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CRANIOFACIAL SKELETON (WE ROBERTS, SECTION EDITOR)

Extra-Alveolar Bone Screws for Conservative Correction of Severe Malocclusion Without Extractions or Orthognathic Surgery

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Abstract

Purpose of Review Evaluate management of challenging malocclusions conservatively (no extractions or orthognathic surgery).
Recent Findings Most malocclusions have a predominately environmental etiology. Optimal esthetics and function are restored by aligning the dentition over the apical base of bone at the appropriate vertical dimension of occlusion (VDO). Extra-alveolar (E-A) anchorage is achieved at three intraoral sites: mandibular buccal shelf (MBS), infrazygomatic crest (IZC), and anterior ramus. MBS and IZC bone screws effectively anchor the conservative correction of severe dental and skeletal malocclusions. All bone screw sites are effective for anchoring lever arms to recover impacted teeth. Rather than extracting teeth, E-A anchorage corrects crowding by retracting the posterior segments to increase arch length. Skeletal malocclusion is corrected by aligning teeth over the apical base of bone and restoring the VDO by retracting and posteriorly rotating the dental arches as segments.
Summary Challenging dental and skeletal malocclusions can be treated routinely via determinate mechanics anchored with E-A bone screws.

Keywords Extra-alveolar · Bone screw · TAD · Orthodontics · Anchorage · Non-extraction · Statically determinate mechanics Conservative treatment · Canine impaction · Horizontal impaction of second and third molars

Introduction

When used for orthodontic anchorage, teeth may interfere with the path of tooth movement and/or be moved into undesirable positions. Ankylosed teeth [1] and osseointegrated titanium implants [2] provide rigid anchorage for tooth movement, but their use is restricted to special circumstances. The first temporary anchorage device (TAD) was a titanium alloy surgical screw placed apical to maxillary incisors for intrusion [3]. Roberts et al. [4] used a retromolar osseointegrated implant to anchor the mesial movement of lower second and third molars to close an edentulous first molar space. Kanomi [5] extended the concept by placing stainless steel (SS) screws between the roots of posterior teeth to retract anterior segments. The eclectic origin for osseous anchorage subsequently resolved into two basic concepts for TADs. Inter-radicular (I-R) devices are placed in the alveolar process between or near the roots of teeth [4, 6, 7]. Extra-alveolar (E-A) or extra-radicular (E-R) TADs are placed outside the alveolar process that supports the roots of teeth [8, 9••].

Skeletal anchorage with I-R TADs is effective [7] for some malocclusions [4, 6], but their positions between the roots of teeth present a number of inherent deficiencies. Few adequate intraoral sites are available [10], and radiographs tend to magnify the space that is available [11], so periodontal ligament (PDL) and roots of teeth can be injured [12]. There is a high failure rate particularly in the mandible [13, 14], and visible scars may occur in areas of esthetically exposed gingiva [15]. Inflamed soft tissue is common around the mini-screws [16], and they often interfere with the path of tooth movement [17]. I-R TADs may move relative to supporting bone because they are not osseointegrated [18, 19]. Even slight movement (<1 mm) of I-R TADs is a significant problem because they are often placed in contact or close to tooth roots [17].

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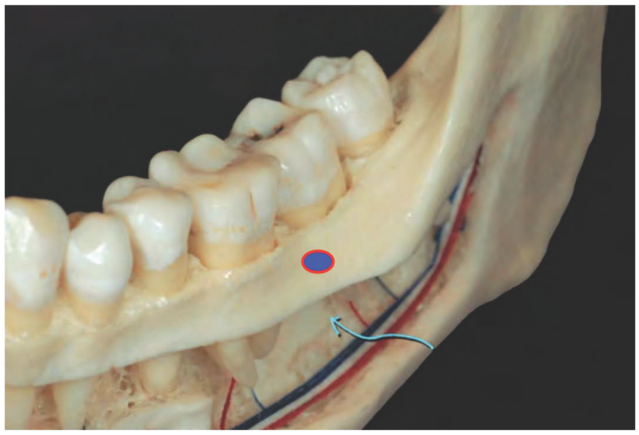

Fig. 1 Cutaway preparation of the posterior mandibular arch with a blue arrow marking the endosseous space available for E-A bone screw in the MBS. The blue oval with a red outline marks the preferred site for TAD insertion

