Original Article

Combined orthodontic and surgical open bite correction: *Principles for success. Part 1*

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This paper is divided into Part 1, the study findings, and Part 2, a detailed explanation of orthodontic and surgical methods used in the study. In this Part 1, treatment protocols will be mentioned, but explained in Part 2.

ABSTRACT

Objectives: To examine the stability of combined surgical and orthodontic bite correction with emphasis on open-bite closure. All study patients were treated with strict and consistent orthodontic and surgical protocols.

Materials and Methods: Study inclusion required all patients to have anterior open bites, maxillary accentuated curve of Spee, 36-month minimum follow-up, and no temporomandibular joint pathology. Thirty patients met the inclusion/exclusion criteria. Importantly, segmental upper arch orthodontic preparation (performed by EG) was used. Surgery consisted of a multisegment Le Fort I (MSLFI) combined with a bilateral sagittal osteotomies (BSSO). Surgery was performed (by ADA and LT) at the Department of Dentistry and Maxillofacial Surgery of the University of Verona, Italy.

Results: The long-term open bite and overjet relapse were not statistically significant. The mean transverse relapse of the upper and lower molars was statistically significant. Of great importance, the upper and lower arch widths narrowed together, maintaining intercuspation of the posterior dentition which prevented anterior open bites from developing.

Conclusions: This study revealed stability of three-dimensional occlusal correction including anterior open bite. Stable open bite closure was achieved by using rigid protocols for orthodontic preparation, surgical techniques, surgical follow-up, and orthodontic finishing. (*Angle Orthod.* 2022;92:161–172.)

KEY WORDS: Open bite; Orthognathic; Orthodontic

INTRODUCTION

Anterior open bite is the lack of overlap of the incisor teeth in centric occlusion.[1] Open bite malocclusion is found in 0.6% of the adult population in the USA. At a younger age, it is more frequent and accounts for 17% of all patients who undergo orthodontic treatment.[2]

The clinical features associated with open bite are variable and may include excessive anterior face height, lip incompetence, Class II or Class III tendency, mandibular retrusion or protrusion, and mandibular anterior crowding. A tendency toward a narrow maxilla is often associated with open bite. The cephalometric features reported in the literature include maxillary accentuated curve of Spee, clockwise rotation of the mandible with a steep occlusal plane, excessive eruption of the maxillary and mandibular incisors, and increased lower facial height.[3,4]

Etiology

The etiology can be related to the morphogenetic theory (aberrant genetic control of the growth pattern) or the adaptive theory (malformation secondary to

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naso-oropharyngeal dysfunction). The etiology in most cases is thought to be multifactorial.[2] In the juvenile population, a statistically significant association was found between sleep breathing disorders, snoring, crossbite, open bite, and increased overjet.[5,6]

Open bite is frequently associated with temporomandibular disorder (TMD) signs and symptoms.[7,8] In 2004, Gesch et al.[8] evaluated the association of all malocclusions with temporomandibular disorders and reported only a linkage between anterior open bite and TMD. Tanaka et al.[9] found that temporomandibular joint (TMJ) stresses were significantly larger in skeletal open bite malocclusions. The wide range of open bite treatment options, the lack of well-defined guidelines, and the high relapse rate may be explained by difficulties in defining etiology.

Open Bite Treatment Techniques

Open bite treatment is challenging for orthodontists and surgeons. The stability hierarchy of Proffit et al.[10] describes open bite correction as the least stable of orthodontic and surgical corrections. Many options have been attempted to close anterior open bites with varying success.

In orthodontics, open bite treatment options range from simple observation, control of childhood habits, to traditional orthodontic appliances, which may produce compensations if a skeletal malformation is present. Traditional orthodontic appliance open bite closure may relapse[11–17] and produce inadequate overbite. Additionally, traditional orthodontics may not produce esthetic corrections and airway enlargement when skeletal malalignments are present.[18]

Recently developed use of temporary anchorage devices (TADs), with or without corticotomies, in selected cases, produced occlusal correction even though there is lack of evidence of long-term stability given that the method is of relatively recent application.[11,19,20]

Surgical procedures such as one-piece or multisegment Le Fort I are often combined with mandibular surgery to correct open bite. This surgical treatment, whether isolated upper jaw osteotomies or bimaxillary osteotomies, was often characterized by unsatisfactory results in terms of long-term stability, final overbite values, and facial esthetics.[21–25]

Part 1 of this paper reports on the stability study of 30 patients while Part 2 will discuss the comprehensive surgical and orthodontic techniques used on the 30 patients. The authors hypothesized that the orthodontic and surgical methods detailed in Part 1 and Part 2 of this paper would produce stable long-term results in malocclusions including anterior open bite.

