Craniofacial management of anterior openbite: a clinical review

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Abstract: Anterior openbite (AOB) malocclusion has been regarded as a complex and challenging malocclusion to manage regarding diagnostic and treatment decisions. The aetiology of AOB is often multifactorial with a combination of anatomical (e.g., skeletal, dental, soft tissue) and habitual/functional factors. Some special anatomical/genetic conditions are also associated with AOB, including craniofacial syndromes, macroglossia, muscular weakness, and abnormal ramus and/or condylar development. Various therapeutic modalities including orthodontic and orthodontic-orthognathic surgical approaches are available and used for the correction of AOB, depending on the aetiology and severity of the malocclusion. Recent studies have evaluated the effectiveness and long-term stability of these different approaches. The aim of this clinical review is to summarize and evaluate the main treatment methods for AOB in the permanent dentition based on the latest literature. Nonsurgical approaches using 'multiloop edgewise archwire (MEAW)', clear aligners, and temporary anchorage devices (TADs) are reviewed. Orthodontic-orthognathic treatment remains the ideal approach for management of moderate to severe AOB. Detailed diagnosis and surgical treatment planning steps are described. Surgical treatment for AOB with complicated craniofacial conditions such as transverse discrepancy, macroglossia, and condylar resorption are also discussed. Retention and stability of AOB treatment is evaluated based on current literature. This clinical review hopes to provide reference for clinical decision making for AOB craniofacial management based on current research evidence.

Keywords: Openbite; 'multiloop edgewise archwire' approach; aligners; temporary anchorage devices (TADs); orthodontic-orthognathic surgery

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Introduction

Background

Anterior openbite (AOB) is defined as the failure of the maxillary and mandibular incisors to overlap, and represents a challenging malocclusion to treat satisfactorily due to its multifactorial aetiology and high relapse rate. A previous study reported the prevalence of AOB in an adult Caucasian American population to be about 3% (1). Depending on ethnicity and age, the prevalence of AOB ranges from 1.5% to 11% and is found to be significantly higher in African Americans as compared to that in Caucasians and Hispanics (1-3). Various therapeutic modalities including orthodontic and orthodontic-orthognathic surgical approaches are available and used for the correction of AOB depending on the aetiology and severity of the malocclusion (4-6).

Rationale and knowledge gap

Various skeletal, dental, soft tissue, and habitual/functional factors can lead to dental or skeletal AOB (7). Some special anatomical/genetic conditions are also associated with AOB, including craniofacial syndromes, macroglossia, muscular weakness, and abnormal ramus and/or condylar development (8-11). Conventionally, fixed appliance treatment with or without tooth extraction is used to treat mild AOB of dental origin (12). Other nonsurgical orthodontic tools including 'multiloop edgewise archwire (MEAW)', clear aligners, temporary anchorage devices (TADs) are explored to assist AOB correction with different biomechanics (13,14). Studies have been done to evaluate the effectiveness and long-term stability of these relatively newer methods (15). A surgical approach is usually more ideal to address more severe AOB, as well as AOB associated with complicated conditions, such as macroglossia or condylar resorption (16,17).

Objective

This clinical review article aimed to summarize and evaluate the main treatment methods for AOB in the permanent dentition based on the latest literature. Diagnostic and treatment details on nonsurgical and orthodontic-orthognathic surgical management of AOB were discussed, including for AOB with complicated craniofacial conditions such as transverse discrepancy, macroglossia, and condylar resorption. Comparison of different nonsurgical modalities was provided. Meanwhile, this review also provides cases that illustrate the discussed approaches for AOB. Stability of surgical and nonsurgical AOB treatment was reviewed. Specifically, results of a recent National Dental Practice-Based Research Network (NDPBRN) Anterior Openbite Study were summarized. Overall, this clinical review article provided an updated evaluation of treatment methods for AOB management in permanent dentition, with an emphasis on surgical approaches, and discussed treatment details for special and complicated craniofacial conditions associated with AOB.

Aetiology

The aetiology of AOB is often multifactorial with a combination of anatomical (e.g., skeletal, dental, soft tissue) and habitual/functional factors (18).