From a biomechanics perspective, E-A TADs are more attractive anchorage units because they avoid the roots of teeth. There are three common types of supplemental anchorage devices that are placed outside the alveolar process: miniplates [20], palatal TADs [2], and buccally positioned mini-screws that do not interfere with molar roots [21, 22]. The success rate for mini-plates is relatively high (Lam [23] 98.6%, Findik [24] 96.8%), but there are significant complications, such as soft tissue inflammation, nerve damage, sinus perforation, and/or infection [23–25]. Moreover, the placement of mini-plates requires flap surgery for placement and removal. On the other hand, E-A bone screws are installed directly in the oral cavity and have high success rates in the mandibular ramus (95%) [26], mandibular buccal shelf (MBS) (92.8%) [27••], and the infrazygomatic crest (IZC) of the impaction of second and third molars maxilla (93.7%) [28••]. Both the MBS and IZC bone screw sites are buccal to the roots of the molars, so they provide skeletal anchorage for tooth movement and full arch corrections to resolve a broad range of malocclusions [8, 9••, 21, 22, 29].

MBS Bone Screws

The buccal shelf is an osseous fossa in the posterior mandible that is lateral to the molar area (Fig. 1). Its anatomical boundaries are between the buccal frenum anteriorly and the attachments of the masseter and temporalis muscles posteriorly. There is a thick cortical plate buccal to the molars, which is well suited for bone screw placement. Mini-screws, designed for I-R sites, have been placed in the buccal shelf area [21], but the only TADs that are specifically designed for the MBS are 2 × 12 mm stainless steel OrthoBoneScrews® (Newton's A Ltd., Hsinchu City, Taiwan). The specifications and operational advantages of SS bone screws are outlined in Fig. 2. MBS bone screws are placed 1–2 mm buccal of the mandibular molars with an axial inclination as nearly parallel as possible to the mandibular first and second molar roots (Fig. 1). The surgical installation procedure begins with local anesthetic. A sharp dental explorer is then sounded through the soft tissue to bone at the preferred skeletal site (Fig. 1), which is usually near the mucogingival junction (Fig. 3). The self-drilling bone screw is rotated (screwed) into the bone perpendicular to the occlusal plane without pre-drilling the site or soft tissue flap reflection [22, 29–31]. This approach is defined as a self-drilling procedure [30, 31]. After installation, the screw head remains at least 5 mm above the level of the soft tissue for facilitating oral hygiene access to prevent the soft tissue irritation, which is a common problem with I-R TADs [7, 10, 13, 14, 16]. Adequate soft tissue clearance is an important reason that MBS bone screws enjoy equal success whether placed in attached gingiva or movable mucosa (Fig. 3) [27••].

Sagittal Problem A skeletal class III malocclusion, with anterior cross-bite and/or open-bite, usually requires orthognathic surgery (Fig. 4). Patients and their parents may be concerned about the expense and surgical morbidity, so compromised treatment (camouflage) with extractions and inter-maxillary elastics is a common alterative. Camouflage treatment may result in an acceptable occlusion, but both facial and dental outcomes are typically compromised [32]. On the other hand, MBS bone screw anchorage is a conservative solution, with no extractions or orthognathic surgery, that offers the potential for ideal management of severe skeletal malocclusions [8, 9••, 17, 22]. The major advantage for MBS bone screws is their anatomical location outside the root area of the alveolar process. They can serve as anchorage to retract buccal segments to correct crowding in either arch [8, 22]. In addition, the line

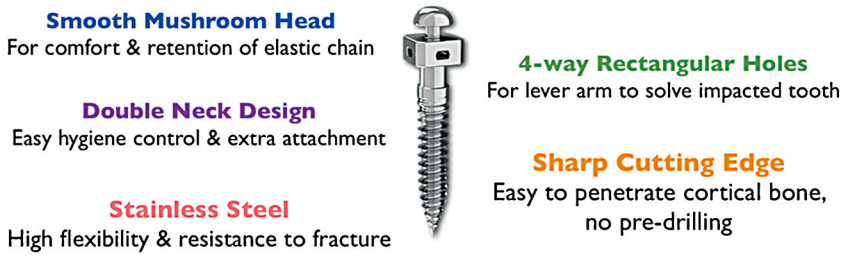

Fig. 2 Design specifications for a 2 × 12-mm stainless steel bone screw (OrthoBoneScrew®). The 12 mm length is suitable for the MBS and IZC, but a 14-mm screw is required for mandibular ramus screws (MRS) because of the thick soft tissue covering the osseous site

