Journal of Cranio-Maxillo-Facial Surgery 53 (2025) 312–317

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Is the orthodontics-first method more stable than the surgery-first approach for orthognathic correction of maxillary deficiency?

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ARTICLE INFO

Keywords:
Surgery first
Orthodontics first
Stability
Occlusion
Orthognathic surgery

ABSTRACT

This study was carried out to compare the stability of Le Fort I maxillary advancement between the surgery-first approach (SFA) and the orthodontics-first approach (OFA), and to evaluate the impact of the quality of post-operative occlusion on maxillary stability.

In total, 26 patients (13 SFA and 13 OFA) were included in this study. Cone beam computed tomography (CBCT) scans taken at T0 (1 week before surgery), T1 (1 week after surgery), and T2 (6 months after surgery) were used for the assessment of maxillary stability. The defective dentitions of the T0 and T1 scans were replaced with 3D-scanned dental models to assess the postoperative occlusions. The study was powered at 80%, with statistical significance for $p < 0.05$.

No statistically significant differences in stability were found between the two groups. The mean posterior maxillary relapse was 0.68 ± 0.48 mm in the SFA group and 0.48 ± 0.38 mm in the OFA group. Quality of occlusal contact was poorly correlated with maxillary relapse in both groups.

The stability of Le Fort I maxillary advancement was similar in the SFA and OFA patients at 6 months following surgery. This was independent of the quality of the immediate postoperative occlusion.

1. Introduction

The conventional method for the surgical correction of maxillary deficiency includes orthodontic incisor decompensation, followed by Le Fort I maxillary advancement. This is known as the orthodontics-first approach (OFA), and has the disadvantage of worsening the occlusion and facial profile prior to surgery (Jeong et al., 2017, 2018a). The surgery-first approach (SFA) has the advantage of immediate correction of the facial appearance, which is often the patient's main concern, followed by a single phase of post-operative orthodontic treatment. The SFA also reduces the total duration of the treatment (Pelo et al., 2017; Saghafi et al., 2020) and may enhance postoperative orthodontic tooth movement due to the regional acceleratory phenomenon (Liou et al., 2011; Keser and Naini, 2022). However, the quality of the immediate postoperative occlusion in SFA patients, and its impact on skeletal stability, have been a point of debate (Kim et al., 2013; Baek et al., 2010; Guo et al., 2018).

The results of studies comparing the stability of the SFA and the OFA have been somewhat inconsistent. Kim et al. and Mah et al. reported that the SFA is less stable than the OFA for correction of mandibular prognathism (Kim et al., 2013, 2014; Mah et al., 2017). Various other authors (Ko et al., 2011; Joh et al., 2013; WS Jeong et al., 2018a; Zhou et al., 2016; Park et al., 2016) have reported no difference in stability between SFA and OFA for the correction of Class III maxillomandibular relationships. However, in those studies, the patients who underwent the SFA had received 3–6 months of preoperative orthodontic treatment, so the concept of SFA was not strictly followed (Wei et al., 2018).

In most studies to date, 2D cephalometric landmarks have been used for the analysis of skeletal relapse. This does not allow the evaluation of rotational movements of the maxilla in the medio-lateral plane. Likewise, the analysis of postoperative occlusion has been limited to 2D radiographic measurements of overjet and overbite, which do not describe fully the pattern and quality of occlusal contacts following surgery. No studies have been carried out on the 3D evaluation of immediate postoperative occlusion and its effect on skeletal stability. This gap in the literature has been highlighted in a systematic review by Muilar et al. (Mulier et al., 2021).

Our study, therefore, had two main objectives. The first was to compare skeletal stability between a group of SFA and OFA cases following Le Fort I maxillary advancement. The second was to explore

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https://doi.org/10.1016/j.jcms.2024.12.011
Received 11 May 2024; Received in revised form 16 September 2024; Accepted 8 December 2024
Available online 24 December 2024

any relationship between the quality of immediate postoperative occlusion and maxillary stability. The rationale of this study was to inform the decision-making process regarding the selection of the SFA for correction of maxillary deficiency, and to provide evidence for the stability of this approach regardless of the quality of the immediate postoperative occlusion.