Anatomical/genetic factors

It was found that many anatomical/skeletal factors such as cranial base angle, maxillary rotation, and shape and size of the mandible are related to AOB (19,20). From the famous implant studies by Björk and Skieller, it was suggested that some developmental/anatomical characteristics were strong indicators for a vertical grower, which led to skeletal AOB (21,22). These factors included amount of condylar growth, direction of condylar growth, lower face height, ratio of the anterior face height to the posterior face height, ramus inclination, the angulation of the lower border of the mandible, and the amount of vertical molar movement during treatment. Determining whether anatomical/genetic factors are the main contributor to a patient's AOB is critical for diagnosis and treatment planning. Thus, obtaining a thorough family history and collecting complete clinical records including radiographic images are important for clinicians treating AOB.

There are some other anatomical conditions that may be associated with anterior openbite but are less commonly encountered. These conditions include craniofacial syndromes, macroglossia, muscular weakness, and abnormal ramus and/or condylar development. AOB is observed in patients with various craniofacial conditions and syndromes. AOB is documented to be associated with amelogenesis imperfecta (23), Apert syndrome (9,10), Crouzon syndrome (9), cleidocranial dysplasia (8), Treacher Collins syndrome (24), genetic polymorphism in MMP9 (25), etc. The relationship between AOB and these craniofacial conditions is not completely clear, but most suspect a genetic origin. Different gene mutations are associated with these craniofacial syndromes, implying that vertical craniofacial growth might be determined by a variety of genes. Given the extensive range of craniofacial growth and developmental abnormalities, management of these patients usually requires a lengthy, multidisciplinary, and comprehensive approach. True macroglossia has been suggested as a possible cause of openbite (11). Patients with muscular weakness syndromes may exhibit restricted growth of the mandible and impaired lengthening of the ramus, as mandibular elevator muscles are the major influence of ramus growth (26,27). A reduction in the masticatory muscles' force of contraction may also lead to molar overeruption of posterior teeth. Many local and systemic pathologies or diseases can prevent normal ramus growth or cause mandibular condylar resorption, leading to AOB (28-31).

Table 1 Comparison of nonsurgical approaches for AOB management: effect on occlusion, advantages, disadvantages, and stability of treatment are included

Method	Effect	Advantages	Disadvantages
MEAW	An average of 4 mm overbite change; retraction and extrusion of the anterior teeth; uprighting movement of the posterior teeth	Noninvasive. Effective for mild to moderate AOB	Require patient cooperation; minimal effect in the skeletal pattern; limited numbers of studies; lack of long-term stability studies
Aligner	An average of 3–4 mm overbite change; maxillary and mandibular incisor retraction and extrusion; slight upper and lower molar intrusion	Noninvasive. Controlling the vertical dimension; effective for mild to moderate AOB	Require patient cooperation; need initial intra-arch space or significant amount of interproximal reduction; additional lab cost; minimal effect in the skeletal pattern; lack of long-term stability studies
TADs	An average overbite change varying from 2.2 to 6.9 mm; molar intrusion	Effective for mild to moderate AOB	Invasive; additional cost; 10% to 30% relapse occurs both in maxillary and mandibular molars

MEAW, multiloop edgewise archwire; AOB, anterior openbite; TADs, temporary anchorage devices.

Functional factors

Functional problems include sucking habits, tongue thrust, and mouth breathing, which have all been reported as causative factors (32,33). Prolonged digit sucking can lead to the development of openbite malocclusion. The duration and frequency of an oral habit can influence the amount of tooth displacement. A tongue thrust is currently considered to be more of an effect rather than a cause of AOB. However, if a patient has a forward resting posture of the tongue, it could affect tooth position due to the long duration of the pressure compared to the actual action of thrusting the tongue forward (5).

Characteristics

Anterior openbite can be classified as dental or skeletal, depending on the original aetiological features. Characteristics associated with skeletal AOB include increased anterior lower face height (long face syndrome), steep mandibular plane, narrow maxilla, mesial inclination of posterior teeth, and upright incisors (4). Signs of excess facial height could be lip incompetence (defined as separation of the lips at rest of more than 4 mm), a shallow mentolabial sulcus, excessive gingival display on smiling, and a convex profile (18,34).