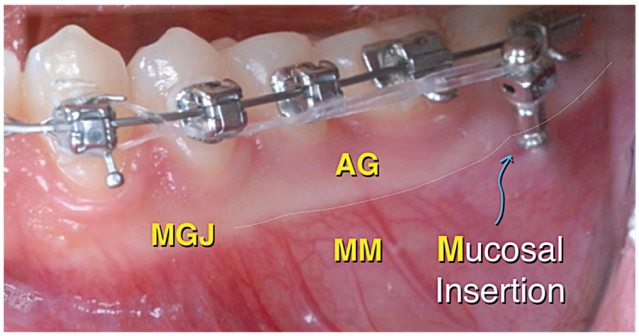

Fig. 3 The mucogingival junction (MGJ) of the mandibular left buccal segment is the demarcation between the attached gingiva (AG) and the movable mucosa (MM)

of force for retraction of the entire lower arch is superior to the center of resistance of the supporting bone, so the arch is both retracted and rotated to intrude the molars [9••, 17, 30, 31]. These mechanics are very effective for resolving class III open-bite malocclusion and decreasing the vertical dimension of occlusion (Fig. 4) [9••, 30, 31].

Transverse Problem Full buccal cross-bites are very difficult malocclusions to correct with conventional orthodontic mechanics. The severe posterior overbite usually requires orthognathic surgery to achieve an optimal outcome. Brodie [33] defined a bilateral full buccal cross-bite as a "Brodie bite or syndrome" because the lower jaw was "telescoped" within the upper arch. A unilateral full buccal cross-bite is deemed a "scissors bite" [34]. MBS bone screws provide adequate vertical anchorage to intrude lower molars to correct these severe functional compromises conservatively (Fig. 5) [35].

Impacted Teeth Ectopic eruption and impaction of teeth are common problems in orthodontics. The clinical prevalence of impaction is about 3.9% [36]. Horizontal oblique (trans-alveolar) lower canine impactions are very difficult to manage because of the surgical risk related to their proximity to the mental nerve, sublingual artery, and roots of adjacent teeth [37–39]. It is important to image the critical structures as part of the pre-surgery planning [37]. Surgical removal of an impaction or placing an implant [38] in the anterior mandibular midline is a risky surgical procedure, which may result in hemorrhage and result in periodontal tissue deficiencies that limit space closure and restorative options [39]. Damage to the mental nerve may result in permanent facial paresthesia plus bleeding from the sublingual artery can cause swelling of the floor of the mouth and tongue that can compromise the airway [38]. To avoid the surgical risk of extraction and restorative procedures, the orthodontic recovery of a trans-alveolar impaction is an attractive option, but very challenging [39]. After preparing an uprighting channel between the teeth, a lever arm anchored by a MBS bone screw managed the alignment of this very difficult impaction and produced a near ideal result (Fig. 6).

IZC Bone Screws

Bone screws are placed in the base of the zygomatic crest eminence on the buccal surface of the alveolar process that supports the roots of the maxillary first and second molars (Fig. 7). The surgical procedure is a two-step process: (1) the tip of the TAD is screwed in perpendicular to the axis of the teeth, and (2) as the screw tip penetrates the cortical plate, the screw driver is rotated ~ 70° in the frontal plane to position the bone screw buccal to the roots of the molars (Fig. 7) [22, 28••]. This is an innovative approach for securing E-A anchorage in the posterior maxilla. The same 2 × 12-mm SS screws, as used for the MBS, are appropriate for the IZC. To facilitate oral hygiene and control soft

