Complications Following One-Stage Versus Two-Stage Surgical Treatment of Transverse Maxillary Hypoplasia

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Purpose: Contemporary literature suggests a similar transverse stability of a surgical-assisted rapid palatal expansion and a segmented Le Fort I osteotomy. The aim of this study was to compare postoperative complications of 1-stage (segmental maxillary osteotomy) and 2-stage (surgical-assisted rapid palatal expansion followed by Le Fort I osteotomy) treated patients to determine the preferred treatment strategy.

Materials and Methods: This retrospective study included 74 consecutive patients (age range: 14 – 57 years; 36 males, 38 females) with a moderate transverse maxillary hypoplasia: 32 patients were treated in a 1-stage protocol and 42 in a 2-stage protocol with a postoperative follow-up of at least 1 year. Dental complications such as loss of teeth, gingival dehiscence, periodontal bone loss, apical root resorption, and surgical complications such as pain, hemorrhage, altered neurosensitivity, wound infection, aseptic necrosis were analyzed. Univariate analysis consisted of a generalized linear model with logit link or Fisher exact test.

Results: No significant difference was found for group characteristics except for longer orthodontic treatment time in the 2-stage group. Incidence and severity of complications were comparable for the 1-stage and 2-stage patients. Only overall pain was significantly greater in the 2-stage patient group ($P = .038$).

Conclusions: Considering a similar complication rate and transversal stability, the choice between 1-stage and 2-stage approach for patients with a moderate transverse maxillary hypoplasia should be patient specific.

J Oral Maxillofac Surg ■*:1-9, 2021*

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Sources of Support: No sources of support.

Conflict of Interest Disclosures: None of the authors have any relevant financial relationship(s) with a commercial interest.

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Received November 17 2020

Accepted February 18 2021

0278-2391/21/00201-9

https://doi.org/10.1016/j.joms.2021.02.025

Malocclusion due to transverse maxillary deficiency can be treated in different ways. In young patients, orthodontic treatment is the only preferred treatment option. When the patient is skeletally mature, additional surgical options need to be considered. There are 2 widely used surgical treatments for transverse maxillary deficiency: the surgically assisted rapid palatal expansion (SARPE) and the segmental maxillary Le Fort I osteotomy. SARPE is deemed the preferred therapy for many surgeons because of allegedly higher accuracy and stability, in addition to fewer complications.[1-4] SARPE only corrects transverse discrepancies and is therefore often followed by a Le Fort I osteotomy to correct vertical and sagittal maxillary discrepancies in a 2-stage treatment approach.[5] A segmental maxillary Le Fort I osteotomy is an alternative treatment strategy and has the advantage of a 1-stage surgical procedure for the correction of transverse, vertical and sagittal discrepancies of the maxilla. For large transverse maxillary deficits, it is esteemed to be less accurate and more prone to relapse.[6] Therefore, in severe maxillary deficiency needing a transverse expansion larger than 6-7 mm, a 2-stage approach is preferred starting with a SARPE followed, if necessary, by additional orthognathic surgery. It should be mentioned that after SARPE, the planned treatment might change.[7] Recent studies reported that SARPE and segmental Le Fort I osteotomy treat maxillary transverse deficiency equally effectively in small to moderate deficiencies up to 6-7 mm.[8-11] Hence, it is suggested that for patients presenting with a moderate maxillary deficiency, the decision between SARPE and segmental Le Fort I osteotomy should not depend on skeletal stability, but on associated risks and morbidity.[11,12]