Clinical treatment

The principles of treatment for AOB include identifying etiology and correcting dental and/or skeletal relationships depending on the etiology and patient's age (35,36). It is not the purpose of this review to focus on early treatment for AOB. However, the presence of an anterior openbite in the mixed dentition usually involves non-nutritive habits such as thumb or finger sucking (37). Treatment appliances such as high pull headgear, vertical-pull chin cup, and functional appliances with bite splints can be used for growth modification especially if unfavorable growth is suspected (18,38). However, weak evidence was found based on the current studies for the effectiveness and long-term stability of these interventions on the vertical growth pattern (35).

In the late permanent dentition, various therapeutic modalities for the treatment of AOB include conventional fixed appliances with tooth extraction, fixed appliances with the 'MEAW' approach, aligners, TADs, and the orthodontic-orthognathic surgical approach. Traditional multi-bracket treatment with extraction of premolars is a typical treatment method especially for dental AOB with crowding. It creates retraction and lingual tipping of maxillary and mandibular incisors and has greater stability of the overbite compared to the nonextraction treatment (39,40). Different orthodontic tools are also developed and studied for their unique application in AOB management based on their own characteristics and biomechanical effect on occlusion. A comparison of these methods including their effect on occlusion, advantages, disadvantages, and stability of treatment is listed in *Table 1*.

The 'MEAW' approach

The multiloop edgewise archwire (MEAW) method was presented by Kim *et al.* as a non-surgical intervention to treat AOB (41). The approach essentially uses a combination of multiloop stainless steel archwires and heavy anterior elastics (*Figure 1*). A modified version of the "MEAW" technique is to use curved nickel-titanium arches and anterior elastics (*Figure 2*). Limited studies that investigated the effects of this technique were found (13,42,43). Cephalometric analysis data from 26 non-growing subjects showed that the overbite increased by an average of 4 mm using this technique. And the openbite was mostly corrected through retracting and extruding anterior teeth, as well as uprighting posterior teeth (42). Specifically, the interincisal angle increased from 127° to 134° on average and the upper and lower molars were uprighted 4–4.5° relative to the bisected occlusal plane (42). Similarly, a retrospective study with 18 subjects examining the curved nickel-titanium arch technique also found that maxillary and mandibular incisors were extruded by 2.16 and 1.49 mm, respectively, with increased overbite (4.38 mm). They concluded that the openbite was eliminated by retraction and extrusion of the anterior teeth while maintaining the vertical positions of the molars (13).

Figure 1 Patient with an anterior openbite treated with MEAW method. MEAW, multiloop edgewise archwire.

The appliance had a minimal effect in the skeletal pattern. Notably, there is a lack of long-term stability studies on this approach.

Aligners

There is a large amount of interest in the use of aligners for AOB. Many successful case reports were published (44-46), as well as studies examining the effectiveness and mechanism of clear aligner therapy for AOB treatment (47-50). It was suggested that clear aligners treat AOB through the "bite block effect", assuming that the aligner tray covering the posterior teeth coupled with the biting force intruded posterior teeth (49). However, it is found that posterior blocks/splints of at least 3–4 mm thickness are needed to create this molar intrusion effect as they should be thick enough to exceed the freeway space of the patient (51,52). With most clear aligners being within 1mm thick, it is unlikely that the "bite block effect" is generated.

A retrospective study based on cephalometric superimposition on records of 45 patients showed an average overbite change of 3.27±1.09 mm (53). Significant maxillary and mandibular incisor retraction and extrusion were found, indicating initial intra-arch space or significant amount of interproximal reduction is needed to correct AOB with aligners. Slight, but statistically significant, upper and lower molar intrusion (0.47 mm and 0.39 mm, respectively) was also noted. Another retrospective cephalometric analysis study was carried out on sixty-nine

