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Morphological Changes in Total and Inferior Part of Maxillary Sinus After Le Fort I Osteotomy, as Determined by Cone-Beam Computed Tomography

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Abstract: To investigate morphological changes of the total and inferior part of the maxillary sinus following Le Fort I osteotomy. 21 skeletal class II and 49 skeletal III patients who underwent orthognathic surgery were enrolled in this retrospective study. Cone-beam computed tomography taken before (T1) and 6 to 24 months after (T2) orthognathic surgery were imported into Mimics 20.0 software to analyze morphological changes of the total and inferior part of the maxillary sinus. Volume of the whole maxillary sinus was significantly reduced after surgery ($P \leq 0.008$), while the volume of the inferior part of the maxillary sinus was significantly greater than before surgery ($P \leq 0.004$). Maxillary sinus floor moved occlusally after Le Fort I osteotomy. Movement in the pitch direction of the posterior maxilla affected the state of the maxillary sinus mucosa after orthognathic surgery. Le Fort I osteotomy exerts a significant impact on the morphology of the total and inferior part of the maxillary sinus.

Key Words: CBCT, Le Fort I osteotomy, maxillary sinus

Orthognathic surgery (OS) combined with orthodontic therapies are a routine treatment procedure for patients with dentofacial deformities. OS results in improved esthetic appearance, neat dentition, and better masticatory function.[1–3] Le Fort I osteotomy is the main orthognathic surgical method used to move the maxillary segment in 3 dimensions (D) to obtain a harmonious positional relationship of the maxilla relative to the overall craniofacial bone.[4,5] Although Le Fort I osteotomy improves the patient's facial contour, it may affect the normal anatomy near the surgical field.

Le Fort I osteotomy traverses the maxillary sinus (MS) cavity and may therefore affect the morphology of the MS.[6–9] According to previous reports, the reduction of maxillary sinus volume (MSV) and maxillary sinus mucosal (MSM) thickening represent clear and significant outcomes of Le Fort I surgery.[10,11] However, previous articles have mostly focused on the morphological changes of MS after the advancement of the maxilla rather than the use of Le Fort I segment osteotomy to regress the anterior maxilla. Moreover, only a very limited number of studies have investigated the influence of the direction of maxilla movement on the morphological structure of MS.[7]

The morphology of the inferior part of the maxillary sinus (IMS) is the anatomically and clinically important structure that can be related to many clinical practices, such as tooth extraction, orthodontic tooth movement, and MS floor augmentation.[12–14] Le Fort I osteotomy may have a major impact on the morphology of the IMS.[15] Meanwhile, changes in the morphology and airflow of MS may lead to remodeling of the sinus floor. Despite these considerations, very few studies have focused on morphological alterations in the IMS before and after Le Fort I surgery.

Therefore, the aim of this study was to evaluate the effect of the different direction in the maxilla movement on morphological changes of MS and IMS for both skeletal class II and III malocclusion before and after Le Fort I osteotomy.

MATERIALS AND METHODS

Patients

This retrospective study was approved by the Peking University School of Stomatology (Approval number: PKUSSIRB-202059185). The study population included patients with skeletal class II and III malocclusion who were admitted to the Department of Oral and Maxillofacial Surgery in Peking University School and Hospital of Stomatology between January 2017 and December 2019. The inclusion criteria were as follows: skeletal class II or III patients, completion of preoperative orthodontics, Le Fort I or Le Fort I segment osteotomy applied for the first time, and imaging involving cone-beam computed tomography (CBCT) 1 week before (T1) and at least 6 months (T2) after surgery. Each participant provided informed consent to participate in this study.

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Surgical Procedure

All skeletal class III patients had undergone 1-piece maxilla advancement surgical procedure. In a manner that differed from class III patients, bilateral maxillary first premolars were extracted before osteotomy in class II patients. After osteotomy and down fracture, a fissure bur was applied to segment the maxilla between the canine and the second premolar. Whether we further divided the maxilla at the median palatal suture depended on the terminal occlusal relationship.

Cone-Beam Computed Tomography Acquisition

High-quality CBCT scans were obtained using an iCAT scanner (NewTom, Verona, Italy). Patients were positioned to ensure that the Frankfort-Horizontal plane paralleled the floor. The machine setting parameters were 120 kV and 5 mA with a scanning matrix of 400×400 and a 15×15 cm field of view. The gray-level depth was 16 bits with a layer thickness set at 0.1 mm. All scanning data were reoriented so that the hard palate was parallel to the horizontal direction. Then, the scan data were exported in DICOM format and analyzed using Mimics 20.0 software (Image Works, Materialise, Belgium).