MATERIALS AND METHODS

A longitudinal retrospective study of 30 malocclusion patients treated at the Unit of Maxillofacial Surgery and Dentistry of the University Hospital of Verona between 2005 and 2012 was completed. Due to the retrospective nature of this study, an exemption was granted by the University of Verona Institutional Review Board (IRB). A total of 229 patients underwent orthognathic surgery during this 7-year period. Inclusion criteria required double jaw surgery, a multisegment maxilla, anterior open bite, an accentuated curve of Spee, presurgical healthy TMJ as assessed on CBCT, and no growth potential. Growth and TMJ remodeling were excluded to eliminate their influences on open bite relapse. Multisegment Le Fort I osteotomy was performed in 135 of the 229 patients. Maxillary double occlusal plane (accentuated curve of Spee) and anterior open bite were present in 51 of the 135 patients. The presence of an anterior open bite was defined by no vertical overlap of the upper and lower incisor tips (0 equals edge to edge). Eight patients were further excluded due to an ongoing or potential systemic pathology involving the temporomandibular joints. Patients were then excluded if dental casts (presurgery, immediate postsurgery, long-term) were not available, or follow-up was less than 36 months. Thirty patients met the established inclusion or exclusion criteria.

The occlusion and TMJs were assessed at every visit by the surgeons and orthodontist. Bite centric occlusion to centric relations (CO to CR) accuracy was carefully assessed clinically and with cone beam computed tomography (CBCT).

Measurements of Dental Casts

All dental cast measures were made by an independent dental technician not involved in the study. The dental casts were mounted on the SAM III articulator (SAM Präzisionstechnik GmbH, München, Germany; Figure 1) and measured with an electronic caliper (EC799A Electronic Caliper, Starrett, Schmitten, Germany). The reproducibility of the results was 0.01 mm. The Dahlberg test was performed to determine accuracy. All measurements were accomplished at three timepoints: presurgery (Pre), immediate postsurgery (IPost), and long-term postsurgery (LPost). LPost was a minimum of 36 months.

Vertical Measurements

The anterior overbite was measured as the vertical distance between the incisal edges of the upper central incisors and the lower central incisors. The anterior open bite correction was the difference between the

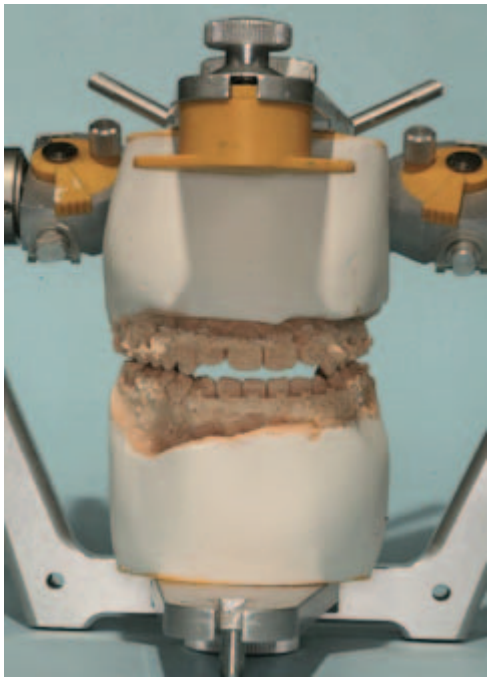

Figure 1. Mounted models used for measurements of overbite, overjet, and widths.

overbite presurgery (Pre) to immediate postsurgery (IPost). Open bite relapse was the difference between the overbite at IPost and the longest LPost.

Transverse Measurements

The transverse molar dimensions were measured at the mesiobuccal cusps of maxillary first and second molars and the mesiobuccal cusps of the mandibular first and second molars. The lower molar widths were only measured Pre and LPost. Mandibular arch width was not measured IPost because surgery did not change the lower arch width.

The expansion of the upper arch was the difference from Pre to IPost. Maxillary expansion relapse was the difference between IPost and LPost. The lower molar width difference Pre to LPost represented pure orthodontic relapse and should have been minimal if arch width and form were not altered during orthodontic preparation.

Anteroposterior Measurements

Incisor overjet values were measured using the methods described already. The extent of sagittal correction was given by the overjet difference at Pre and at IPost. Overjet relapse was the overjet difference between IPost and LPost.

Statistical Analysis

Student's *t*-test for paired samples was used given the observational nature of the study. Correlations were performed between overjet, overbite, and molar widths at Pre, IPost, and LPost. A P value of $<.05$ was considered statistically significant.

Orthodontic Preparation

All patients underwent presurgical orthodontic preparation and postsurgical orthodontic refinement lasting an average of 20 months in total and performed by one orthodontist (EG). The fact that only one orthodontist was involved is important to the homogeneity of orthodontic care and thus significant to statistical conclusions. The presurgical orthodontic philosophy (Table 1) and appliance (Table 2) specific to surgery are listed. For further details and a complete explanation, see Part 2 of this paper.

Surgery

The surgical movements were planned to correct the face, airway, and bite as described by Arnett et al.[26–32] Presurgical open bite did not determine the surgical movements; the face and the airway determined how and where the corrected Class I occlusion was positioned (Table 3).

All 30 treatment plans and surgeries were performed by two surgeons (ADA, LT).