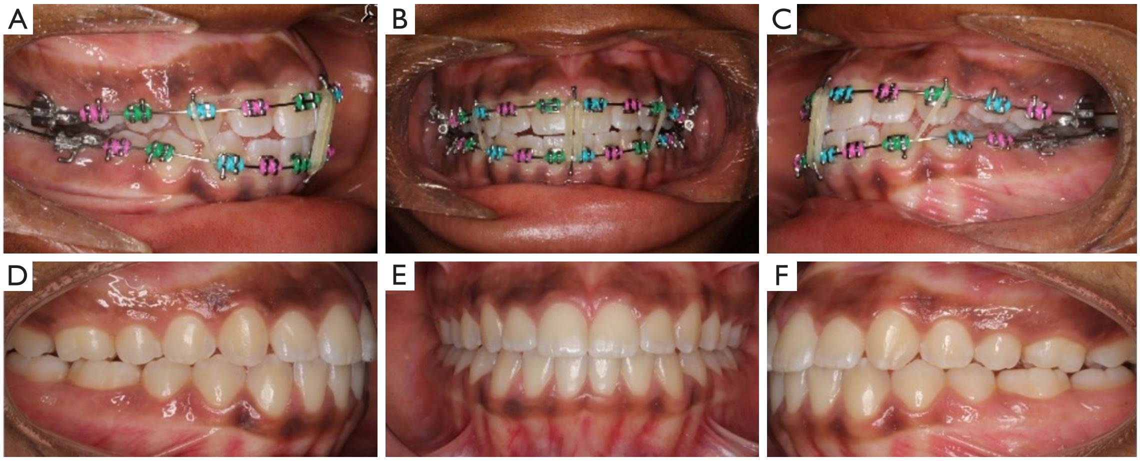

Figure 2 Patient with an anterior openbite treated with a modified version of the "MEAW" technique: using curved nickel-titanium arches and anterior elastics. (A-C) Intraoral photographs of orthodontic fixed appliance treatment using the modified version of MEAW technique. (D-F) Intraoral photographs of final treatment results. MEAW, multiloop edgewise archwire.

Figure 3 Patient with anterior openbite treated with temporary anchorage devices. (A-C) Intraoral photographs of orthodontic fixed appliance treatment with bilateral placement of miniscrews. (D-F) Intraoral photographs of final treatment results.

adult non-extraction cases treated by aligners (54). The average overbite change in this study was 3.3±1.4 mm. Data showed that there was greater upper molar intrusion and mandibular plane angle reduction in the Class II group, and there was more lower incisor extrusion in the Class III group (54). Another study comparing the clear aligner and the miniplate-supported posterior intrusion methods showed that clear aligner and TADs have different effects on teeth when treating adult AOB. It was found that clear aligner therapy corrected AOB through extruding upper and lower incisors, while miniplates created molar intrusion and hence counterclockwise mandibular autorotation (55).

Aligners appear to be effective in controlling the vertical dimension in AOB patients, but most of the overbite correction is achieved through upper and lower incisor movements. However, prospective, randomized controlled trials with larger sample sizes are needed to further examine this modality.

Temporary anchorage implants and devices

TADs such as mini-implants, miniscrews, and miniplates have been used in AOB treatment by reducing the vertical height of the buccal segments (56) (*Figure 3*). Common anchorage sites are the infrazygomatic crest region, the vestibular and palatal regions of alveolar bone, and the median and paramedian palatal regions. There have been many papers evaluating treatment outcomes and stability of this method (14,57-60).

The study by Scheffler *et al.* used TADs in combination with a maxillary intrusion splint (61). Molar was intruded 2.3 mm on average, leading to satisfactory correction of AOB. The authors also pointed out that there was 0.5–1.5 mm of re-eruption of the upper molars and that vertical control of the lower molars while intruding the upper molars was critical for achieving facial height reduction.

A systematic review was conducted in 2020 to explore the stability of AOB treatment with TADs (14). The included studies reported an average overbite change varying from 2.2 to 6.93 mm. The review also showed a mean relapse of –1.23 mm of the overbite, and a 12% and 27% relapse rate of the upper and lower molar intrusion, respectively. The paper pointed out that this was similar to the relapse rate that was reported with the surgical approaches, which was 10% to 30% in both upper and lower molars.