2. Materials and methods

This study was a retrospective analysis of an SFA group and an OFA group, with 13 cases each, which were matched for magnitude of surgical correction. All patients underwent Le Fort I maxillary advancement for correction of antero-posterior maxillary deficiency through the same multidisciplinary orthognathic clinic. No presurgical orthodontic treatment was carried out for the SFA patients. A standard 3D digital prediction planning and surgical protocol was followed for all the patients and the printed occlusal guiding wafer was only used during surgery. Intermaxillary guiding elastics were used during the postoperative healing period, as required. Patients who had previous facial surgery, cleft lip and palate, or a history of dentofacial trauma were excluded. The analysis was based on CBCT scans, which were taken 1 week prior to surgery (T0), at 1 week (T1), and 6 months (T2) following surgery.

2.1. Replacement of defective images of dentition on the CBCT scans

The postoperative CBCT scans (T1) were not suitable for analysis of the immediate postoperative occlusion due to the distortion of the dentition and streak artefacts. The dental study models, taken 1 day before surgery, were therefore scanned using an intra-oral scanner (TRIOS3; 3Shape A/S, Copenhagen, Denmark) and imported to IPS Case Designer® software (KLS Martin, Tuttlingen, Germany) for replacement of the defective dentition. The 3D models were then imported into VRMesh software (Virtual Grid, Seattle, USA) for visualization of the dental contacts and the generation of an occlusal map for the maxillary dentition (Fig. 1). Color coding indicated the proximity of the occlusal surfaces, with a range between +0.5 mm and −0.5 mm being taken to represent occlusal contact. An interocclusal distance of 0.0 mm represented an edge-to-edge occlusion. Maxillary occlusion was subdivided into the anterior region (from the right canine to the left canine) and posterior regions (from the premolars to second molars on the right and left sides). The occlusal contact distribution was subdivided into three groups: group A — three regions with contacts; group B — two regions with contacts; and group C – one region with contacts. The overjet, overbite, and the number of teeth in occlusal contact were also recorded.

2.2. Assessment of skeletal stability

The DICOM (Digital Imaging and Communications in Medicine) files for the CBCT scans were converted to 3D STL (Standard Tessellation Language) format. The horizontal (axial) reference plane was defined as passing through the left and right orbitale and left porion landmarks, while the sagittal plane passed through the nasion, perpendicular to the horizontal plane. The coronal plane was then orientated perpendicular to the other two, passing through the sella. The 3D models at T0, T1, and T2 were transformed with the coordinates of the nasion set as the origin (0, 0, 0).

Surface-based registration (SBR) was used to superimpose the T0 and T1 scans, to allow measurement of surgical movement, as well as the T2 and T1 scans, to allow measurement of surgical relapse. The registration of the corresponding scans was on stable structures of the anterior cranial base, the zygomatic arches, and the forehead. Landmarks on the right and left greater palatine foramina and incisive foramen were selected to allow 3D measurement of maxillary movements between the scans. The translation and rotation of the coordinates of these three landmarks were recorded with six degrees of freedom, along the x, y, and z axes, as well as in pitch, roll, and yaw. The x, y, and z axes represented left/right (L/R), anterior/posterior (A/P), and superior/inferior (S/I) directions, respectively. The anteroposterior relapse values were divided into four groups: group 1 (<0.5 mm), group 2 (0.5–1.0 mm), group 3 (1.0–1.5 mm), and group 4 (1.5–2.0 mm) (Fig. 2). The magnitude of relapse, measured as a percentage of the surgical movements (relapse ratio), was calculated as $((T1-T2) \times 100)/(T0\text{–}T1)$. The relapse ratio values were divided into three groups: group 1 (<10%), group 2 (10–20%), and group 3 (>20%).