Multiple complications have been reported following segmented Le Fort I osteotomy. A systematic review by Haas Junior et al.[13] uncovered postoperative infection (32.6%), oral fistulae (19.3%), periodontal damage to adjacent teeth (12.8%), and soft tissue damage (10.2%) to be the most prevalent complications. A more limited patient group experienced the necessity for blood transfusion (2.1%), segmental necrosis (2.1%), nonunion (1.6%), and intraoperative bleeding (1.1%). Ho et al.[14] reported 1 case (1.2%) with loss of 1 tooth and 3 cases (3.5%) with delayed segmental bone union. A systematic review by Carvalho et al.[15] reported complications following SARPE. Epistaxis (2.5%), postoperative pain (2.0%), and inadequate expansion (4.5%) were the most frequent complications. Dental complications such as periodontal damage, incisor discoloration, buccal bone loss, mobility and even loss of teeth have been described.[16,17] To the best of our knowledge, a comparative study of complications of 1-stage segmental maxillary osteotomy and 2-stage SARPE-Le Fort I osteotomy has not yet been carried out. The aim of this study was to comparatively assess postoperative complications of 1-stage and 2-stage protocols to determine the preferred patient-specific treatment strategy.

Material and Methods

PATIENTS

This retrospective study included patients who underwent surgical treatment for transverse maxillary hypoplasia between January 2013 and November 2018. The study adhered to the tenets of the Declaration of Helsinki. Institutional review board approval was obtained (S62686). Postoperative complications of 1-stage segmental maxillary osteotomy and 2-stage therapy were evaluated and compared. All patients who underwent a multipiece maxillary Le Fort I osteotomy were included in the 1-stage group. Indications for performing a segmented Le Fort I in this study consisted of anterior open bite with a dual-plane maxilla, moderate transversal maxillary hypoplasia, or severe proclination of the maxillary anterior teeth. Inclusion criteria for the 2-stage group consisted of a SARPE surgery with tooth-borne distraction followed–after full alignment of teeth-by 1-piece Le Fort I osteotomy with or without concomitant bilateral sagittal split osteotomy. Included indications for SARPE consisted of moderate to large transversal maxillary deficiency with unilateral or bilateral cross bite, buccal corridors, and/or dental maxillary crowding. Exclusion criteria for both groups were follow-up of less than 1 year, diagnosis of a craniofacial syndrome, cleft lip, and/or palate or secondary correction following midface trauma.

SURGERY

Surgeries were conducted by the same surgical team following the same surgical technique protocol. The SARPE procedure was performed as described by Smeets et al.[18] and Verquin et al.[17] An osteotomy was performed at the level of the transpalatal suture, pterygomaxillary suture, zygomatic buttress, lateral nasal wall, and nasal septum (Fig 1). Activation of the tooth born distractor Hyrax® (Dentaurum, Ispringen, Germany) started 5 to 7 days postoperatively, twice daily at a rate of 0.25 mm per activation. After expansion, the distractor device was blocked and either left in place or replaced with a transpalatal arch for a consolidation period of 6 months.

A 1-piece Le Fort I was performed as described by Bell et al.[19] Virtual planning was transferred to the surgical field with the use of computer-aided design/computer-aided manufacturing (CAD/CAM) printed intermediate and/or final splints. The final splint was fixated to the mandibular dentition with the use of a