Maxillary Sinus Grouping and Morphology Analysis

The MSs of both skeletal class II and III patients were divided into 3 groups according to the vertical movement direction of the posterior maxilla: group 1 (those without vertical height alteration), group 2 (those with lengthening of the posterior maxilla), and group 3 (those with impaction of the posterior maxilla).

Maxillary sinus volume and the volume of the inferior part of the maxillary sinus (IMSV) were also measured using Mimics 20.0 software (Image Works, Materialise, Belgium). The IMSV was defined as the sinus volume from the bottom of the sinus up to the nasal cavity floor (NCF) before and after surgery (Fig. 1). The morphology of the preoperative and postoperative MS and IMS was generated by drawing a boundary line in 2D images layer-by-layer, and their volumes were automatically calculated by Mimics software. The distance between the nasal cavity plane and the base of the sinus at every maxillary posterior tooth site represented the height of the inferior part of the maxillary sinus (IMSH) (Fig. 2).

Maxillary sinus mucosal thickening before and after surgery was classified into 4 grades according to the proportion occupied by the MS: grade 1 (barely no mucosal thickening), grade 2 (mucosal thickening occupied one third or less of the MSV), grade 3 (mucosal thickening occupying one third to two third of the MSV, and grade 4 (mucosal thickening occupying more than two thirds of the MSV)[15,16] (Fig. 3). By comparing the grades of the MSM before and after surgery, we were able to evaluate whether the thickness of the MSM was thinner, thicker, or remained unchanged.

Statistical Analysis

To evaluate measurement error, 10 pairs of CBCT images were selected from the total sample and repeatedly measured at an interval of 1 week. Intraclass correlation coefficients were then used to investigate intraoperator and interoperator reliability.

Because the sample size of the data was small and did not follow a normal distribution, nonparametric tests were used for statistical analysis. Descriptive statistics are shown as mean ± SD. The Wilcoxon signed-rank test was used to investigate changes in MS indices before and after surgery. The Mann-Whitney U test was used to investigate the index alterations between skeletal class II and III patients. The Kruskal-Wallis H test was used to investigate changes in MSM thickening between groups A P value <0.05 was considered significant. All analyses were performed using SPSS, version 23.0 (IBM Corp., Armonk, NY).

RESULTS

According to our inclusion criteria, there were 20 males (40.8%) and 29 females (59.2%) class III patients ranging in age from 19 to 37 years (mean age, 25.22 ± 4.49 y), and 8 males (38.1%) and 13 females (61.9%) class II patients ranging in age from 23 to 38 years (mean age, 29.61 ± 4.57 y) included in this study. The follow-up duration was 7 to 24 months (mean, 13.19 ± 4.57 mo).

Intraoperator correlation coefficients varied from 0.875 to 0.932, while interoperator correlation coefficients varied from 0.843 to 0.912, thus demonstrating that all of the data measured were accurate and reproducible.

Morphological Changes of the Maxillary Sinus

The mean preoperative and postoperative MSV in skeletal class II and III patients are presented in Supplemental Table 1 (Supplemental Digital Content 1, http://links.lww.com/SCS/E377). The reduction of MSV in class II and III patients was 505.43 ± 1035.83 and 995.53 ± 1601.73 mm^3 ($P = 0.008$ and <0.001, respectively). Alterations of the MSV in different patient groups are shown in Supplemental Table 2 (Supplemental Digital Content 2, http://links.lww.com/SCS/E378). Group 3 of the class II patients and groups 1 and 3 of the class III patients all revealed significant reductions in MSV following Le Fort I osteotomy ($P = 0.006$, 0.012, and < 0.001, respectively).

The mean preoperative and postoperative IMSV in skeletal class II and III patients are presented in Supplemental Table 1 (Supplemental Digital Content 1, http://links.lww.com/SCS/E377). The increase of IMSV in class II and III patients was 286.80 ± 672.01 and 191.23 ± 575.90 mm^3 ($P = 0.004$ and 0.002, respectively). Alterations in the IMSV of different patient groups are shown in Supplemental Table 2 (Supplemental Digital Content 2, http://links.lww.com/SCS/E378). Group 2 of the class II patients and groups 1 and 2 of the class III patients showed a significant increase in the IMSV after Le Fort I osteotomy ($P = 0.001$, 0.039, and 0.006, respectively). The mean preoperative and postoperative IMSH for all patients are presented in Supplemental Table 3 (Supplemental Digital Content 3, http://links.lww.com/SCS/E379). The IMSH increased to some extent, except for the second molar site in group I skeletal class II patients.

