proportions of soft and hard tissues, due to oedema. In this study, comparisons were performed at 2–4 months after surgery (mean 2.8 months) (T1), but also at 6–12 months after surgery (mean 9.3 months) (T2) in order to evaluate the

*Table 3*. Correlation and proportion of movements assessed between T1 (2–4 months postoperative) and T0 (preoperative), between points in soft tissue and points in hard tissue in relation to the true vertical line (TVL).[a]

| T1–T0 | Nasal projection | A′ | Upper lip | Lower lip | B′ | Pog′ |
|---|---|---|---|---|---|---|
| (A:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | [d] | NS | NS | NS | NS |
| $r^2$ | – | 35.9% | – | – | – | – |
| Proportion | – | 0.70 | – | – | – | – |
| (**Upper incisor**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | NS | [c] | NS | NS | NS |
| $r^2$ | – | – | 13.1% | – | – | – |
| Proportion | – | – | 0.67 | – | – | – |
| (**Lower incisor**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | [b] | NS | NS | [d] | [d] | [d] |
| $r^2$ | 5.4% | – | – | 61.5% | 68.1% | 49.8% |
| Proportion | 0.19 | – | – | 0.73 | 0.81 | 0.86 |
| (**B**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | [c] | NS | NS | [d] | [d] | [d] |
| $r^2$ | 10.6% | – | – | 50.6% | 82.6% | 77.4% |
| Proportion | 0.20 | – | – | 0.77 | 0.87 | 0.92 |
| (**Pog**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | [c] | NS | NS | [d] | [d] | [d] |
| $r^2$ | 13.7% | – | – | 34.5% | 63.0% | 86.6% |
| Proportion | 0.19 | – | – | 0.72 | 0.81 | 0.86 |

NS, non-significant difference; Sig., significance level; A′, point A of soft tissue; A, point A of hard tissue; B′, point B of soft tissue; B, point B of hard tissue; Pog′, soft pogonion; Pog, hard pogonion.
[a] Pearson's correlation; adjusted $r^2$ is the explained variance, adjusted for the population. Proportion is the movement proportion soft tissue–hard tissue.
[b] Significant difference at $P < 0.05$.
[c] Significant difference at $P < 0.01$.
[d] Significant difference at $P < 0.001$.

*Table 4.* Correlation and proportion of movements assessed between T2 (6–12 months post-operative) and T0 (preoperative), between points in soft tissue and point in hard tissue in relation to the true vertical line (TVL).[a]

| T2–T0 | Nasal projection | A′ | Upper lip | Lower lip | B′ | Pog′ |
|---|---|---|---|---|---|---|
| (A:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | [d] | NS | NS | NS | NS |
| $r^2$ | – | 41.9% | – | – | – | – |
| Proportion | – | 0.66 | – | – | – | – |
| (**Upper incisor**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | NS | [c] | NS | NS | NS |
| $r^2$ | – | – | 42.7% | – | – | – |
| Proportion | – | – | 0.69 | – | – | – |
| (**Lower incisor**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | NS | NS | [d] | [d] | [d] |
| $r^2$ | – | – | – | 61.7% | 73.7% | 59.7% |
| Proportion | – | – | – | 0.74 | 0.89 | 0.91 |
| (**B**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | NS | NS | [d] | [d] | [d] |
| $r^2$ | – | – | – | 54.4% | 86.1% | 81.5% |
| Proportion | – | – | – | 0.73 | 0.88 | 0.89 |
| (**Pog**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | [a] | NS | NS | [d] | [d] | [d] |
| $r^2$ | 9.6% | – | – | 34.7% | 68.6% | 86.9% |
| Proportion | 0.17 | – | – | 0.71 | 0.86 | 0.87 |

NS, non-significant difference; Sig., significance level; A′, point A of soft tissue; A, point A of hard tissue; B′, point B of soft tissue; B, point B of hard tissue; Pog′, soft pogonion; Pog, hard pogonion.

[a] Pearson's correlation; adjusted $r^2$ is the explained variance, adjusted for the population. Proportion is the movement proportion soft tissue–hard tissue.

[b] Significant difference at $P < 0.05$.

[c] Significant difference at $P < 0.01$.

[d] Significant difference at $P < 0.001$.

changes due mainly to residual oedema absorption.