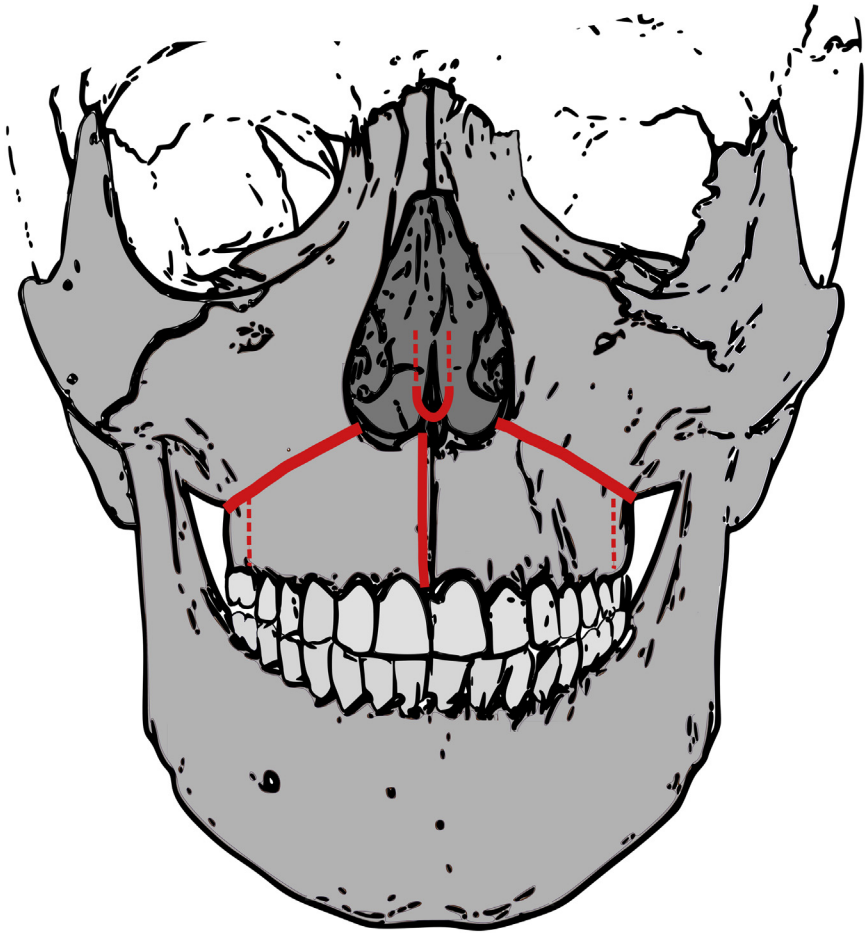

FIGURE 1. Surgical technique of SARPE. This figure depicts the performed surgically-assisted rapid palatal expansion (SARPE) with pterygomaxillary disjunction and nasal septum separation.

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wire for a period of 6 weeks. In case of incomplete healing of the maxillary bone after the SARPE procedure, the same osteotomy cuts of the SARPE were used for Le Fort I osteotomy. Segmental Le Fort I was performed as described by Meeuwis et al.[20] Interdental and horseshoe osteotomies were carried out using a piezotome and chisels (Figs 2, 3). A paramedian osteotomy was performed in the event of a 2-piece Le Fort I osteotomy. Iliac crest bone graft was placed between the maxillary segments in case of transversal widening. Perioperatively, a transpalatal arch was placed to stabilize the transversal widening. Postoperative antibiotic treatment consisted of amoxicillin/clavulanic acid 875 mg 3 times a day for a period of 5 days.

DATA COLLECTION AND ANALYSES

The following patient characteristics were collected: age, gender, orthodontic treatment duration, technicalities of the maxillary osteotomy, concomitant bilateral sagittal split osteotomy, time interval between SARPE and Le Fort I. Skeletal and dental expansion were calculated by comparing preoperative and immediate postoperative postero-anterior cephalograms following segmental Le Fort I and SARPE. Skeletal expansion was measured between the right and left maxillary points as described by Berger et al.[21] Dental expansion was determined by calculating the width between the most buccal points of the maxillary molars.[22] Before each surgical procedure, the following clinical and radiographic examinations were performed: detailed extraoral and intraoral clinical examination, clinical photography, and cone-beam computed tomography (CBCT). Clinical examination took place 1 week, 3 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively. Transverse occlusion was clinically evaluated 1 year postoperative. CBCT was acquired 1 week, 6 months, and 1 year postoperatively.

Postoperative surgical complications documented were hemorrhage (eg epistaxis, mucosal bleeding), removal of osteosynthesis plates due to infection, palatal ulceration, aseptic necrosis of the palate, oronasal communication, epiphora, and mechanical failure of the distractor.

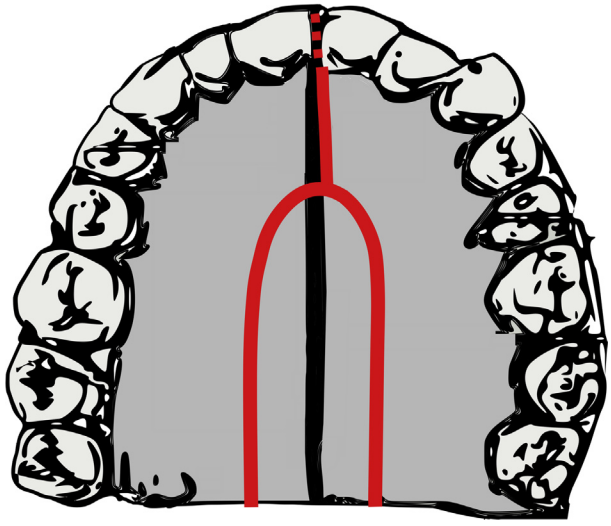

FIGURE 2. Surgical technique of 2-piece Le Fort I osteotomy. This figure depicts the performed 2-piece Le Fort I osteotomy with horse-shoe and paramedian osteotomy.