The two surgeons operated the 30 cases using identical technique, producing identical surgical results and thus valid surgical findings. Many previous studies

Table 1. Stable Presurgical Orthodontic Philosophy for the Upper and Lower Arches[a]

Parameter	Upper Arch	Lower Arch
Arch form	Maintain	Maintain
Arch width	Maintain	Maintain
Curve of Spee	If accentuated: maintain	If accentuated: flatten
	If reverse: flatten	If inverted: flatten
	If flat: maintain	If flat: maintain
Incisors	Decompensate	Decompensate
Teeth	Level marginal ridges and align to maximize intercuspation	Level marginal ridges and align to maximize intercuspation

[a] Orthodontic philosophy guides presurgical orthodontic tooth movements and improves stability, periodontal health, and bite correction accuracy. Importantly, when an upper arch accentuated curve of Spee was present, it was maintained during orthodontic preparation.

Table 2. Effective Presurgical Orthodontic Appliances for the Upper and Lower Arches[a]

	Upper Arch	Lower Arch
Arch	Continuous archwire: maintain arch form Segment archwire: place 4 months presurgery at location of maxillary curve of Spee break to allow orthodontic relapse prior to surgery	Continuous archwire: maintain arch form
Appliances	First molars: place bands, headgear tubes, and lingual cleats	Incisors: place brackets slightly low to allow deep overbite during surgery

[a] Specific orthodontic requirements are listed that enable maximal intercuspation in the operating room. Maxillary expansion requires mandatory bands on the upper first molar teeth to prevent dislodging during surgery. Upper first molar lingual cleats or sheaths allow cross arch elastics or a transpalatal bar after surgery to maintain expansion of the maxilla.

suffered from having different surgeons and surgical techniques reported as one. The current study employed one technique and, therefore, the findings offer enhanced validity and significance.

Every patient underwent a Multisegment Le Fort I (MSLFI),[33] bilateral sagittal split osteotomies (BSSO), and simultaneous esthetic procedures, including genioplasty, malar augmentation, or fat grafting, when indicated.[34] Bimaxillary surgery was used to correct both jaws in three dimensions and, importantly, to allow occlusal plane alterations, which controlled the face (nasal base and chin) and airway changes.[26–32,35–37] Surgical techniques in the operating room (Table 4) and procedures to maximize intercuspation of the upper and lower dentition (Table 5) are listed. For further details and a complete explanation, see Part 2 of this paper.

Postsurgical Treatment

After surgery, the patients were followed closely by the surgeons and orthodontist. Elastics were routinely worn by all patients (Figure 2). If needed, light equilibration, in-to-out elastics or a transpalatal bar were used to remove any posterior interference immediately, which could open the anterior bite. By immediately closing the bite and maximizing posterior intercuspation, width coordination between the upper and lower arches was maintained. After braces removal, an upper Hawley type appliance was placed along with a lower anterior fixed braided wire. The key to retainer design was to allow posterior intercuspation, which maintains arch width coordination (Figure 3). For further details and a complete explanation, see Part 2 of this paper.

Table 3. Effective Surgical Treatment Planning Philosophy[a]

1. Facial correction
2. Airway correction
3. Bite correction
4. Bimaxillary surgery necessary for 1, 2, 3 corrections

[a] The face-airway-bite philosophy guided orthodontic planning (incisor decompensation) and three-dimensional bimaxillary surgical movements.

RESULTS

Of the 30 patients, 19 were female and 11 male, with an average age of 26 ± 7.65 years (range, 17–43 years). Postoperative mean follow-up was 49.43 (range, 36–92 months).

Based on presurgical dental overjet, 24 patients were Class III while 6 were Class II. Twenty-one cases had asymmetry when viewed frontally.

The curve of Spee was studied on dental casts prior to orthodontic preparation. In 28 patients, the bilateral maxillary occlusal plane break occurred between the lateral incisors and canines (Figure 4); consequently, the multisegment was placed between the lateral and canine teeth. In two patients, the bilateral occlusal plane break occurred between the canines and first premolars; consequently, the interdental osteotomies were placed between the canine and first premolar teeth.

Postsurgical CT scans did not show degenerative TMJ changes. In one case, there was mild flattening of one condylar head, which did not create occlusal alterations such as centric occlusion–centric relation (CO-CR) discrepancy or pain symptoms.

Overbite (Table 6)

The mean overbite at all time points is listed in Table 6. The open bite relapse from IPost to LPost was −0.21 ± 0.61 mm (range, −0.82 to +0.40 mm). Open bite

Table 4. Effective Surgical Techniques in the Operating Room[a,b]

1. Use intermediate splint
2. Perform BSSOs first
3. Place two plates with unicortical screws per BSSO side
4. Graft to BSSO
5. Perform MSLFI second
6. Omit final splint
7. Place two plates per MSLFI side with monocortical screws
8. Graft to LFI

[a] Basic surgical techniques used and that produced stable occlusal corrections for the study patients. Bimaxillary surgery allows correction of midlines, cants, yaws, anteroposterior positions, and occlusal planes of both jaws—total control.

[b] BSSO indicates bilateral sagittal osteotomy; LFI, Le Fort I; MSLFI, multisegment LFI.