2.3. Statistical analysis

Data were analysed using SPSS version 23.0 software (IBM, New York, USA). The descriptive statistics were expressed as mean ± SD. Differences in surgical movements (T0–T1) and skeletal relapse (T1–T2) within each group were assessed using a one-sample t-test or Wilcoxon signed test, depending on the normality of the data. A two-sample t-test

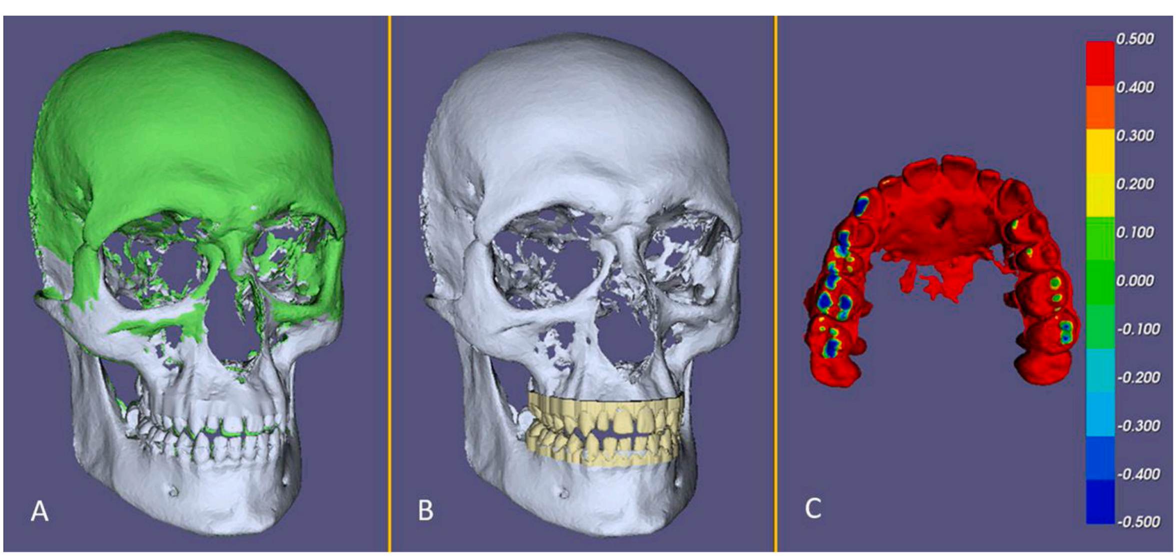

Fig. 1. Illustration of the 3D analysis of T1 CBCT scans: (A) registration on the anterior cranial base using surface-based registration; (B) replacement of the defective dentition using scanned dental models; (C) colour-coded map of occlusal contacts (threshold: −0.5 mm–0.5 mm). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

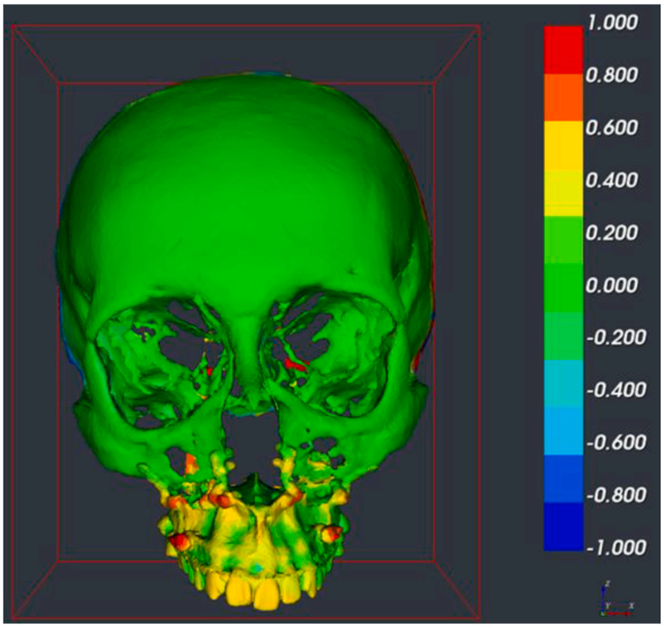

Fig. 2. Superimposed T1 and T2 CBCT scans, showing relapse of the anterior maxilla at 6 months. The yellow colour indicates a range of 0.4–0.6 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