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Postoperative pain was assessed using the visual analog scale.[23] Patients experiencing a visual analog scale score of 7 or more were considered positive. Infection was evaluated and categorized as mucosal infection, maxillary sinus infection, and submucosal abscess formation. Malunion and nonunion were assessed clinically and with the help of CBCT imaging. Neuro-sensory disturbances (NSD) of the maxillary nerve were evaluated using the light-brush technique. Altered sensitivity was categorized according to the duration of symptoms: less than 3 weeks, 3 weeks to 1 year and more than 1 year. The period of altered sensitivity in the 2-stage group was the sum of the duration of NSD reported after SARPE and after Le Fort I osteotomy.

The following postoperative dental complications were clinically evaluated: loss of teeth, tooth discoloration, and gingival recession. Alveolar bone resorption at the interdental osteotomy site was evaluated using CBCT 6 months and 1 year postoperatively. In the segmented Le Fort I group, the postoperative diastema was measured using CBCT. Apical root resorption of the central incisor was evaluated using CBCT 1 year postoperatively, applying the Levander classification.[24] Levander subdivided apical root resorption into 4 categories (Fig 4). Class 1 root resorption involves an irregular root contour. Class 2 amounts up to 2 millimeter apical root resorption. Levander class 3 consists of apical root resorption from 2 mm to one third of the original root length. Class 4 resorption exceeds one third of the original root length.

Characteristics of the 2 treatment groups were compared using a Pearson chi-square and Mann-Whitney U tests. Complications with binary outcomes were compared using a generalized linear model with logit link for binary variables when sufficient data were available. Fisher exact test was used in case of few data. Numerical outcomes were evaluated using analysis of variance. *P*-value < .05 was considered significant.

Results

PATIENTS

After applying inclusion and exclusion criteria, 74 patients were enrolled in this study. Thirteen patients of the 2-stage group were excluded because SARPE was followed by segmental Le Fort I. The 1-stage group included 32 patients (mean age 27.2 y; male/female 1/1.5) and the 2-stage group included 42 patients (mean age 24.5 y; male/female 1.2/1). The mean time interval between SARPE and Le Fort I surgery was 18.8 months. There were no statistical differences for age ($P = .251$), gender ($P = .234$), and skeletal maxillary expansion ($P = .775$) between the 2 treatment groups. Unpaired t-test determined a significantly shorter orthodontic treatment duration for 1-stage patients in comparison with 2-stage patients ($P = .034$) and significantly more dental expansion following SARPE ($P = .009$). The mean postoperative created diastema for segmented Le Fort I osteotomy was 1.5 mm. Patients without dental or periodontal complications had a mean diastema of 1.3 mm and patients with dental or periodontal complications including severe root

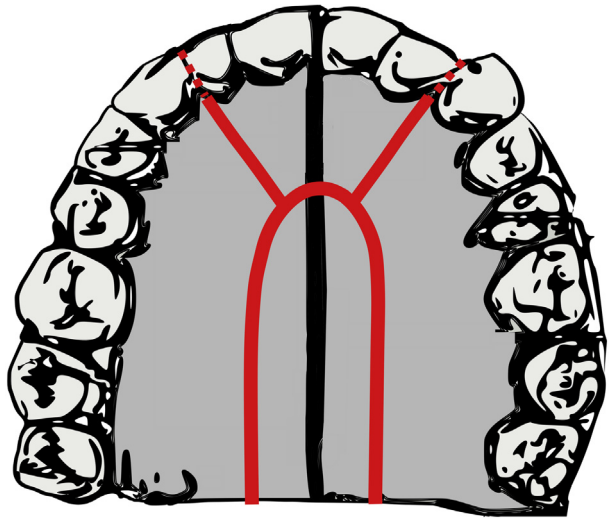

FIGURE 3. Surgical technique of 3-piece Le Fort I osteotomy. This figure depicts the performed 3-piece Le Fort I osteotomy with horse-shoe and interdental osteotomy distal of the lateral incisors.