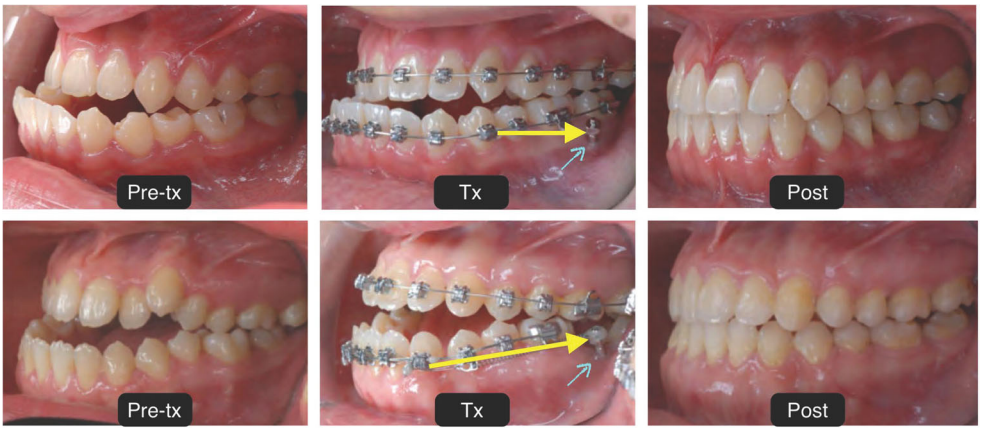

Fig. 4 The upper panel shows buccal views of a skeletal class III malocclusion in an adult with a 12-mm sagittal discrepancy at three time points: pre-treatment (Pre-tx), during active treatment (Tx), and post-treatment (Post). The lower panel is similar for a patient with a 8-mm sagittal discrepancy with an anterior open-bite. Blue arrows show the position of the MBS bone screws, and the yellow arrows document the lines of force to retract and posteriorly rotate the lower arches to conservatively correct the severe malocclusions

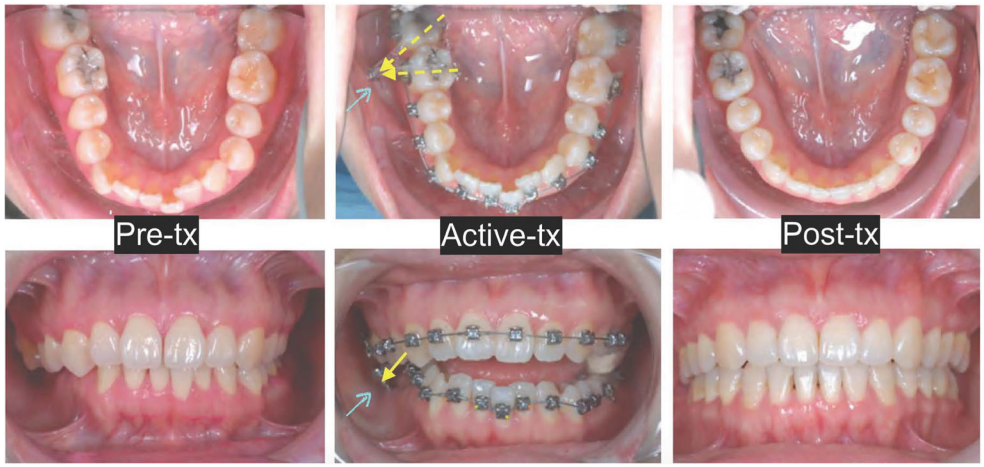

Fig. 5 Occlusal (top) and frontal (below) intraoral photographs show the pre-treatment (Pre-tx), active treatment (Tx), and post-treatment (Post) views for the treatment of a unilateral full buccal cross-bite. Skeletal anchorage with a unilateral MBS bone screw (blue arrow) provided conservative mechanics to intrude the lower right molars. The lines of force, for the elastics attached to the lingual surfaces of the lower right molars, are shown in the vertical and horizontal planes with a solid and dashed yellow arrows, respectively

tissue irritation, the head of each bone screw is positioned at least 5-mm superior to the level of the supporting soft tissue (Fig. 7) [28••, 29].

Sagittal Problems Class II malocclusion with severe overjet (> 10 mm) in an adult usually requires orthognathic surgery [40]. Correcting a full unit class II molar relationship in an adult is a challenging task with conventional mechanics (Fig. 8). The E-A location of IZC bone screws is ideal for anchoring mechanics to retract the buccal segments for resolving crowding, as well as or for retracting and posteriorly rotating the entire maxillary arch [9••, 41]. IZC bone screws are optimal anchorage for the conservative resolution of class II skeletal malocclusion (Fig. 8).