or Mann–Whitney test was used to assess the differences between the groups. Pearson's or Spearman's correlation analysis was used to evaluate the relationships between skeletal stability and both the quality of the immediate postoperative occlusion and the magnitude of the surgical movements.

The errors in landmarking and reproducibility of the measurements were calculated in terms of the absolute mean difference between the repeated measurements. The size of measurement error was calculated using Dahlberg's formula. Intraclass correlations (ICCs) between the two measurements were calculated using a two-way mixed model to test for absolute agreement. At the 95% confidence interval, with a power of 80% and probabilities of <0.05, the G power sample size calculation required a total sample of 24 cases for two groups.

3. Results

In total, 26 skeletal Class III patients (13 SFA and 13 OFA) were included in the study. The mean age was 29.8 ± 9.5 years; 15 (57%) being male and 11 (43%) being female. Genioplasty was performed on seven (18%) patients. All the patients completed their postoperative orthodontic treatment. Figs. 3 and 4 show the 3D CBCT scans for one of the SFA cases, with its occlusion before surgery, immediately after surgery, and at the completion of treatment. Fig. 5 shows the decompensated occlusion of an OFA case.

The errors for the repeated measurements were less than 0.5 mm using Dahlberg's formula. The errors for the repeated measurement of maxillary translation at T0–T1 and T1–T2 were less than 0.5 mm. The random errors for the repeated measurements of pitch, roll, and yaw were less than 1°. There was excellent correlation (>0.991) between repeated occlusal measurements. The mean difference in the repeated measures of occlusal contacts was 0.07 ± 0.27 mm, which was not statistically significant.

3.1. Postoperative occlusal characteristics

Immediately following surgery, there was a significant difference in overjet ($p = 0.001$) and overbite ($p = 0.001$) between the two groups. The OFA patients had more statistically significant regional occlusal contacts ($p = 0.009$) and more teeth in contact ($p = 0.004$) than the SFA cases. Table 1 shows the occlusal characteristics of the SFA and OFA cases before surgery (T0) and at 1 week following surgery (T1). It also shows the changes in occlusal parameters as a result of surgery (T0–T1).

3.2. Surgical movements (T0 to T1)

There was no statistically significant difference in the anteroposterior surgical movements between the two groups, with the means and standard deviations being 7.07 ± 1.05 mm for SFA and 6.75 ± 1.56 mm for OFA. There was a significant difference between the groups for the vertical movements (2.5 ± 1.81 mm for OFA, 1.19 ± 1.27 mm for SFA; $p = 0.025$). The maxilla moved to the right in both groups (0.75± 1.05 mm for SFA and 0.53 ±0.39 mm for OFA). Table 2 shows the surgical movement and relapse for both groups.

3.3. Skeletal relapse at 6 months postoperatively (T1 to T2)

The maxilla relapsed posteriorly by 0.68 ± 0.48 mm in the SFA group and by 0.48 ± 0.38 mm in the OFA group. The difference of 0.20 mm was not statistically significant. The vertical relapse of the maxilla in the SFA group was 0.78 ± 0.50 mm, and 0.46 ± 0.54 mm in the OFA group, while the mediolateral relapse in the SFA group was 0.33 ± 0.38 mm, and 0.46 ± 0.54 mm in the OFA group. No statistically significant differences were detected. In addition, there was no statistically significant difference in the stability of the rotational movements between the two groups (Table 2).