Overall, TADs could be an effective and relatively stable option for treating mild to moderate AOB, especially in situations where patients decline orthognathic surgery or when orthognathic surgery is not feasible. However, it is a relatively new technique and the quality of the evidence examining long-term stability is low and randomized controlled trials are in dire need.

The orthodontic-orthognathic surgical approach

Since nonsurgical modalities mentioned above only create overbite change up to 4 mm based on the current literature, an orthodontic-orthognathic approach may often provide the most ideal correction in moderate to severe AOB patients with more than 3mm AOB in order to achieve at least 1mm overbite after correction. Historically, AOB deformities often have common combined clinical and radiographic

Figure 4 Patient with a severe anterior openbite and transverse discrepancy required pre-operative extractions and a SARPE before the definitive double-jaw orthognathic surgery (multisegmental Lefort I osteotomy, bilateral sagittal split osteotomy, and genioplasty). These images are published with the patient's consent. (A) Pre-surgical extraoral frontal smiling photo. (B) Post-surgical extraoral frontal smiling photo. (C) Pre-surgical extraoral profile photo. (D) Post-surgical extraoral profile photo. (E) Pre-surgical intraoral frontal photo showing anterior openbite with transverse discrepancy. (F) Final intraoral frontal photo. SARPE, surgically-assisted rapid palatal expansion.

identifiers upon presentation, which would individually otherwise be nonspecific (*Figure 4*). Skeletal AOB can be categorized based on the skeletal relationship between the maxilla and mandible, and different skeletal classifications exhibit different clinical characteristics, as detailed in *Table 2*. Strategies for correction and surgical techniques may also vary based on the skeletal classifications. For example, openbite patients with vertical maxillary excess (VME) or Class II patients with concomitant anterior openbite are good candidates for surgical correction.

Surgical solutions for the orthognathic closure of the AOB are first determined by a comprehensive approach to total facial-surgical skeletal correction. The initial review of the orthognathic surgery patient also takes into consideration the patient's facial skeletal growth, which ultimately determines the timing of surgery. Studies show that facial skeletal growth in the anterior-posterior direction on average ceases in females between the ages of 15–16 years, and in males between the ages of 17–18 years (62,63). Growth cessation, or growth deceleration to the point that is clinically insignificant that would result in minor post-surgical changes that are recoverable by nonsurgical means, can be best monitored in the clinical setting with serial cephalometric radiographic examinations in 6-month intervals or more traditionally with hand-wrist radiographs (64). Elective orthognathic surgery may be performed during early skeletal maturity (~13–15 in females and ~15–17 in males) for Class II skeletal patients and those with significant quality of life considerations. However, cautious delay should be practiced in patients with Class III skeletal relationships as hyperplastic mandibles can continue to grow in the anterior-posterior direction for years beyond these maturity norms. At any age, surgical treatment for patients with anterior openbite with progressive joint deformities such as idiopathic condylar resorption (ICR) should also be delayed to monitor the progression and regression of disease. Orthognathic surgery should be performed after observing

Table 2 Clinical characteristics that may present in skeletal Class I, II, and III openbite deformities

Anterior openbite and skeletal class	Clinical characteristics
Class I	VME, clockwise mandibular rotation, increased interlabial gap, increased incisor display at rest, transverse maxillary hypoplasia, possible dual planes of occlusion, Class III rotation to Class I
Class II	VME, increased lower facial height, mandibular/chin recession, increased incisor display at rest, Class II skeletal deformity, possible dual planes of occlusion, transverse maxillary hypoplasia, increased mandibular plane angle, Class I rotation to Class II
Class III	VME, mandibular anterior-posterior hyperplasia often camouflaged by clockwise rotation of the mandible, midface and maxillary anterior-posterior hypoplasia, possible dual planes of occlusion, transverse maxillary hypoplasia, reverse curve of Spee, increased mandibular plane angle

VME, vertical maxillary excess.

that the ICR patients do not show any clinical symptoms or radiological changes for at least six months (65).

The orthodontic preparation process may also vary depending on different skeletal classifications. Conventionally, pre-surgical orthodontics (Phase I) precedes orthognathic surgical correction (Phase II), followed by further post-surgical orthodontics to complete and finish treatment (Phase III).