Preoperative characteristics of the MSM state in skeletal class II and III patients are shown in Supplemental Table 4 (Supplemental Digital Content 4, http://links.lww.com/SCS/E380). Postoperative changes of the MSM in the skeletal class II and III patients are shown in Supplemental Table 5 (Supplemental Digital Content 5, http://links.lww.com/SCS/E381). No significant differences were detected after surgery with respect to changes of the MSM in patients with different skeletal deformities ($P = 0.06$). The proportion of MSM thickening was 28.6% in skeletal class II patients and 27.6% in skeletal class III patients.

The preoperative characteristics of the MSM state in different groups were divided according to the direction of vertical movement, as shown in Supplemental Table 4 (Supplemental Digital Content 4, http://links.lww.com/SCS/E380). Postoperative changes of the MSM in different MS groups are shown in Supplemental Table 5 (Supplemental Digital Content 5, http://links.lww.com/SCS/E381). No significant differences were detected after surgery with respect to changes in the MSM

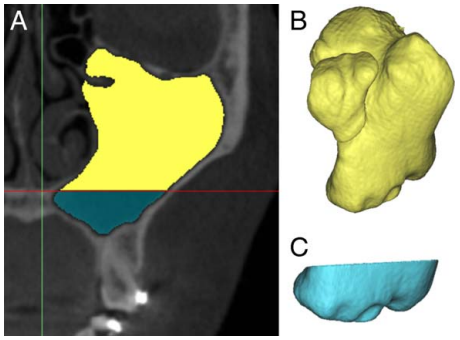

FIGURE 1. Analysis of maxillary sinus volume. (A) Segmentation of maxillary sinus according to the nasal cavity floor. (B) Morphology of the whole maxillary sinus. (C) Morphology of the inferior part of the maxillary sinus.

in different groups ($P = 0.499$). The proportion of MSM thickening was 22.9% in group I, 15.2% in group II, and 36.1% in group III MS.

DISCUSSION

Le Fort I osteotomy can improve a patient's facial appearance and esthetics, but can also affect MS morphology close to the surgical approach.[17,18] In previous related studies, the subjects were mostly patients with skeletal class III malocclusion[6,7,10]; these studies showed that the total volume of the MS was reduced after surgery; this is consistent with the results of the present study in that the total volume of the MS was reduced to 995.54 mm^3 in class III patients. The reduction observed in the MSV can be attributed to the remodeling of the posterior wall of the MS caused by the advancement of the maxillary dental segment.[7,16] In the present study, we also focused on changes in the MSV after Le Fort I segment osteotomy for skeletal class II patients; we found that the mean reduction in the volume of the MS after surgery was 505.42 mm^3. The intraoperative extraction of the maxillary first premolar, its corresponding MS space was occupied by the adjacent maxillary bone segment. By grouping all the MSs according to the direction of vertical movement, we found that in group 3, the MSV was significantly reduced postsurgery. In contrast to group 3, the MSV in group 2 did not change significantly after surgery. The direction of vertical movement in the maxilla may affect the overall height of the MS to a certain extent, thereby influencing the changes in the volume of the MS.

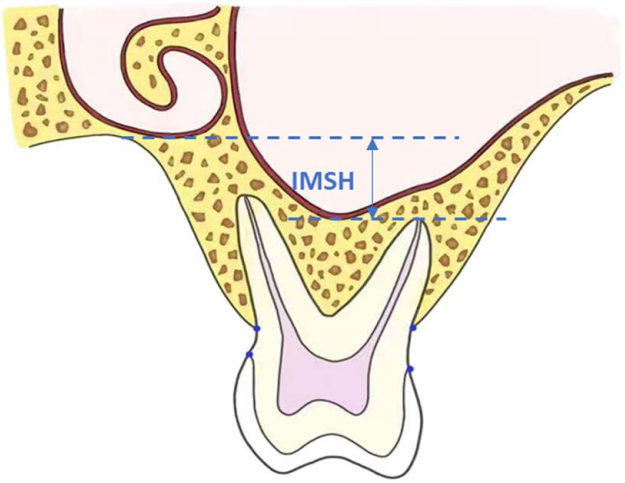

FIGURE 2. Measurement of the maxillary sinus on coronal slices. IMSH indicates height of the inferior part of the maxillary sinus.