The relationships in the proportions of movement between hard and soft tissue have been presented throughout the years by numerous authors[10–15]; however, strong correlations are more often discovered in the mandible than in the maxilla and in the horizontal than in the vertical direction.[9] In the work of Chew et al.,[29] this relationship was found to occur in a linear manner between upper incisor and upper lip, but in a non-linear manner in the subnasale region. Louis et al.[26] found a small correlation between soft and hard tissues for maxilla movements and reported a great variability in the proportions of movement between hard and soft tissues in the literature, even in studies that controlled vertical movements in the maxilla. Also in the current study, stronger correlations were found in the mandible than in the maxilla. In the maxilla, a correlation between upper incisor and upper lip ($P < 0.01$) and between A and A′ ($P < 0.001$) were accurately identified both in T1–T0 and in T2–T0. In T2–T1 (relapse) this correlation was not present, probably due to the small degree of relapse in both hard and soft tissue points in the maxilla. The explained variance ($r^2$) for the relationship between A and A′ was between 35.9% (T1–T0) and 41.9% (T2–T0), and between the upper incisor and upper lip was between 13.1% (T1–T0) and 42.7% (T2–T0), indicating the extent of the relationship between the movements of the two points without interference of other factors. In other words, in T1–T0, the movement suffered by A′ was 35.9% exclusively due to the movement suffered by A, and the movement suffered by upper lip was only 13.1% (lower relationship) exclusively due to the movement suffered by upper incisor. In the same manner, in T2–T0, the movement suffered by A′ was 41.9% exclusively due to the movement suffered by A, and the movement suffered by upper lip was 42.7% exclusively due to the movement suffered by upper incisor. The rest of these soft tissue movements were due to others factors, for example due to movements in other hard tissue points, in other soft tissue points, or even so due to soft tissue accommodation in the soft tissue point evaluated.

Previous studies have shown a proportion of movement between soft and hard tissues in the maxilla of 33–60% when the V–Y closure technique is not employed, and of 90–100% when it is employed, although these studies did not take into consideration the long-term effects and postoperative orthodontic treatment.[26] For example, Stella et al.[25] found a relationship of 46% between soft and hard tissues at the level of the A point without the V–Y closure technique; and Louis et al.[26] found a relationship of 80% between upper lip and upper incisor with the V–Y closure technique. For the relationship between A′ and A, and between upper lip and upper incisor, this study identified respective proportions of 70% and 67% (T1–T0) and 66% and 69% (T2–T0). The V–Y closure technique was used in all the cases in this study. In contrast, for retraction of the maxilla (the opposite movement), Park and Hwang[20] found a value of 67% for the upper lip and upper incisor proportion and reported the values found by other authors: Lines and Steinhauser,[10] 50%; Lew et al.,[30] 43%. Nadkarni[23] found a value of 33% for this proportion.

The anterior nasal spine may be an important component in the projection of the nasal tip; therefore leaving it intact during surgery may result in a greater projection of the nasal tip. However, some authors have reported that the presence or absence of the nasal spine shows no significant relationship with alterations found in the nasal morphology.[9] In this study the anterior nasal spine was removed in all the cases perioperatively. This probably determined the lower values of nasal projection in T2 and T1 than in T0. The correlation identified between nasal projection and lower incisor, B, and Pog (in T1–T0) and nasal projection and Pog (in T2–T0 and T2–T1) is probably due to the mandible movement in the posterior direction having the same negative value as the diminution presented in values of nasal projection in T1 and T2 due to nasal spine removal. However, it is clinically difficult to establish a cause and effect relationship between mandible points and the nasal tip. The correlation between nasal projection and upper incisor in T2–T1 seems to be established based on the degree of relapse presented by the nasal tip position (nasal projection) in this period.

For Chew et al.[29] and Joss et al.,[17] the linear relationship between hard and soft tissue was stronger in the mentum region in Pog and Pog′, i.e., for this point, regardless of the degree of movement in osseous tissue, the soft tissue movement always

*Table 5*. Correlation and proportion of movements assessed between T2 (6–12 months postoperative) and T1 (2–4 months postoperative), between points in soft tissue and points in hard tissue in relation to the true vertical line (TVL).[a]