In general, the orthodontist's preoperative goal is to position teeth in the most architecturally sound position over basal bone prior to surgery. During the decompensation process of pre-surgical orthodontics, the orthodontist also aims to both level and align teeth and coordinate arches, including intentional dual and multi-planar orthodontic leveling, if appropriate (66).

After Phase I orthodontics is complete, progress models (either physical models or digital scans) are prepared to check occlusal stability. If occlusal stability can be shown with progress models with or without segmentalization and excessive enameloplasty, the surgeon will prepare preoperative data for surgical planning. Methods for surgical planning vary between traditional model surgery and image based surgical planning. Preoperative data for medical modeling for virtual surgical planning includes clinical photographs, clinical measurements, a CT scan taken in centric relation, bite registrations, physical models in both pre and post-operative occlusion, and intraoral scans (67).

Surgical plans and execution for surgical AOB correction vary depending on the desired aesthetic outcomes, weighing heavily on the surgeon to make intra-operative adjustments, particularly to manipulate incisal display, symmetry, cant correction, and chin projection. Virtual surgical planning provides the ability to examine the skeletal dimensions and structures (and to a less predictable extent the soft tissue structures) in a dynamic three-dimensional process that accounts for anatomy and detailed nuances otherwise not viewable with traditional model surgery on articulators alone. This includes the ability to view osteotomy design, maxillo-mandibular yaw deformities, nasal and orbital anatomy and complex facial asymmetries, turbinate positions, osseous genioplasties, bone contacts and interferences, lingula and nerve positions, and condylar anatomy. Virtual surgical planning provides greater predictability and more reproducible results as compared to traditional model surgery on articulators (67-69).

Any true maxillary transverse hypoplasia that presents with crossbite and any maxilla with multiple planes of occlusion after Phase I orthodontics almost always requires a segmental maxillary osteotomy. Severe transverse maxillary hypoplasias with severe AOB may require a staged approach where surgically assisted rapid palatal expansion (SARPE) should be considered as the first surgery prior to definitive orthognathic repair (*Figure 4*).

The two most common orthognathic surgical plans for the AOB repair are (I) LeFort I one-piece or multi-piece segmental osteotomy with autorotation of the mandible and (II) LeFort I one-piece or multi-piece segmental osteotomy with bilateral sagittal split osteotomy of the mandible (*Figure 5*). Either plan may be performed with an osseous genioplasty. Double jaw surgeries provide more aesthetic flexibility. However, double jaw surgeries show greater openbite relapse rates long term with the loss of anterior overbite, particularly in cases requiring multisegmental LeFort I osteotomies (70). Overcorrection of the AOB with an exaggerated overbite in select Class III skeletal deformity cases may reduce relapse rates.

Balancing genioplasties are a useful tool to achieve not only aesthetic balance, but to achieve desired functional

Figure 5 Classic presentation of adult anterior openbite. Case was treated with the most common surgical correction for anterior openbite: a double jaw bi-maxillary advancement and three-piece LeFort I osteotomy. These images are published with the patient's consent. (A) Pre-surgical extraoral frontal photo. (B) Post-surgical extraoral frontal photo. (C) Pre-surgical extraoral frontal smiling photo. (D) Post-surgical extraoral frontal smiling photo. (E) Pre-surgical extraoral profile photo. (F) Post-surgical extraoral profile photo. (G) Pre-surgical extraoral right 3/4 smiling photo. (H) Post-surgical extraoral right 3/4 smiling photo. (I-K) Pre-surgical intraoral photos showing anterior openbite. (L-N) Intraoral photographs of final treatment results.

outcomes as well (*Figure 6*). Osseous genioplasties can vary in osteotomy design that can specifically include the genial tubercles in order to increase the airway volume (71), and intentional high angled osteotomies can slide the osseous segment anteriorly and superiorly to aid in the closure of lip incompetence, thereby improving both chronic mouth breathing habits, oral hygiene, and speech and swallow function.