Table 5. Techniques That Maximize Dental Intercuspation[a,b]

1. Perform orthodontic alignment, marginal ridge leveling, derotations, and axial inclination corrections
2. Perform presurgery composite bonding of worn buccal cusps
3. Perform presurgery equilibration of teeth
4. Perform MSLFI
5. Omit final splint

[a] These steps maximize intercuspation, which stabilizes surgical maxillary expansion and coordination of upper and lower arch forms and widths. Maxillary width increases relapse with flat teeth and are stable when the teeth intercuspate (lock together). Bonding and equilibration may be accomplished by either the orthodontist or surgeon the week prior to surgery.
[b] MSLFI indicates multisegment Le Fort I.

relapse was not statistically significant. 60% (18/30) of patients had no relapse or an increase in overbite from IP to LPost. A total of 12 patients had no open bite relapse from IPost to LPost. Meanwhile, 6 patients experienced an increase in overbite from IPost to LPost.

Only 12 of 30 (40%) patients experienced any open bite relapse tendency. Of the 12 patients in the relapse tendency group, nine patients demonstrated a positive overbite between 2 and 4 mm (ideal = 3) at LPost. Only 3/30 patients had an overbite of less than 2 mm (range, 0.5 to 2 mm) at LPost. It should be stressed that the minimum follow-up was 36 months.

Upper Arch Width (Table 7)

The maxillary molars narrowed from IPost to LPost. Mean relapse at the maxillary first molars was –1.87 ± 1.92 mm (range, –3.79 to +0.05) and –1.71 ± 2.89 mm (range, +1.18 to –4.60) at the maxillary second molars. Mean width decrease (surgical relapse) was statistically significant for the maxillary first and second molars (M1: $P < .001$; M2: $P = .003$).

Lower Arch Width (Table 8)

The mandibular molars narrowed from IPost to LPost. The mean relapse at the first molars was –0.82 ± 1.52 mm (range, –2.34 to +0.7), whereas the second molar width decrease was –1.02 ± 2.12 mm (range, –3.14 to +1.1). LPost mean mandibular molar decrease was statistically significant (M1: $P = .008$; M2: $P = .019$). No surgical procedures altered the mandibular molar widths. The LPost decrease of molar width, therefore, represents orthodontic relapse. Perhaps, with preparation for surgery, the mandibular molar widths were inadvertently increased.

Overjet (Tables 9 and 10)

Six patients had Class II malocclusion and 24 patients presented with Class III malocclusions. Overjet was measured from incisor tip to incisor tip.

Class II Malocclusions (Table 9)

In the Class II mandibular advancement group (6 of 30), long-term overjet relapse (IPost to LPost) was minimal –0.34 ± 0.52 mm (range –0.86 to +0.18). This relapse was insignificant and generally in a Class III direction.

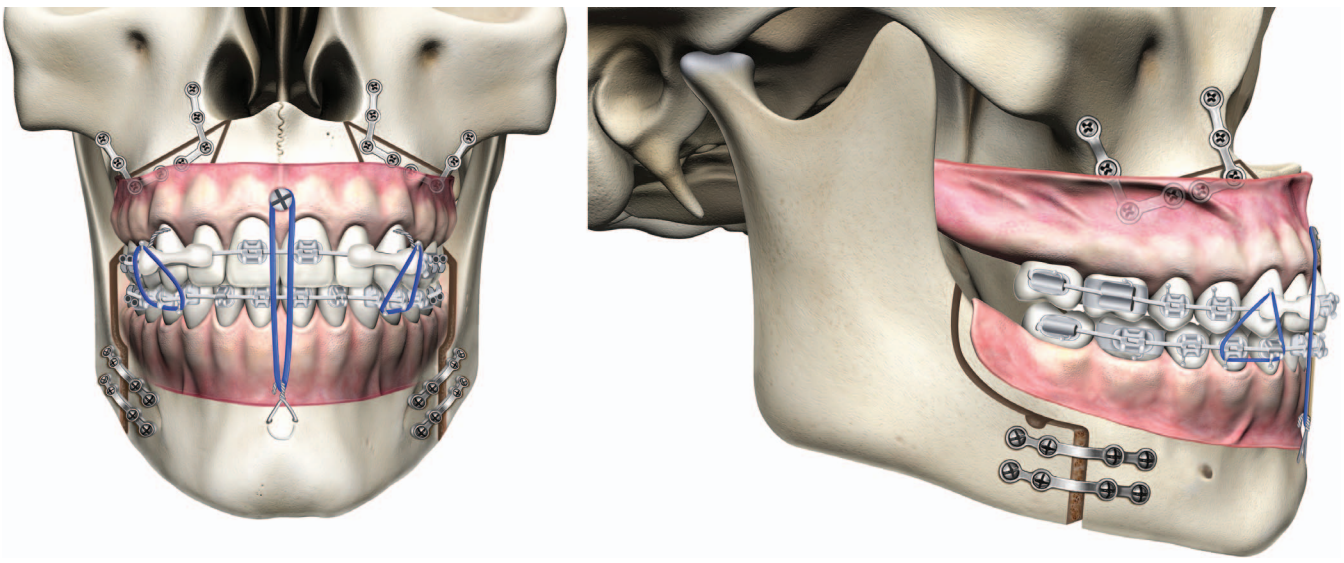

Figure 2. Elastic wear postsurgery. Daytime: Canine triangles (maxillary canine to mandibular canine and first premolar), midline skeletal anchorage (maxillary midline screw to B point wire); one elastic each position. Nighttime: same pattern; two elastics each position. Note: patients instructed to not open while elastics in place. Note: elastics removed for two 30-minute periods each day to exercise joints. Note bands on the upper first molars, which are necessary during surgical intermaxillary fixation to avoid dislodging under traction.