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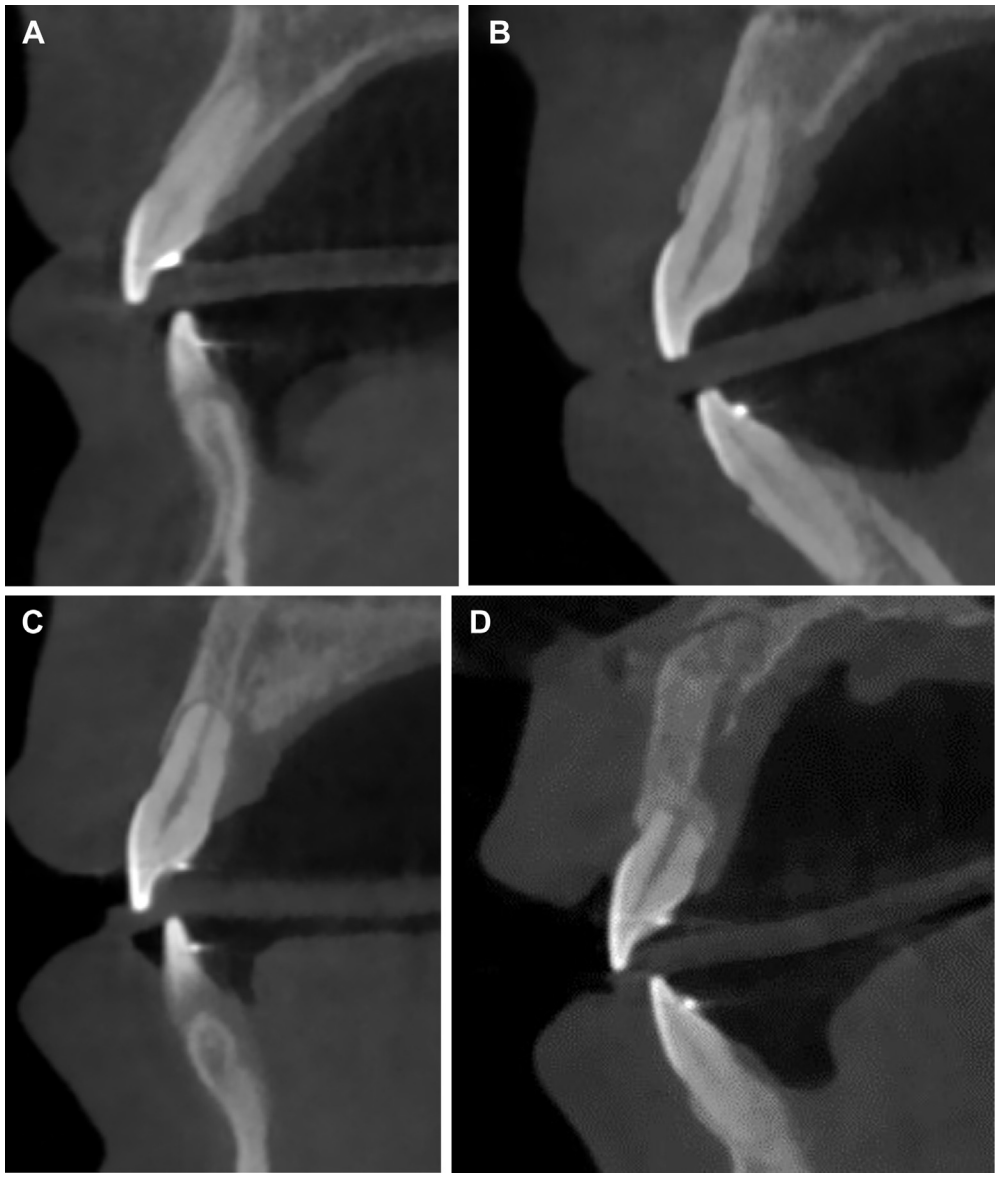