There was no statistically significant correlation between the magnitude of maxillary advancement and the detected relapse at 6 months for both groups. In both groups, weak correlations were noted between the magnitude of roll, pitch, and yaw, and the associated relapse. In the OFA group, a moderate significant correlation was detected between the magnitude of surgical pitch and its relapse ($r =$

Fig. 3. The 3D CBCT models, with replaced dentitions, for one of the SFA patients: (A) T0 (before surgery), (B) T1 (immediately after surgery), and (C) T2 (at completion of treatment).

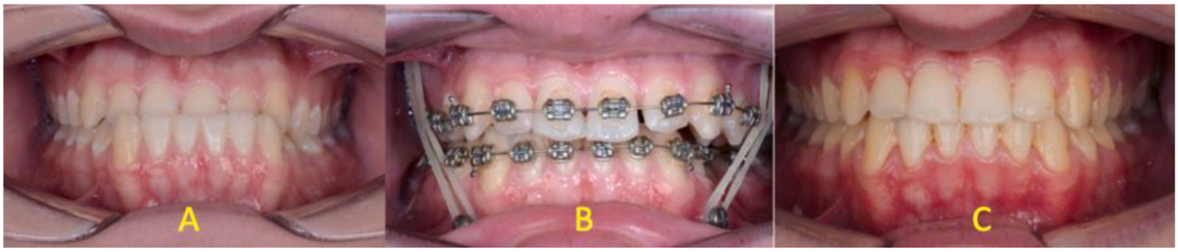

Fig. 4. Clinical photos for an SFA case, showing occlusion before surgery (A), immediately after surgery (B), and at completion of treatment (C).

Fig. 5. Clinical photos for an OFA case, showing the occlusion before start of the treatment (A), at decompensation before surgery (B), and at completion of treatment (C).

Table 1
Occlusal characteristics of the SFA and OFA cases before surgery (T0) and at 1 week following surgery (T1).

Occlusion	SFA		OFA		SFA		OFA		Difference OFA and SFA (*p*-value)
	Pre-operative (T0)	1 week post-op (T1)	Pre-operative (T0)	1 week post-op (T1)	(T0–T1)	*p*-value	(T0–T1)	*p*-value	
Overjet (mean ± SD)	−1.90 ± 1.53	4.43 ± 1.47	−3.06 ± 1.73	3.73 ± 1.47	6.41 ± 1.62	**0.001**	6.8 ± 1.66	**0.001**	0.240
Overbite (mean ± SD)	−1.40 ± 1.11	0.61 ± 1.29	−1.96 ± 1.49	1.18 ± 1.17	2.01 ± 1.96	**0.020**	3.15 ± 1.30	**0.001**	0.252
Number of teeth in contact	5 ± 3.71	4.15 ± 2.07	5.38 ± 2.39	6.53 ± 1.66	0.85 ± 4.23	0.486	1.15 ± 3.15	0.401	**0.004**
Occlusal regions (mean ± SD)	2.06 ± 1.03	2.27 ± 0.75	2.07 ± 0.64	2.76 ± 0.43	0.21 ± 1.29	0.500	0.69 ± 0.75	**0.014**	**0.009**
Contact distribution									
Anterior region	9 (69%)	10 (76%)	6 (46%)	10 (76%)					
Right posterior region	10 (76%)	10 (76%)	11 (84%)	13 (100%)					
Left posterior region	8 (61%)	7 (53%)	10 (76%)	10 (76%)					
Number of regions									
Three regions	6 (46%)	4 (31%)	3 (23%)	10 (76%)					
Two regions	3 (24%)	6 (46%)	8 (61%)	3 (24%)					
One region	3 (24%)	1 (8%)	2 (16%)	0					

0.65, $p = 0.015$). There was no correlation between the quality of the postoperative occlusion and posterior surgical relapse in the two groups. A weak correlation was detected between posterior relapse and the immediate postoperative overjet ($r = 0.11$, $p = 0.23$) and overbite ($r = 0.17$, $p = 0.35$) in both groups. A moderate correlation ($r = 0.68$, $p = 0.010$) was noted between occlusal contact distribution and anticlockwise relapse of surgical pitch in the OFA group. A relapse of less than 10% of the maxillary surgical advancement was noted in 10 SFA cases and 11 OFA cases. The magnitude of posterior surgical relapse was <1.0 mm in 10 SFA cases and 12 OFA cases at 6 months following surgery.