| T2–T1 | Nasal projection | A′ | Upper lip | Lower lip | B′ | Pog′ |
|---|---|---|---|---|---|---|
| (A:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | NS | NS | NS | NS | NS |
| $r^2$ | – | – | – | – | – | – |
| Proportion | – | – | – | – | – | – |
| (**Upper incisor**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | [a] | NS | NS | NS | NS | NS |
| $r^2$ | 5.6% | – | – | – | – | – |
| Proportion | 1.33 | – | – | – | – | – |
| (**Lower incisor**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | NS | NS | [c] | NS | NS |
| $r^2$ | – | – | – | 13.9% | – | – |
| Proportion | – | – | – | 0.56 | – | – |
| (**B**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | NS | [a] | NS | NS | [d] | NS |
| $r^2$ | – | 6.2% | – | – | 86.1% | – |
| Proportion | – | 0.16 | – | – | −0.50 | – |
| (**Pog**:) | | | | | | |
| Correlation | | | | | | |
| Sig. | [a] | NS | [c] | NS | NS | [d] |
| $r^2$ | 9.0% | – | 10.1% | – | – | 86.9% |
| Proportion | 0.57 | – | 0.40 | – | – | 0.68 |

NS, non-significant difference; Sig., significance level; A′, point A of soft tissue; A, point A of hard tissue; B′, point B of soft tissue; B, point B of hard tissue; Pog′, soft pogonion; Pog, hard pogonion.

[a] Pearson's correlation; adjusted $r^2$ is the explained variance, adjusted for the population. Proportion is the movement proportion soft tissue–hard tissue.

[b] Significant difference at $P < 0.05$.

[c] Significant difference at $P < 0.01$.

[d] Significant difference at $P < 0.001$.

occurred in the same proportion. The correlation found between hard and soft tissues in the mandible in this study is extremely strong. In T1–T0 and T2–T0 the three hard tissue points, lower incisor, B, and Pog, and the three soft tissue points, lower lip, B′, and Pog′, all presented strong correlations between them ($P < 0.001$), with proportions ranging between 71% and 92%. Explained variance ($r^2$) for the relationship between these points ranged from 34.5% to 86.9% and indicates the extent to which the movement of one point is related to that of another point without the interference of other factors. In other words, in T1–T0 and T2–T0 the movement suffered by these three soft tissues points (lower lip, B′, and Pog′) were exclusively due to the movements suffered by the three hard tissue points (lower incisor, B, and Pog) ranging from 34.5% (Pog and lower lip – lower relationship) to 86.9% (Pog and Pog′ – higher relationship). The rest of these soft tissue movements were due to other factors, for example due to movements in other hard tissue points, in other soft tissue points, or even due to soft tissue accommodation in the soft tissue point evaluated. The movement of these six points could be explained graphically through six circles, not exactly superimposed, but with large linking areas common to two or more circles. In T2–T1 (relapse) this correlation was present only between lower lip and lower incisor ($r^2$ = 13.9% – lower relationship), B′ and

*Table 6*. Correlation and proportion of movements assessed between T1 and T0, T2 and T0, and T2 and T1, between only hard tissue and only soft tissue points, in relation to the true vertical line (TVL).[a]

| | T1–T0 | | | T2–T0 | | | T2–T1 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Correlation | | Proportion | Correlation | | Proportion | Correlation | | Proportion |
| | Sig. | $r^2$ | | Sig. | $r^2$ | | Sig. | $r^2$ | |
| (Between hard tissues:) | | | | | | | | | |
| Upper incisor and Pog | [a] | 8.0% | −0.23 | NS | – | – | NS | – | – |
| Lower incisor and B | [d] | 67.3% | 1.06 | [d] | 69.6% | 0.98 | NS | – | – |
| Lower incisor and Pog | [d] | 46.6% | 0.99 | [d] | 52.1% | 0.95 | NS | – | – |
| B and Pog | [d] | 74.1% | 0.93 | [d] | 78.8% | 0.97 | NS | – | – |
| (**Between soft tissues**:) | | | | | | | | | |
| Nasal projection and B′ | [a] | 9.8% | 0.23 | NS | – | – | NS | – | – |
| Nasal projection and Pog′ | [c] | 11.1% | 0.22 | [a] | 9.1% | 0.19 | NS | – | – |
| A′ and upper lip | [a] | 6.4% | 0.58 | NS | – | – | NS | – | – |
| Upper lip and lower lip | NS | – | – | [a] | 6.6% | −0.26 | NS | – | – |
| Lower lip and B′ | [d] | 52.3% | 0.89 | [d] | 54.4% | 0.82 | [a] | 54.4% | −12 |
| Lower lip and Pog′ | [d] | 48.3% | 0.84 | [d] | 46.9% | 0.81 | NS | – | – |
| B′ and Pog′ | [d] | 75.7% | 0.94 | [d] | 82.0% | 0.98 | NS | – | – |

NS, non-significant difference; Sig., significance level; A′, point A of soft tissue; A, point A of hard tissue; B′, point B of soft tissue; B, point B of hard tissue; Pog′, soft pogonion; Pog, hard pogonion.