Figure 3. Left: The retainer design stabilized the maxillary dental arch but, importantly, allowed maximal intercuspation to hold maxillary width increases. The retainer does not separate the posterior teeth in any fashion to maintain intercuspation and width stability. Right: A long-lasting lingual wire retainer was positioned on the mandibular anterior teeth from canine to canine.

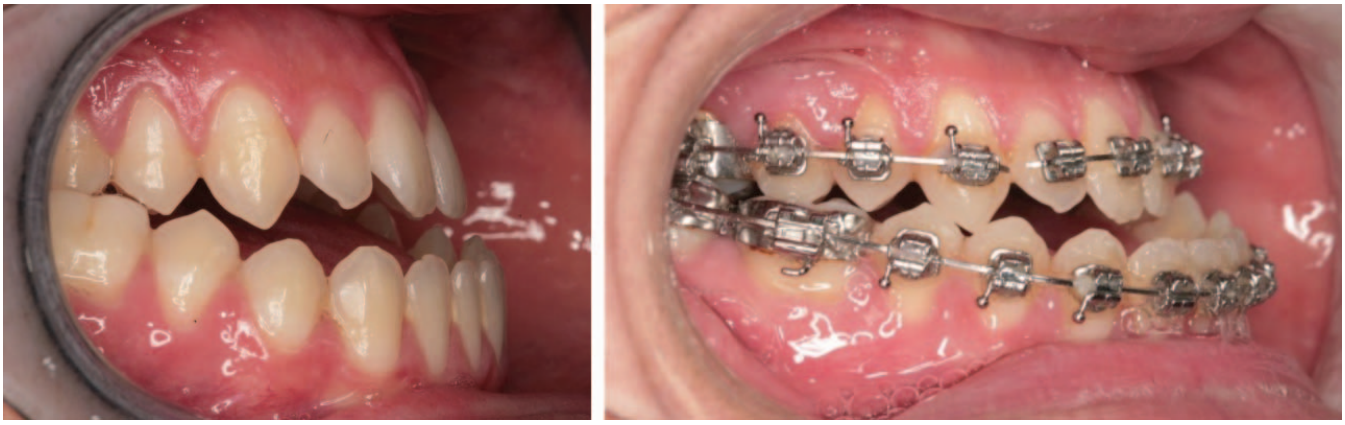

Figure 4. Left: curve of Spee break between the canine and lateral incisor. Right: orthodontic archwire cut at preorthodontic break in the curve of Spee between the canine and lateral incisor. Note: bands on upper first molars and not brackets, which dislodge in the operating room during intermaxillary fixation.

Table 6. Overbite Changes[a]

	Pre	IPost	LPost	Pre to IPost	IPost to LPost	Pre to LPost
Mean (SD), mm	−1.77 (1.88)	2.42 (0.54)	2.21 (0.63)	+4.19 (2.02)	−0.21 (0.61)	+3.98 (1.98)
P value	—	—	—	<.001	.069	<.001

[a] — indicates not applicable; IPost, immediate postsurgery; LPost, longest term postsurgery; Pre, presurgery; SD, standard deviation. The relapse of overbite was not statistically significant.

Table 7. Upper Jaw Transverse Dimensions[a,b]

Maxillary Molar	Pre	IPost	LPost	Pre to IPost	IPost to LPost	Pre to LPost
First, mean (SD), mm	50.20 (2.59)	52.95 (2.95)	51.08 (2.81)	+2.75 (1.81)	−1.87 (1.92)	+0.88 (2.10)
P value	—	—	—	<.001	<.001	.21
Second, mean (SD), mm	55.23 (2.64)	58.88 (3.79)	57.17 (3.41)	+3.65 (2.81)	−1.71 (2.89)	+1.94 (4.31)
P value	—	—	—	<.001	.003	.002

[a] Measurements were taken at the first and second maxillary molar buccal cusp tips.
[b] — indicates not applicable; IPost, immediate postsurgery; LPost, longest term postsurgery; Pre, presurgery; SD, standard deviation. The LPost narrowing of maxillary width was statistically significant.

Table 8. Lower Arch Transverse Dimensions[a,b]

Mandibular Molar	Pre	LPost	Pre to LPost
First, mean (SD), mm	45.52 (2.91)	44.70 (3.29)	−0.82 (1.52)
P value	—	—	.008
Second, mean (SD), mm	52.13 (3.44)	51.11 (3.55)	−1.02 (2.12)
P value	—	—	.019

[a] Measurements were taken at the first and second mandibular molars. No immediate postsurgery value was reported because there is no change in the mandibular arch with surgery. Relapse values were measured from immediate Pre to LPost. Note narrowing of the mandibular molar arch width mirroring the narrowing of the upper arch. The LPost narrowing of mandibular width was statistically significant.