FIGURE 4. Levander classification. This figure depicts 4 sagittal cone-beam computed tomography images of maxillary central incisors corresponding to the 4 classes of the Levander classification. *A*, Class 1 root resorption includes an irregular root contour. *B*, Class 2 amounts up to 2 millimeter apical root resorption. *C*, Levander class 3 consists of apical root resorption from 2 mm to one third of the original root length. *D*, Class 4 resorption exceeds one third of the original root length.

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resorption (Levander class 3 or more) reported a mean diastema width of 1.7 mm ($P = .443$). Table 1 describes the patients and surgical characteristics.

COMPLICATIONS

Table 2 presents the postoperative complications after 1-stage and 2-stage surgery. Three patients (9.4%) showed bone resorption following segmental Le Fort I osteotomy. Tooth discoloration and gingival recession was present in respectively 2 (4.8%) and 1 (2.4%) patient of the 2-stage treatment. Severe apical resorption (Levander Class 3 or more) was reported in 53.1% of the 1-stage patients and 66.7% of the 2-stage patients. This difference was not significant ($P = .311$). No loss of teeth was reported.

Pain was significantly more reported in the 2-stage patient group ($P = .038$). NSD was present for more than 4 weeks after surgery in 59.4% of the 1-stage patients and 76.2% of the 2-stage patients ($P = .125$). Asymmetrical expansion was noticed in 2 patients (4.8%) after the SARPE procedure. Mechanical failure did not occur. Transverse unilateral posterior crossbite was reported in 2 patients (6.2%) in the 1-stage and 2 patients (4.8%) in the 2-stage group at 1 year postoperatively.

Table 1. PATIENT AND SURGICAL CHARACTERISTICS

	1-Stage		2-Stage	
	Number (n)	%	Number (n)	%
Total	32		42	
Male	13	40.6	23	54.8
Female	19	59.4	19	45.2
Age (years ± SD)	27.2 ± 11.3		24.45 ± 9.05	
Skeletal maxillary widening (mm ± SD)	2.7 ± 2.2		2.9 ± 2.8	
Dental maxillary widening (mm ± SD)	3.0 ± 2.9		5.2 ± 2.9	
Orthodontic treatment time (months ± SD)	19.8 ± 13.6		25..4 ± 8.7	
Time between surgeries (months ± SD)			18.77 ± 6.15	
Concomitant BSSO	25	78.1	33	78.6
2-piece	14	43.7		
3-piece	18	56.2		
Distal of LI				
Q1	13	40.6		
Q2	14	43.7		
Distal of C				
Q1	5	15.6		
Q2	4	12.5		
Mean postoperative diastema (mm)	1.5 ± 0.9		5.8 ± 2.7	

This table shows the description of the demographic and surgical characteristics of 1- and 2-stage patients. Time between SARPE and Le Fort I is described for the 2-stage patient group. The location of the interdental osteotomy of 3-piece Le Fort I patients is specified.

Abbreviations: BSSO, bilateral sagittal split osteotomy; C = canine; LI = lateral incisor; Q1 = first quadrant; Q2 = second quadrant; SD, standard deviation.

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Three patients (9.4%) reported mucosal or maxillary sinus infection after segmental Le Fort I osteotomy and 4 patients (12.5%) underwent removal of osteosynthesis hardware due to infection. Six patients (14.3%) of the 2-stage group showed signs of mucosal infection or abscess formation, and in 3 patients (7.1%), hardware was removed.