Impacted Teeth The incidence of impaction is the highest for mandibular and maxillary third molars followed by maxillary canines (≤ 7.5%) [37]. Impacted maxillary canines are best managed in the late mixed or early permanent dentition (age 10–12 years). The positional changes between 8 and 10 years of age are often indicative of the potential for impaction. CBCT is optimal imaging for designing an appropriate treatment plan [42]. If spontaneous eruption of a maxillary canine is unlikely, surgical intervention and orthodontic recovery is a

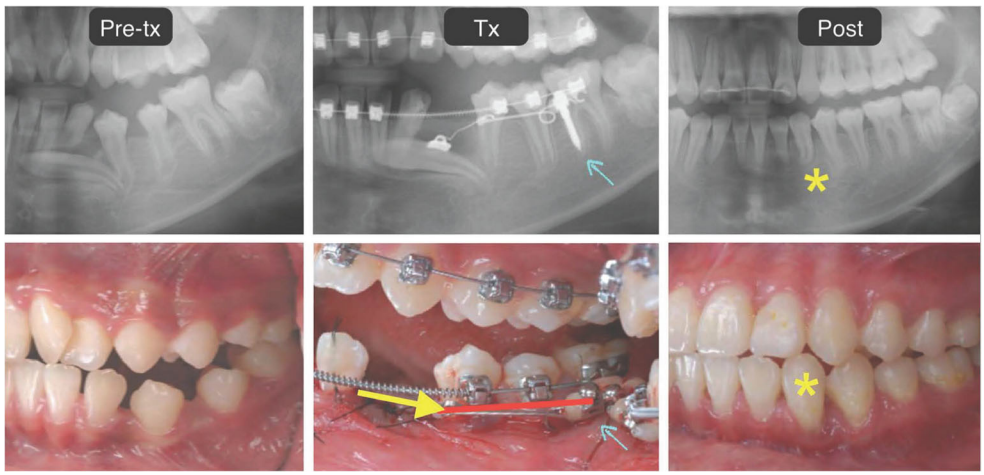

Fig. 6 The correction of a horizontal impaction of lower left canine on the lingual surface of the anterior mandible is show pre-treatment (Pre-tx), during active treatment (Tx) and post-treatment (Post) in panoramic radiographs (above) and right buccal intraoral photographs (below). A unilateral MBS bone screw (blue arrows) provides the skeletal anchorage to conservatively upright and extrude the impaction. As shown in the lower central photograph, a lever arm (red line) is attached to the bone screw that is activated to provide traction to upright and align the impaction. It is shown as a red line, and the line of force is a yellow arrow. Note the severely impacted canine was aligned to a near ideal relationship (yellow asterisks)