4. Discussion

This was the first study to apply a 3D method to compare surgical stability and the quality of the immediate postoperative occlusion between OFA and SFA cases. Surface-based registration (SBR) was applied to superimpose the T1 and T0 scans in order to measure surgical movement. The same method was applied to superimpose T2 to T1 scans in order to measure surgical relapse. This method provides a comprehensive and robust analysis of the maxillary position vertically, mediolaterally and anteroposteriorly, as explained in our previous publication (Saghafi et al., 2024). In this study, the magnitude of relapse of the maxilla was <1.0 mm in 10 of the SFA and 12 of the OFA cases at 6 months following surgery. This indicates that Le Fort I maxillary advancement is of comparable stability in both the SFA and OFA. In contrast, the systematic review by Wei et al. (2018) found greater relapse in SFA patients, which was both statistically and clinically significant. Similarly, Peiro-Guijarro et al. (2016) reviewed 11 studies, and reported that relapse of more than 1.5 mm occurred more frequently in SFA cases than in OFA cases. However, bimaxillary surgery was performed in 70% of these cases, and this may have had an impact on maxillary stability (Peiro-Guijarro et al., 2016).

On the other hand, similar relapses in both SFA and OFA groups has been reported in several other studies (Park et al., 2015, 2016; Ann et al., 2016; J-H Jeong et al., 2018a, b). However, in these studies, preoperative orthodontic treatment was carried out 3–6 months before surgery for the SFA patients, which does not strictly conform to the criteria of the SFA. The guiding occlusal wafer was left for 2–4 weeks following surgery in the SFA cases, which the authors claimed contributed to the noted stability. The studies were limited to 2D analysis, and the relapse was

Table 2
A comparative analysis of the surgical changes (T0–T1) and relapse (T1–T2) in the SFA and OFA groups.

	SFA ($N = 13$)	OFA ($N = 13$)	Absolute mean difference	*p*-value
	Absolute mean ± SD	Absolute mean ± SD		
Surgical movement (T0–T1)				
Right/left	0.75 ± 1.05	0.53 ± 0.39	0.22	0.482
Posterior/anterior	7.07 ± 1.52	6.75 ± 1.56	0.32	0.634
Superior/inferior	1.19 ± 1.27	2.57 ± 1.81	**1.37**	**0.025**
Pitch	1.91 ± 2.19	2.88 ± 2.60	0.97	0.192
Roll	1.22 ± 1.12	2.01 ± 2.01	0.78	0.239
Yaw	1.34 ± 1.32	1.56 ± 1.50	0.21	0.721
Relapse (T1–T2)				
Right/left	0.33 ± 0.38	0.54 ± 0.61	0.21	0.414
Posterior/anterior	0.68 ± 0.48	0.48 ± 0.38	0.20	0.262
Superior/inferior	0.78 ± 0.50	0.46 ± 0.54	0.32	0.185
Pitch	1.33 ± 1.20	2.08 ± 1.62	0.75	0.271
Roll	1.21 ± 0.88	1.13 ± 1.11	0.08	0.561
Yaw	0.95 ± 0.70	1.19 ± 2.07	0.24	0.655

measured at point A, which is subject to remodeling due to the post-surgical orthodontic treatment. The quality of postoperative occlusion was not evaluated in their studies.

In our study, the two cohorts of cases were matched according to the amount of surgical advancement. None of our cases had undergone any other orthognathic surgery that might have influenced maxillary stability. Other studies have reported a greater magnitude of surgical movement in SFA cases to allow for the planned postsurgical orthodontic decompensation, but this was not the case in our study (Baek et al., 2010; Kim et al., 2014).