[a] Pearson's correlation; adjusted $r^2$ is the explained variance, adjusted for the population. Proportion is the movement proportion of tissue in the first measurement in relation to the movement in the second measurement.

[b] Significant difference at $P < 0.05$.

[c] Significant difference at $P < 0.01$.

[d] Significant difference at $P < 0.001$.

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B ($r^2$ = 86.1%), and Pog′ and Pog ($r^2$ = 86.9% – higher relationship), probably due to being closer between themselves and to the significant degree of relapse found in these points (except for B and B′).

It is noteworthy that the levels of relapse found in measures of nasal projection, lower lip, lower incisor, Pog, and Pog′, although statistically significant, were low (0.20–0.64 mm), which may have a very small effect on the patient clinically. The correlation found between B and A′ ($P < 0.05$; $r^2$ = 6.2%; proportion 16%) and Pog and upper lip ($P < 0.01$; $r^2$ = 10.1%; proportion 40%) in relapse may be due to the repositioning in the anterior direction of the mandible, taking the upper lip in the same direction, once the touch between upper and lower lip occurs in the postoperative period.

For the relationship between lower lip and lower incisor, B′ and B, and Pog′ and Pog, this study identified respective proportions of 73%, 87%, and 86% (T1–T0), and 74%, 88%, and 87% (T2–T0). Hu et al.,[8] in their study, mention values found by them and by other authors for the lower lip and lower incisor proportion (71% for males and 82% for females; Ingervall et al.,[15] 88%; Lines and Steinhauser,[10] 75%; Suckiel and Kohn,[31] 83%), B′ and B (90% for females and 92% for males; Fanibunda,[13] 107%; Ingervall et al.,[15] 106%; Gjorup and Athanasiou,[14] 103%; Robinson et al.,[12] 100%), and Pog′ and Pog (94% for females and 106% for males; Fanibunda,[13] 94%; Ingervall et al.,[15] 107%; Lines and Steinhauser,[10] 100%). Joss et al.[17] reported a proportion of 100% for B′ and B and for Pog′ and Pog, while Gaggl et al.[32] reported 83% for Pog′ and Pog and also cited 100% for other authors including Fromm and Lundberg.[33] In this study, in T2–T1 (relapse), the proportion found between lower lip and lower incisor was 56%, between B′ and B was 50%, and between Pog′ and Pog was 68%, while Eggensperger[21] found values of 63%, 60%, and 36%, respectively for these points; these values found for Pog′ and Pog contradict the higher values found in the literature.

Surgery in one jaw may have an effect on the soft tissue of the other jaw, although many studies have shown that proportions of movement of the soft tissues in double-jaw surgery are similar to those in single-jaw surgery.[29,34–36] The results presented in this study confirm this assertion. The effects on mandible and maxilla in this study, performed on patients submitted to double-jaw surgery, were similar to the results found in other studies in relation to patients submitted to single-jaw surgery, partly because the effects of hard tissue movements of one jaw were generally restricted to the soft tissues of the same jaw (except for B and A′, and Pog and upper lip in T2–T1).

In addition to the relationship between hard and soft tissues, this study also sought to identify the relationships between only hard tissue points and only soft tissue points, an aspect rarely addressed in other studies. The results were generally close to those found for the relationship between hard and soft tissues in T1–T0 and T2–T0. There was a strong correlation between mandible points (lower incisor, B, and Pog for hard tissues, and lower lip, B′, and Pog′ for soft tissues), the correlation between B and Pog, and B′ and Pog′ being the ones with the greater $r^2$ values and proportions of movement. In the maxilla, a small correlation was found between A′ and upper lip only in T1–T0, indicating the presence of other factors in the movement of these points. Between maxilla and mandible points, a statistical correlation was found for hard tissues between upper incisor and Pog (T1–T0), although a cause and effect relationship was difficult to establish clinically, and for soft tissues between nasal projection and B′ (T1–T0) and Pog′ (T1–T0 and T2–T0), probably due to the mandible movement in the posterior direction having the same negative value as the diminution presented in the nasal projection values in T1 and T2 due to nasal spine removal, as occurred between nasal projection and B and Pog.