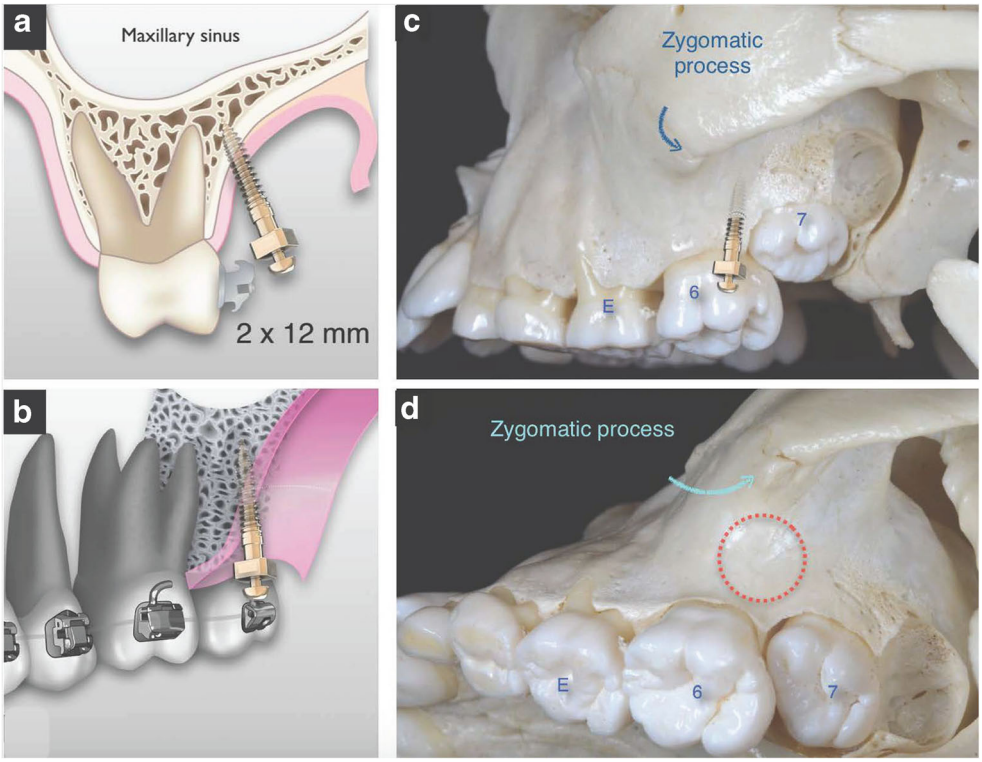

Fig. 7 The infrazygomatic crest (IZC) emerges from the base of the alveolar process on the buccal surface. The labeled teeth are the second deciduous molar (E), first permanent molar (6), and an unerupted second molar (7). **a** A 2 × 12-mm bone screw is inserted in the IZC. **b** In an adult, an IZC bone screw can be placed buccal to either the first or second molars. The preferred location is between the first and second molars as shown. **c** In a skull ~ 6 years of age, the IZC is sufficiently developed as a site for an IZC bone screw buccal to the first molar (6). **d** In the occlusal (axial) view, the preferred site for an IZC bone screw is shown with a dotted red circle. Submitted to the Angle Orthodontist for publication

superior solution to extraction, even if the canine is transposed with an adjacent tooth [43]. The unilateral loss of a canine is often a difficult esthetic and functional problem. Surgically uncovering and alignment of an impaction using an IZC bone screw anchorage is the preferred approach (Fig. 9). A lever arm anchored by the TAD can apply complex mechanics without disturbing adjacent teeth. However, the labial gingiva may be receded after a deep canine impaction is aligned. In the long term, these problems usually recover spontaneously to an acceptable level, but follow-up is required to determine if augmentation surgery is required [44].

Ramus Bone Screws Impacted second molars have a prevalence of 0.16–2.3% [45, 46], which may be related to variable expression of a WNT10A mutation in ectodermal dysplasia. That conclusion is consistent with family pedigree analysis in Asia [47]. It is usually desirable to recover horizontally impacted mandibular second molars [46]. However, impacted third molars may also be valuable dental units if the adjacent first or second molars are compromised or missing. Uprighting horizontally impacted third molars prior to extraction may be a wise measure to avoid damaging the adjacent second molar and its periodontium as well as the inferior alveolar [48]. However, uprighting horizontally impacted second and third molars ("stacked molars") is a complex task for an orthodontist and an oral surgeon. Horizontally impacted lower second molars can be uprighted surgically [49], but if they are deeply impacted, this is a risky surgical procedure.

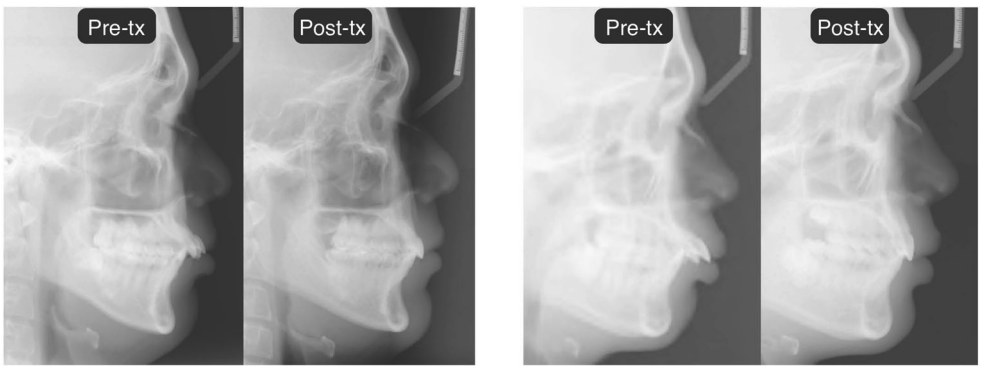

Fig. 8 Cephalometric radiographs show before (Pre-tx) and after treatment (Post-tx) images for two adults with severe class II malocclusion, associated with flaring of the maxillary incisors. The malocclusions were conservatively corrected with traction from bilateral IZC bone screws