An enlarged tongue (macroglossia) can cause facial-dental skeletal deformities and if present with an AOB, the potential for openbite relapse after surgical correction is greater. Macroglossia has several congenital and acquired causes such as muscular hypertrophy, Down's syndrome, and primary tumors and pathologies of the tongue. In cases of pseudomacroglossia, the tongue may be normal in size, but appears large relative to its anatomic interrelationships (66). Pseudomacroglossia can be caused by (I) habitual posturing and thrusting of the tongue; (II) tonsillar and adenoid hypertrophy; (III) low palatal vaults causing a decrease in oral cavity volume; (IV) transverse, vertical, or anteoposterior deficiency of the maxillary and/or mandibular arches causing a decrease in oral cavity volume; and (V) tumors causing tongue displacement.

Partial glossectomy as an adjunct to correct an AOB has

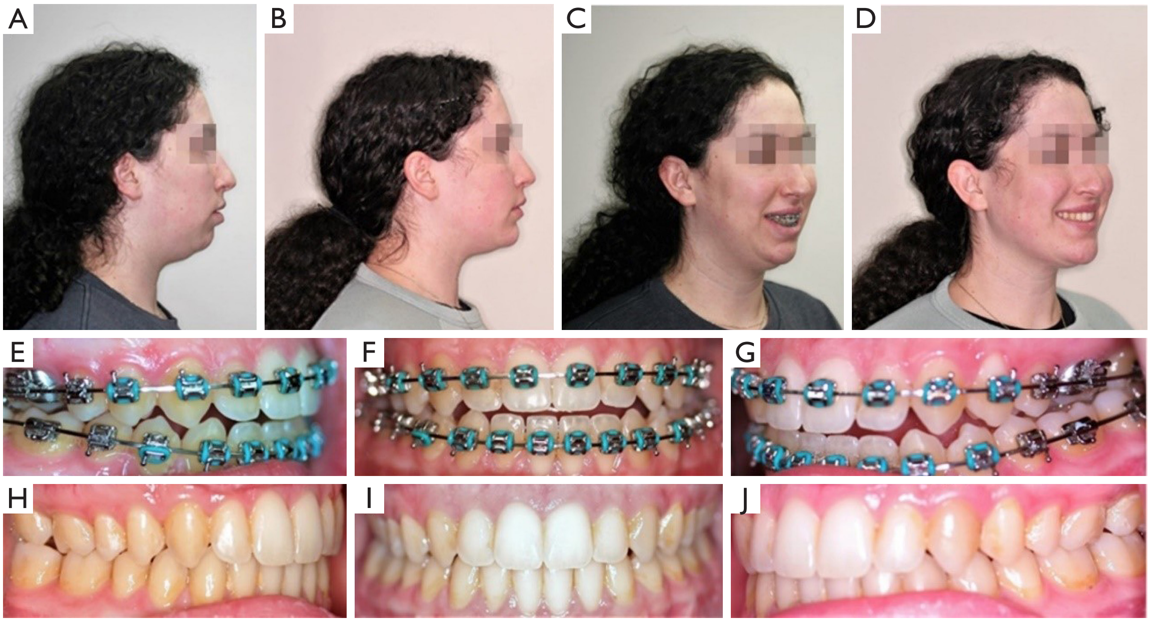

Figure 6 Patient with an anterior openbite and retrognathic mandible: mandibular bilateral sagittal split osteotomy and balancing genioplasty were performed. These images are published with the patient's consent. (A) Pre-surgical extraoral profile photo. (B) Post-surgical extraoral profile photo. (C) Pre-surgical extraoral right 3/4 smiling photo. (D) Post-surgical extraoral right 3/4 smiling photo. (E-G) Pre-surgical intraoral photos. (H-J) Intraoral photographs of final treatment results.

been described (72). There are several surgical techniques available for tongue reduction. Due to the adaptability of the tongue, it is reasonable to delay surgical treatment of macroglossia at least 12 months after orthognathic surgery. If the symptoms of macroglossia prohibit sustained orthodontic progress and decompensation or cause a significant decrease in the quality of life, glossectomies may be performed prior to orthognathic surgery. In either sequence, it is not ideal to perform a glossectomy and orthognathic surgery simultaneously due to the potential risk of hematoma and airway compromise during an orthognathic post-operative period of elastic traction in maxillomandibular fixation. There are no well controlled studies that establish a reduction in AOB relapse with orthognathic surgery and glossectomies.