[b] — indicates not applicable; LPost, longest term postsurgery; Pre, presurgery; SD, standard deviation.

Class III Malocclusions (Table 10)

In the Class III group, the overjet relapse (IPost to LPost) was minimal −0.57 ± 0.77 mm (range, –1.34 to +0.20). This relapse was not statistically significant and generally in a Class III direction.

Clinical Case Example

A representative single case from the study is presented in Figure 5: patient introduction; Figure 6: orthodontic preparation (prepared and finished by Dr. EG); and Figure 7: long-term surgical results (by Drs. ADA and LT).

DISCUSSION

For orthodontists and surgeons, successful treatment of malocclusion, in particular open bite, is difficult. Results may be unsatisfactory in function, esthetics, airway, and stability, with high relapse rates reported in the literature.[11–18,21,22,25]

This study described the details of successful occlusal correction that employed highly defined and strict orthodontic and surgical protocols. The problem with much literature reporting is that surgeons and orthodontists use the same terminology to describe treatment and yet do the same treatment differently. For example, all orthodontists refer to presurgical orthodontic preparation and, yet, accomplish that with different procedures and with varying success. Similarly, surgeons all accomplish surgical intermaxillary fixation (IMF) and, yet, no two surgeons do IMF the same nor with equal accuracy. The current study used assiduous protocols to standardize techniques and terminology for orthodontics and surgery.

Orthodontic Occlusal Relapse

Orthodontic relapse literature. Orthodontic relapse, especially open bite, has been widely published. Lopez-Gavito et al.[15] reported that at least 35% of orthodontic only open bite closures relapsed. In papers by de Freitas et al.[13] and Janson et al.[14] involving orthodontic open bite closure, 25.8% of extraction patients and 38.1% of non-extraction patients presented with open bite at the long-term follow-up. Additionally, Remmers et al.[16] reported that 27% of patients had a negative overlap in the posttreatment period and concluded that stability of orthodontic anterior open bite closure was very poor. Baek et al.[12] reported that significant orthodontic overbite relapse occurred the first year (80%) after maxillary molar intrusion to correct open bites.

Table 9. Class II Malocclusion Overjet[a,b]

	Pre	IPost	LPost	IPost to LPost
Mean (SD), mm	6.5 (3.02)	1.92 (0.74)	1.58 (0.74)	−0.34 (0.52)
P value	—	—	—	.06

[a] Note the excellent stability. Overjet relapse (IPost to LPost) was statistically insignificant.

[b] — indicates not applicable; IPost, immediate postsurgery; LPost, longest term postsurgery; Pre, presurgery; SD, standard deviation.

Orthodontic relapse etiology. The orthodontic relapse literature is extensive as are the proposed etiologies. However, the magnitude of dental tooth movement is consistent; orthodontic treatment relapse strongly correlates with the magnitude of orthodontic dental movements required to correct the malocclusion.[38] The farther a tooth was moved dentally to correct the occlusion, the greater the orthodontic relapse.[21,39–48] Therefore, it is prudent to avoid large orthodontic dental movements in presurgical orthodontic preparation to minimize orthodontic relapse after surgery. According to this principle, orthodontic preparation is used to correct dental issues such as rotation, inclination, and alignment (Tables 1 and 2) while surgery corrects three-dimensional skeletal discrepancies.

Surgical Occlusal Relapse

Surgical relapse literature. Surgical relapse, including anterior open bite, has been extensively reported. Open bite surgical correction, as stated by Proffit and others has the greatest tendency for relapse.[3,10,15,29,38] With Le Fort I osteotomy, McCance et al.[24] reported that the majority of patients had no

Table 10. Class III Malocclusion Overjet[a,b]

	Pre	IPost	LPost	IPost to LPost
Mean (SD), mm	−2.79 (3.25)	1.83 (0.6)	1.26 (0.42)	−0.57 (0.77)
P value	—	—	—	.23

[a] Note the excellent stability. Overjet relapse (LPost to IPost) was statistically insignificant.

[b] — indicates not applicable; IPost, immediate postsurgery; LPost, longest term postsurgery; Pre, presurgery; SD, standard deviation.