Variations between the findings of this study and other results reported in the literature may be explained partly through differences in the sample size, case selection, surgical procedure, fixation type, cephalometric analysis method, statistical method used, and facial pattern differences between different races. There is great miscegenation in the population of southern Brazil. The studied population consists of people descended from various ethnic groups: Germans, Italians, Portuguese, Spaniards, Africans, Indians, etc. In this context we cannot say that there was only one race being evaluated. The effects of the movement of the jaw bones on the soft tissue profile also varies with the extent of this movement, however the division of the sample into smaller groups according to this degree of movement would have led to a very low number of individuals in some groups and very different numbers between the groups, which would have hindered the statistical analysis. The same would apply to the division of the sample by gender. However, the use of a consistent and controlled study design, the method of data acquisition and statistical analyses, reliable computer programmes, and a sample that followed specific inclusion and exclusion criteria, make the results reliable and applicable to the routine clinical situation.

According to Hellsing,[37] a change in the NHP with an extension of 20° can result in an increased position of the TVL. Nevertheless, the head position in this study could be controlled, as all radiographs were taken at the same trained service using the same device.

The true horizontal reference plane in NHP is a less variable reference plane than conventional cephalometric reference planes. Also, variables based on NHP better describe true-life appearance.[38–40] NHP, like any body posture, comprises a small range of positions. NHP (and the TVL) represents a more reliable (and less variable) reference plane for cephalometric analysis, even after 15 years, than the conventional intracranial reference planes. The variance in NHP after 15 years was found to be 4.8°, and this remains significantly less than the variance in intracranial reference planes to the vertical (25–36°).[39] The Frankfort horizontal is a useful compromise for studying skulls, but not for orienting NHP in the living. Since intracranial landmarks are not stable points in the cranium because of variation in identifying them, their vertical relationships to each other are therefore also subject to biological variation (e.g. sella to nasion, porion to orbitale).[38] When the cranial base is used as the reference line for measuring the profile, false findings can be generated because the cranial base is as variable as the dental and facial structures that are measured from it. Measuring a variable to a variable leads to variable facial outcomes.[6,7] These variations in cephalometric findings occur when intracranial reference lines are used.[38] Measurements involving cranial base landmarks are inaccurate in defining the actual clinical profile and should not dictate head posture used for treatment planning.[6] Registration of the head in NHP has the advantage that an extracranial vertical or a horizontal perpendicular to that vertical can be used as a reference line for cephalometric analysis. Reproducibility of NHP was close to 2° as compared with sella–nasion, basion–nasion, and porion–orbitale, which showed standard deviations between 4.5° and 5.6°.[6,7,18,38,40] The small differences found in registering NHP constitute a limited problem in comparison with the variations in intracranial reference lines.[41] NHP has been shown to be the most accurate and reproducible head position.[38,40] Using NHP, facial evaluation can be based directly on the face and is not influenced by the variability in cranial base identification. NHP (not Frankfort) is the head position that most patients use habitually.[38] True mandibular position can be recorded if the cephalometric radiograph is taken at NHP, due to greater stability.[38,40] So the recommendation is to use the NHP for cephalometric analysis of dentofacial anomalies.[38]

According to Sforza et al.,[27] recent investigations in cephalometry show a strong correlation between soft and hard tissues in the horizontal but not in the vertical direction, and that lip position may be accurately predicted. In addition, when the treatment plan is discussed, patients should be warned that changes due to weight and age cannot be predicted and that in the long term the prediction through conventional cephalometry is not possible.[17,21]

In this study significant changes were observed in the evaluated points in the mandible and maxilla between measurements taken preoperatively and postoperatively in the short and medium term. A degree of relapse was found in the nasal projection, lower lip, lower incisor, Pog, and Pog′ points. The correlation was higher in the mandible than in the maxilla. The correlations between only hard tissues and between only soft tissues, an aspect that has rarely been discussed in published articles, follow a similar pattern to the correlations found between hard and soft tissues. The results of this study on double-jaw surgery were similar to the results found in studies on single-jaw surgery, both for the maxilla and mandible. In double-jaw surgery, the influence of hard tissue movements was mostly restricted to soft tissues of the same jaw, even though there were exceptions. Further research in the field of facial evaluation after orthognathic surgery is needed and will benefit from the constant technological developments in computed tomography scans and computer programmes.

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## Competing interests

None declared.

## Ethical approval

The research protocol was approved by the local ethics committee (São Lucas Hospital–Pontifícia Universidade Católica do Rio Grande do Sul–Porto Alegre, Brazil), with reference number OF. CEP-887/11.

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