Thirteen patients were excluded because SARPE was followed by segmented Le Fort I osteotomy. Two of the excluded patients (15.4%) reported pain following surgical treatment and 1 patient (7.7%) had osteosynthesis plates removed due to infection. One patient (7.7%) reported gingival recession and bone resorption and 3 patients (23.1%) showed signs of severe root resorption. Mechanical failure occurred in 1 patient (7.7%) and asymmetrical expansion was observed following SARPE in 1 patient (7.7%). NSD was resolved within 1 year in all 13 patients. Loss of teeth, tooth discoloration, hemorrhage, abscess formation, oro-nasal communication, aseptic necrosis, malunion, and lacrimation did not occur following SARPE or segmental Le Fort I surgery.

Discussion

This study aimed to assess complications after 1-stage segmental maxillary osteotomy and a 2-stage procedure with SARPE followed by 1-piece Le Fort I osteotomy. Most complications reported in this study were of transient nature and no life-threatening events occurred. Postoperative pain was significantly more present in patients who underwent a 2-stage procedure ($P = .038$). Other postoperative complications were comparable for 1-stage and 2-stage procedures. Thirteen patients were excluded from this study because SARPE treatment was followed by segmental Le Fort I. This illustrates that it is not always possible to avoid a multisegmental Le Fort I by performing a SARPE procedure.

For dental complications, no statistical difference was found between 1-stage and 2-stage treatment strategies. The most frequent dental complication in the 1-stage group was periodontal bone resorption at the interdental osteotomy site (9.4%). Two-stage procedures were associated with gingival recession in 1 patient (2%) and tooth discoloration in 2 patients (4.8%). Thermal vitality test confirmed pulpal necrosis of the discolored teeth hence root canal treatment was performed. Posnick et al.[12] reported tooth discoloration in 1.1% of patients treated with segmental or nonsegmental maxillary osteotomy and gingival recession in 6.5% of segmental Le Fort I patients. Apical root resorption was relatively high in both groups 1 year after treatment, as, respectively, 25.0 and 35.7% of the 1-stage and 2-stage patients presented with a Levander

Table 2. COMPLICATIONS

	1-Stage		2-Stage		*P*-value
	Number	%	Number	%	
Dental					
Tooth loss	0	0.0	0	0.0	1
Tooth discoloration	0	0.0	2	4.8	0.502
Gingival recession	0	0.0	1	2.4	1
Bone resorption	3	9.4	0	0.0	0.077
Levander classification					
1	7	21.9	2	4.8	
2	7	21.9	11	26.2	
3	9	28.1	13	31.0	
4	8	25.0	15	35.7	
Mean ± SD	2.6 ± 1.1		2.9 ± 1.0		
Surgical					
VAS ≥7	1	3.1	8	19.0	0.038*
NSD					
<4 weeks	12	37.5	7	16.7	
4 weeks-1 yr	14	43.7	25	59.5	
>1 yr	5	15.6	7	16.7	
Hemorrhage	0	0.0	1	2.4	1
Infection					
Mucosal	2	6.2	3	7.1	0.881
Sinusitis	1	3.1	0	0.0	0.432
Abscess	0	0.0	3	7.1	0.254
Plate removal	4	12.5	3	7.1	0.442
Oro-nasal communication	0	0.0	0	0.0	1
Palatal ulcer	0	0.0	0	0.0	1
Aseptic necrosis	1	3.1	0	0.0	0.432
Malunion/nonunion	0	0.0	0	0.0	1
Asymmetrical expansion	/	/	2	4.8	/
Epiphora	0	0.0	0	0.0	1
Mechanical failure	/	/	0	0.0	/
Lateral crossbite	2	6.2	2	4.8	0.783

In this table, complications are compared between 1-stage and 2-stage patients.
Abbreviations: NSD, neurosensory disturbances; SD, standard deviation; VAS, visual analog scale.
* Indicates a significant *P*-value ($P < .05$).