Complex AOB cases which involve condylar instability and resorption may be simultaneously treated with orthognathic surgery and total alloplastic TMJ replacement. These cases are for the large part treated in similar fashion with Phase I pre-surgical orthodontics and Phase III post-surgical orthodontics. It is not uncommon for patients with quiescent ICR to have AOB relapse post-surgically and require repeated orthognathic surgery revisions and bilateral total TMJ replacement. Establishing the presence of active TMJ disease may require adjunctive higher level imaging that shows metabolic activity within the condyle, such as 99m-technetium-methylene diphosphonate scans (17).

Retention and stability

It has been recognized that surgical correction of AOB has the greatest tendency for relapse among all the orthognathic surgical movement (70,73-75). There has been a reported difference between relapse rates of single versus double jaw surgeries for AOB correction. With single jaw LeFort I osteotomies only, one retrospective study reported that the severity of AOB was significantly reduced after surgery, although the majority of the patients didn't have positive overbite in the long term (76). In another retrospective study, it was observed that 75% of the 54 patients who underwent LeFort I and sagittal osteotomies had significant relapse of overbite at long term (77). Surgical relapse etiology is often multifactorial. Arnett *et al.* reported six factors related to surgical openbite relapse: (I) unstable presurgical orthodontics, (II) inadequate orthodontic surgical appliances, (III) inadequate surgical treatment planning, (IV) inadequate surgical techniques, (V) poor occlusal stability intraoperatively and immediately post-surgically, and (VI) post-surgical TMJ remodeling (78).

Many studies have been performed to evaluate treatment outcomes and stability for AOB (4,16,18,35,38,77,79-84). A meta-analysis by Greenlee *et al.* (79) found that there was a change of mean overbite from −2.8 to 1.6 mm in the surgical group, and −2.5 to 1.4 mm in the non-surgical group. During the mean 3.5 years of follow-up, the overbite relapsed to 1.3 mm in the surgical group and 0.8 mm in the non-surgical group. So positive overbite was maintained in 82% of the AOB patients treated surgically and 75% of the patients treated non-surgically at 12 or more months after treatment, indicating reasonable stability for these treatment modalities on AOB.

A large, multicenter, prospective cohort study on anterior openbite was conducted from the NDPBRN, with the purpose of exploring treatment recommendations, patient satisfaction, treatment success rate, and overall stability, with both conventional and newer therapies for adult AOB patients (15,85-88). Interesting findings included relatively high stability of AOB treatment during the short follow-up period (>9 months post-treatment), and high patients' satisfaction over treatment results, regardless of treatment or retention regime (87). It was found that factors associated with high stability in patients treated with fixed appliance only were extraction and less initial lower incisor proclination.

This clinical review aimed to provide evaluation and recommendation on AOB treatment in permanent dentition based on current research evidence with emphasis on orthodontic-orthognathic surgical method. We believe this will provide a practical clinical guidance for clinicians to make the best decision depending on the individual situation of their patients.

However, as challenging as it is to treat AOB, it is understandable that studies for AOB treatment evaluation are difficult to conduct due to the multifactorial nature and relatively low prevalence rate. There is a lack of updated and prospective studies on this topic. There is also a limited number of studies on long-term follow up on varies modalities. Study results and recommendations must be viewed with caution. And more randomized controlled trials are needed to elucidate the interventions for craniofacial management of AOB.

Conclusions

Although satisfaction of patients is relatively high, AOB treatment remains a challenging area in orthodontic and orthognathic craniofacial management. Eliminating the etiology of the openbite and avoiding mechanics that worsen the openbite, like extrusion of molars, will help improve treatment outcome. If a high likelihood of relapse is anticipated, overcorrection may be built into the treatment plan, such as overcorrection of overbite in a LeFort I surgical procedure. Additionally, the continued use of retention appliances is very much advised in most cases of AOB.

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