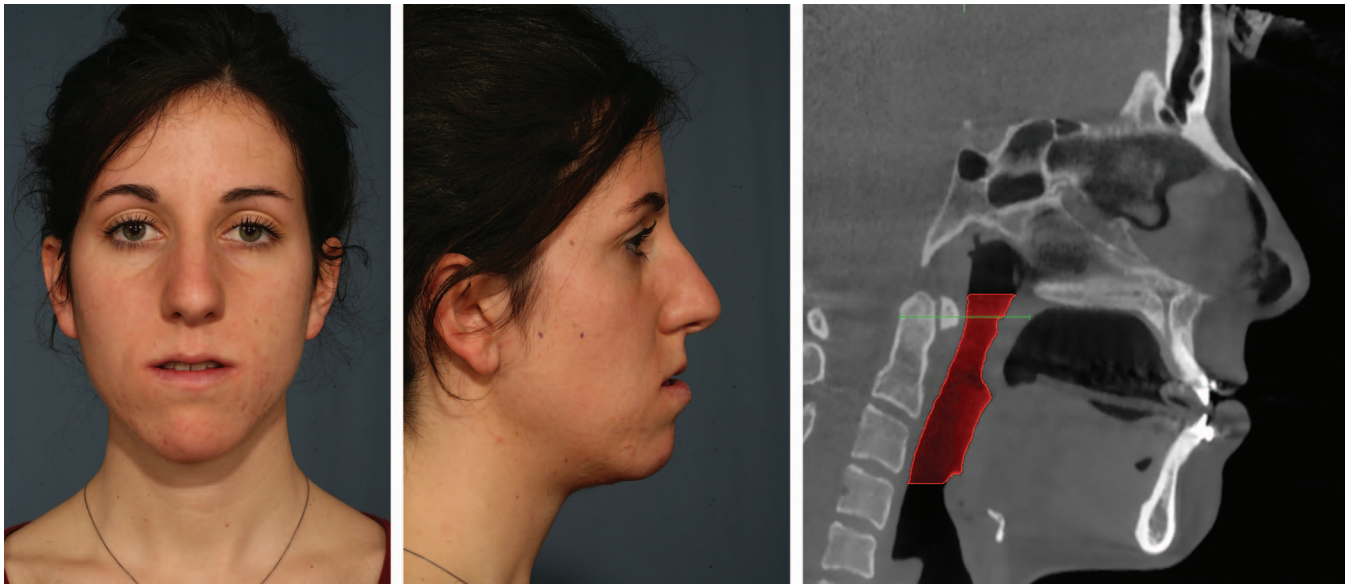

Figure 5. Sample Patient Introduction: 27-year-old female. Left: Frontal facial photo exhibiting midface flatness, mentalis strain, and partially closed lip posture. Center: profile facial photo exhibiting large nose, midface flatness, upper lip retrusion, lower lip protrusion, chin retrusion, and short throat length. Right: normal airway dimension, Class III open bite malocclusion. Note: Class III occlusion, but chin retrusion secondary to steep mandibular occlusal plane.

positive overbite at long term but the magnitude of presurgery open bites was decreased. In another retrospective study of 54 patients who underwent Le Fort I and sagittal osteotomies, Proffit et al.,[49] observed a significant loss of anterior overbite in 75% of the patients at long term.

Surgical relapse etiology. Major surgical occlusal relapse etiology categories include the following:

1. unstable presurgery orthodontics (Table 1);
2. inadequate orthodontic surgical appliance (Table 2);
3. inadequate surgical treatment planning (Table 3);
4. inadequate surgical techniques (Table 4);
5. lack of posterior dental intercuspation for any reason when leaving the operating room (Table 5); and
6. TMJ remodeling after surgery.

Full descriptions of stability techniques will be detailed in Part 2 of this paper.

Figure 6. Sample Patient Orthodontic Preparation: Typical study orthodontic preparation by Dr. EG shown. Top row: Preorthodontic occlusal relationship. Note: Upper arch narrow with dual plane occlusal break between the canines and lateral incisors. Note: Lower arch with mild anterior crowding. Note: Dental relationship with significant Class III open bite. Bottom row: presurgical orthodontic preparation maintaining arch widths, forms, and dual plane upper arch. The upper archwire was sectioned 4 months presurgery to ensure stability of orthodontic preparation.

Figure 7. Sample Patient Long-Term Results: Surgery performed by Drs. ADA, LT including cheekbone and orbital rim augmentation, multisegment Le Fort I advancement, mandibular bilateral sagittal split osteotomies, and bimaxillary occlusal plane counterclockwise rotation. Top row left and center: facial photos exhibit normal projections of nose, midface, upper lip, chin, and increased throat length. Note: no mentalis strain. Note: Normal profile balance of midface, nose, upper lip, lower lip, chin and neck. Top row right: airway larger than presurgery. Bottom row: occlusal correction with maximal intercuspation, which maintains occlusal coordination of the upper and lower arches.

Unstable Presurgery Orthodontics (Table 1)

The net surgical relapse is the sum of orthodontic relapse and surgical relapse. Denison et al.[50] reported open bite patients treated with orthodontic preparation and one-piece Le Fort I osteotomy had a high degree of instability at 1-year follow-up. However, their study and other studies used orthodontic preparation to match arch forms, arch widths, and curves of Spee prior to the one-piece Le Fort I procedures. It is possible that Denison et al. and others reporting surgical relapse were, in fact, reporting orthodontic relapse occurring in surgical cases. In standard or traditional orthodontic preparation combined with a one-piece Le Fort I, the orthodontic arch form, arch width, and curve of Spee changes relapse after surgery, opening the bite.[21] Haymond has published a linkage between presurgical orthodontic expansion and postsurgical open bite relapse.[21] Further supporting the premise that presurgical orthodontic tooth movement should be limited was the systematic review by Haas Junior et al.,[51] which found that segmental Le Fort I osteotomy expansion relapse was more dental than skeletal.[32,52] Additionally, Berger et al.[53] and Wertz[54] reported that orthodontic sutural expansion (skeletal) was stable while dental expansion was unstable. It follows that multisegment maxillary expansion (skeletal) with minimal presurgical orthodontic dental movements improves expansion stability.[21]

In particular, orthodontic maxillary curve of Spee leveling to close open bites has been shown to be a highly unstable movement[15] as are changes in arch widths and forms.[21,39–48,55] The occlusal stability revealed in the current study compared to the relapse reported in the previous literature is likely related to the differences in orthodontic preparation techniques and surgical techniques. In this study, the arch forms, arch widths, and maxillary plane of occlusion were maintained during orthodontic preparation, therefore limiting orthodontic relapse postsurgery. The upper arch wires were cut 4 months prior to surgery to allow undesirable orthodontic dental expansion or plane of occlusion changes to relapse prior to surgery, rather than after surgery.