The IMS is closely related to many surgical procedures, such as tooth extraction, root canal therapy, and implant treatments.[12] In this study, we investigated changes of IMS morphology after Le Fort I osteotomy for the first time. The NCF is defined as the upper boundary of the IMS because it is located in the down-fractured dental bone segment, and the morphology of the NCF is not affected during surgery.[19] We found that IMSV increased significantly after Le Fort I osteotomy in patients with different skeletal deformities. The measurement of IMSH before and after Le Fort I osteotomy confirmed that the increase in IMSV was caused by the increased IMSH. These results indicate that the MS floor moved occlusally; this might be due to the increased pressure in the sinus cavity related to total volume reductions and fluid accumulation in the MS after surgery; this pressure compresses the air volume of the MS. Compared with the MS in groups 1 and 3, the distance between the MS floor and NCF was increased in group 2 MS due to the downwards movement of the posterior maxilla, thus resulting in a more significant increase in postoperative IMSV. Group 3 MS with skeletal class II deformity was the only group showing a postoperative reduction in IMSV; this may have been caused by a combination of posterior maxillary upwards movement and Le Fort I segment surgery that removed part of the sinus space.

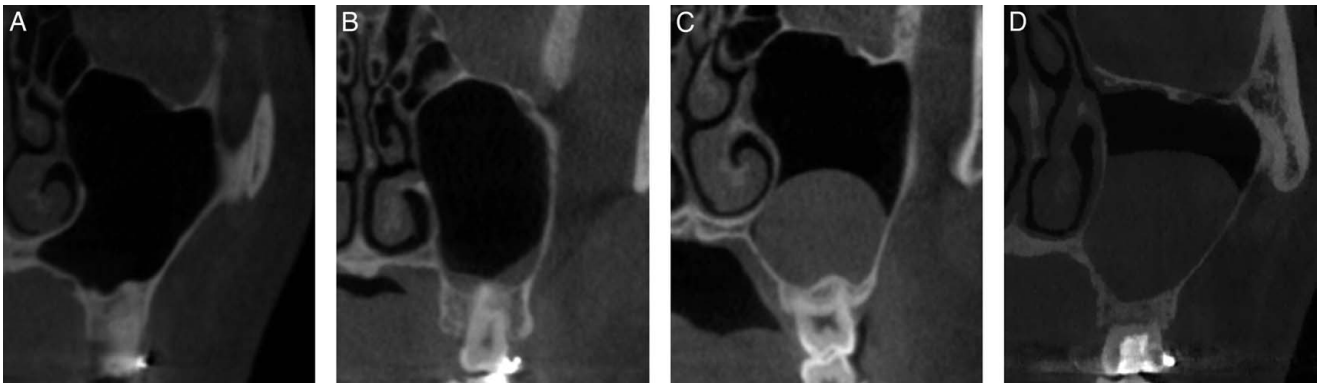

FIGURE 3. Maxillary sinus mucosa thickening grading according to the proportion occupied in the maxillary sinus. (A) Grade 1, barely any mucosal thickening. (B) Grade 2, occupying one third or less of the volume of the maxillary sinus. (C) Grade 3, occupying one third to two third of the maxillary sinus. (D) Grade 4, occupying more than two third of the maxillary sinus.

Le Fort I osteotomy divided the MS results by immediate postoperative MS effusion which may induce inflammatory changes in the MSM.[15,16] Although the incidence of maxillary sinusitis was relatively low, previous radiological studies have found that MSM thickening was common following OS.[10] A thickening of the MSM not only induces upper respiratory symptoms but also interferes with oral treatment in the region adjacent to the MS. In this study, we focused on the effects of different Le Fort I osteotomies (1-piece or multisegment) and different directions of vertical movement of the posterior maxilla (groups 1–3) on the mucosal thickening of the MS. We found that vertical movement of the posterior maxilla, rather than differing Le Fort I osteotomy methods, has an impact on the inflammatory state of the MSM after surgery. Although not statistically significant, impaction of the posterior maxilla was more likely to result in postoperative thickening of the MSM than pure anterior-posterior movement and lengthening of the posterior maxilla. This may be due to the fact that impaction of the maxillary segment is not conducive to the drainage of blood and effusion into the MS after surgery. Therefore, hemostasis after Le Fort I osteotomy and removal of the MS fluid before rigid internal fixation are more important for patients with posterior maxillary impaction.

This study was associated with some limitations that the proportion of patients with skeletal class II deformity in the population seeking orthognathic treatment was relatively small, thus resulting in the relatively insufficient patients with skeletal class II included in this study. Larger sample size and more consistent follow-up time points may be more meaningful for the study of MS-related complications after OS.

CONCLUSION

The 3D analyses in this study enabled us to understand the morphological changes of MS and IMS after Le Fort I osteotomy which will serve as a reference for subsequent MS-related surgery treatment.

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Prkra Mutation Alters Long Noncoding RNA Expression During Embryonic External Ear Development

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