The poor quality of the compensated postoperative occlusion has been considered to be one of the disadvantages of the SFA, due to its potential negative impact on postoperative skeletal stability (Guo et al., 2018; Valls-Ontanon et al., 2023; Yang et al., 2017). Studies on the relationship between the immediate postoperative occlusion and relapse in the SFA and OFA have been limited to overjet and overbite. At 1 month following surgery, Ann et al. and Joh et al. reported greater overjet among SFA cases and greater overbite in OFA cases (Joh et al., 2013; Ann et al., 2016), while Park et al. reported similar overjet and overbite at 1 week following surgery (Park et al., 2016). However, their results were based on 2D cephalometric analyses of cases that had bimaxillary osteotomy. The analysis of 2D radiographs is limited due to magnification and distortion (Hung et al., 2020). Previous studies have not commented on the quality of postoperative occlusion and its relationship with the stability of surgical outcome (Joh et al., 2013; Park et al., 2014, 2016; Ann et al., 2016; Liao et al., 2010; Akamatsu et al., 2016).

In this study, the assessment of occlusion by replacing the defective image of the dentition on the postoperative CBCT scans using 3D images of dental models is a novel technique. The generation of an occlusal map, where occlusal contact was represented by an interocclusal distance of −0.5 mm to 0.5 mm, allowed an accurate quantitative assessment of the occlusion. This innovative approach for the assessment of postoperative occlusal contacts allowed objective 3D measurement of dental occlusion (Saghafi et al., 2024). Our findings showed that at 1 week following surgery, the OFA group had a greater number of teeth and occlusal regions in contact. The horizontal skeletal relapse at 6 months showed no correlation with the quality of the immediate postoperative occlusion, which confirmed that maxillary stability in both SFA and OFA groups was not related to occlusal contacts, overjet, or overbite.

The use of intermaxillary elastics in the early postoperative stage has been shown to be effective in enhancing maxillary stability (Zhou et al., 2016), and these were applied routinely in all of our cases.

The 3D analysis of maxillary translation and rotation was based on the landmarks that are not subjected to remodeling and are not affected by the bone cuts. This allowed the comprehensive evaluation of the maxilla with six degrees of freedom and its rotation across the three cartesian axes (x, y, z). We recommend this approach to replace 2D cephalometric analysis.

Previous studies have measured incisal inclination, overjet, and overbite, in their assessment of occlusal stability (Baek et al., 2010; Liao et al., 2010; Akamatsu et al., 2016; Park et al., 2014; Seifi et al., 2018). However, these do not characterise the quality of the occlusal contacts. In our study, a comprehensive 3D descriptive assessment of the occlusion was achieved. This would not have been possible without replacing the defective dentition of the immediate postoperative CBCT scans, using the IPS Case-Designer software, which was found to have a high level of accuracy (0.2 mm). This was less than the voxel size of the CBCT (0.40 mm) (Baan et al., 2021).

While our sample size calculation showed 12 cases in each group to be adequate to detect a moderate difference (effect size = 0.6), a larger sample size would have been beneficial. Although most skeletal relapse of the maxilla has been shown to occur within the first 6 months following surgery (Zhou et al., 2016; Fahradyan et al., 2018; Jakobsone et al., 2011; Dowling et al., 2005), a longer follow-up would be recommended.

In summary, our study showed that Le Fort I osteotomy using the SFA is stable, despite the limited occlusal contacts immediately following surgery. Therefore, we recommend that other orthognathic teams should consider this approach. In addition to its stability, it shortens the overall duration of treatment and reduces the anxiety that patients experience as a result of presurgical orthodontic decompensation.

Ethical statement/confirmation of patients' permission

Ethical approval was obtained to conduct the study (R&D reference: GN20OD634, REC reference: 21/NE/0019).

Conflicts of interest

The authors have no conflicts of interest to declare.

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