Inadequate Orthodontic Surgical Appliance (Table 2)

The key to Le Fort I expansion in the operating room is having orthodontic bands on the upper first molar teeth. During surgery and intermaxillary fixation, tremendous lateral pull is placed on the upper first molar orthodontic appliance, and a band is mandatory to avoid dislodgement (Figure 2).

Inadequate Surgical Treatment Planning (Table 3)

Several authors, such as Haymond et al.[21] and Hoppenrejis et al.,[22] advocated clockwise rotations of the occlusal plane to reduce potential relapse after open bite correction. A steep occlusal plane is a common feature of open bite patients. Increasing the steepness of the occlusal plane has not been shown to improve stability, optimize the airway, and certainly is ill advised facially.[29,56] In the current study, the face, airway, and bite (FAB) were all corrected.[26–32] Therefore, counterclockwise occlusal plane changes were performed on 30/30 patients. The goal of the counterclockwise occlusal plane change was to optimize the airway and facial esthetics while correcting the occlusion. It can be stated from these data that counterclockwise treatment did not affect long-term overbite and overjet stability.

Inadequate Surgical Technique (Table 4)

Surgical operating room protocols were employed to produce stable results. The upper jaw segmentation, banded upper first molar teeth, maximizing dental intercuspation, and no final splint were key techniques among many that avoided postsurgical relapse. See Part 2 for further explanation.

Lack of Posterior Dental Intercuspation (The Importance of Intercuspation) (Table 5)

In this study, statistically significant width relapse of the maxillary first and second molars occurred and, yet, this relapse did not produce anterior open bite as predicted by Reyneke et al.[4] and Haymond et al.[21] Reyneke et al.[4] postulated that expansion relapses, leading to posterior interferences and frequently anterior open bite relapse. Contrary to this prediction, anterior open bite did not occur in the current patient population even with statistically significant maxillary narrowing after surgery. The reason maxillary width relapse did not open the bite was that the lower arch narrowed simultaneously with the upper arch, therefore maintaining posterior intercuspation. The reason for this coordinated narrowing of the upper and lower arches was excellent intercuspation. Posterior dental intercuspation is essential to avoid open bite relapse. Dental intercuspation, if deep, synchronizes maxillary and mandibular arch form and width changes that may occur after surgery.

TMJ Remodeling After Surgery

TMJ remodeling must be briefly discussed in the context of occlusal relapse. Occlusal relapse of overbite, overjet, and widths all occur if the TMJ structures remodel after surgery. Late open bite relapse after surgery or orthodontics may be evidence of progressive condylar remodeling. Progressive condylar remodeling after surgery has been documented extensively and is associated with displacement and compression of the condyles in the operating room.[57–59]

Complications

Multisegment Le Fort I is mandatory for transverse and open bite stability. Multisegment Le Fort I, when compared to traditional Le Fort I (one-piece osteotomy) and orthodontic treatment alone, has more complications.[60] However, Posnick et al.[61] evaluated the percentage of maxillary complications, including gingival recession, pulpal injury, oronasal fistula, and the need for hardware removal in a retrospective cohort study of 262 patients, concluding that segmentation of the Le Fort I osteotomy was a safe method of addressing skeletal deformities.[34] Additionally, Ho et al.,[60] in a retrospective study of a consecutive series of 85 patients who underwent multisegmented Le Fort I osteotomies, defined the procedure as safe and associated with a low percentage of complications. These data are in agreement with results in this study group of 30 patients.

CONCLUSIONS

- According to the findings described in this paper, segmental orthodontic preparation combined with segmental upper jaw surgery produces satisfactory anteroposterior, vertical, and transverse (arch form and width) long-term corrections.
- The study findings indicate that specific protocols (Tables 1–5) for diagnosis and treatment can provide adequate and stable results in adult malocclusions including open bite. The success of the protocols was verified by the stability of the malocclusion correction in the study group.
- The results found in this study demonstrate that orthodontic surgical correction of dental skeletal open bite is clinically safe and stable in the long term. Further, the procedures *as* outlined within the paper are stable treatments of overjet, overbite, arch form, arch width, and maxillary accentuated curve of Spee deformities. Additionally, the correction was achieved

without compromising facial esthetics and the airway. Likewise, it is important to establish the health of TMJ accurately, considering the influence that any anatomic condylar degenerative process may have on the long-term result.

- To duplicate these results, treatment must adhere to specific orthodontic and surgical principles to minimize orthodontic relapse and optimize the predictability and stability of the surgical results.

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