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classification of 4. The study of Mordenfeld and Andersson[25] reported 1 patient (5%) with apical root resorption following midline-split Le Fort I osteotomy. Makedonas et al.[26] evaluated root resorption in patients who underwent orthodontic treatment using the Levander classification and reported grade 3 resorption in 25.6% and grade 4 in 0.6% of the patients. A possible explanation for the relative high incidence of severe apical root resorption in the current study can be that the interdental osteotomy might have impaired the periodontal vascularization.[25] This ischemic event can lead to cell necrosis and subsequent root resorption. Second, it is hypothesized that orthodontic closing of the created diastema following segmental Le Fort I and SARPE might have contributed to root resorption, as orthodontic treatment is a well-described risk factor.[27,28] However, this study did not find a large discrepancy regarding postoperative diastema in 1-stage patients with (1.7 mm) and without (1.3 mm) dental or periodontal complications including severe root resorption. Despite the fact that 1-stage treated patients underwent a shorter orthodontic treatment, there was no significant difference in incidence and severity of root resorption. Further research with the use of 3-dimensional volumetric analysis of root resorption following segmental Le Fort I and SARPE treatment is recommended to investigate the relatively high frequency of root resorption.

Infection was comparable for both groups. Two-stage treated patients reported relatively more abscess formation (1 patient after SARPE and 2 patients after Le

Fort I osteotomy). Incision and draining of the abscess under local anesthesia followed by antibiotic treatment swiftly alleviated the symptoms. Varying incidences are reported concerning removal of osteosynthesis plates after Le Fort I.[12,29] The study of Falter et al.[30] reported removal of hardware due to infection in 13.7% of the patients. In the present study, incidence of infection-related removal of osteosynthesis plates was similar for both groups.

Aseptic necrosis of the palate is a troublesome complication of segmented Le Fort I osteotomy. Kramer et al.[31] identified segmented Le Fort I osteotomies to be more susceptible to ischemic complications, although other studies did not find a relevant association between maxillary segmentation and decreased vascularization.[32,33] Consensus on treatment strategy of aseptic necrosis is currently lacking.[34] In this study, 1 patient of the 1-stage procedure presented with aseptic necrosis of the palate, which was successfully treated with systemic antibiotics and local chlorhexidine gluconate oral rinse.

Asymmetrical expansion is a frequently described complication after SARPE, as Verlinden et al.[35] reported an incidence of 6.8%. In the present study, asymmetrical expansion occurred in 2 patients. In 1 patient, this was orthodontically corrected, while the other patient was surgically treated using a yaw-correction during a subsequent Le Fort I osteotomy.

Based on complication rate, no clear distinction was found in the present study between 1-stage and 2-stage treatment. In addition to complication rate, the significantly longer orthodontic treatment time in 2-stage treated patients might influence the preferred treatment strategy, bearing in mind the related costs to health care systems. Cost-analysis of a 1-stage versus 2-stage treatment approach, including complications, treatment outcome, and long-term outcome stability should be the scope of a further study.

A limitation of this study was the retrospective design, which inherently introduces selection bias of the 2 treated groups such as the difference in indications for the 1-stage and 2-stage treatment approach. The use of tooth-borne distractors in this study might have an influence on incidence of complications. However, Zandi et al.[36] reported comparable complications for bone-borne and tooth-borne distraction after SARPE. Patient satisfaction as well as orthodontist's preference were not reviewed in the present study. Nasal alar base width changes after SARPE and Le Fort I were not evaluated in this study, nor were changes of incisor inclination after SARPE versus Le Fort I. Further research of nasal changes using 3D stereophotogrammetry and (cone-beam) CT is recommended.

To the best of our knowledge, this is the first comparative assessment of complications following 1-stage segmental Le Fort I osteotomy and 2-stage SARPE-Le Fort I osteotomy. The regular follow-up of up to 1 year postoperatively allowed for a detailed analysis of complications.

In conclusion, this study reports and compares complications after 1-stage segmental maxillary osteotomy and 2-stage SARPE followed by 1-piece Le Fort I osteotomy, to correct mild transverse maxillary hypoplasia. Pain was significantly more present following the 2-stage approach. The incidence and severity of other complications were similar for both patient groups. Considering an equivalent complication rate and comparable transversal stability, the choice between 1-stage and 2- stage approach for patients with a moderate transverse maxillary hypoplasia should be patient specific and decided after thorough discussion seeking patient's informed consent.

Acknowledgement

The authors would like to thank biostatistician Wim Coucke for his analysis and advice.

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