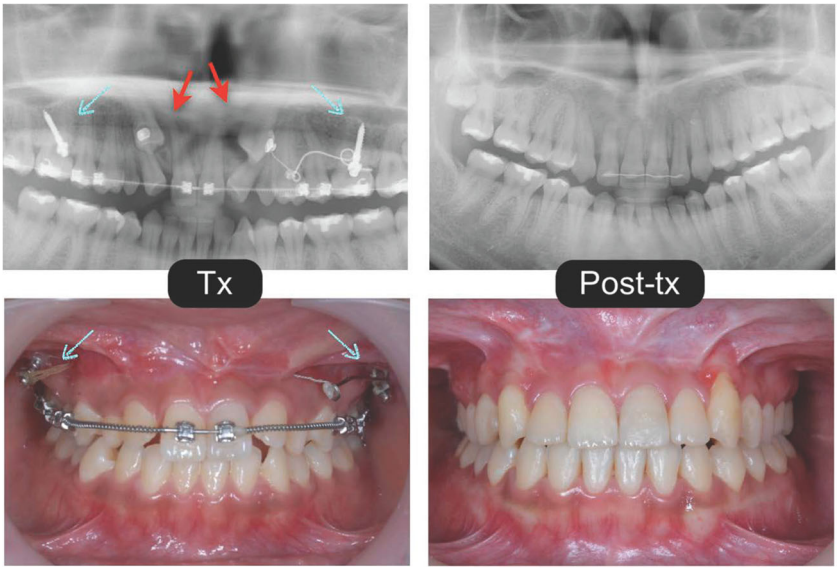

Fig. 9 Active treatment (Tx) and post-treatment (Post-tx) radiographs (above) and intraoral photographs (below) show the correction of deeply impacted maxillary canines (red arrows) with IZC screws (blue arrows) combined with/without a lever arm. In the lower right view, note that the labial gingiva on the upper right canine is near ideal, but gingiva on the upper left canine may require augmentation when Post-tx healing is complete

For deeply impacted molars, a superior line of force anchored by a ramus bone screw (RBS) is needed for uprighting the tooth (teeth) prior to applying conventional mechanics. There are no previous reports of TADs in the mandibular ramus probably because of the thick soft tissue. However, the osseous structure in this area is dense compact bone that is amenable to surgical fixation [50, 51] and should be a good site for TADs.

Lin [52] reviewed six different methods for recovering deeply impacted molars. He concluded that the most reliable and effective approach was to surgically expose the deeply impacted molars and upright them with traction via a RBS. From a biomechanics perspective, the anterior ramus of the mandible is an ideal location for an anchorage screw to upright a horizontally oriented impaction (Fig. 10).

Horizontally impacted mandibular molars ("stacked molars") are complex problems that are refractory to routine orthodontic treatment (Fig. 10). An efficient treatment strategy requires development of an anchorage device that is suitable for the challenging intraoral sites in the posterior mandible. Many methods for uprighting and aligning molars have been proposed, but they are not appropriate for deep horizontal impactions. The RBS offers a superior line of force that is ideal for deeply impacted mandibular molars. This approach has proven successful in challenging clinical applications (Fig. 10) [53–55].

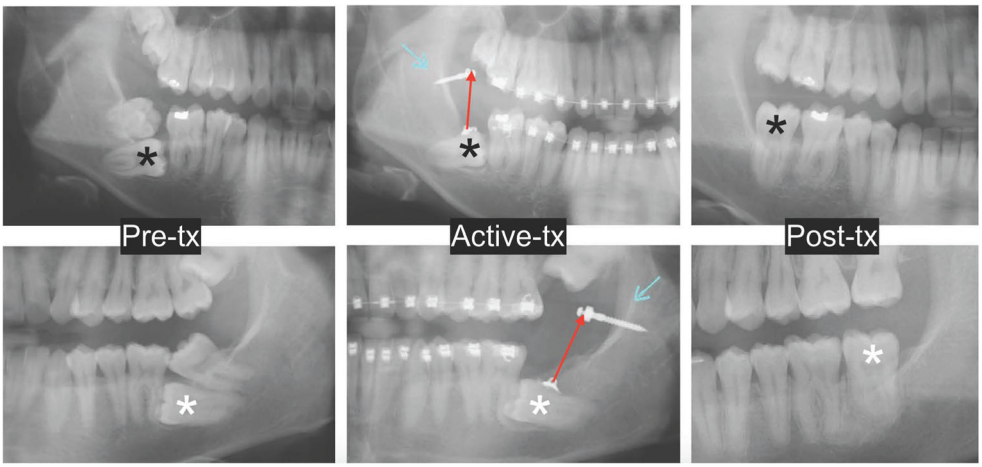

Fig. 10 Mandibular second molars are horizontally impacted with overlying third molar impactions ("stacked molars") bilaterally. The right and left sides of the same patient are shown in the upper and lower panels, respectively. The third molars are extracted, and the second molars are uprighted with a ramus bone screw in each anterior ramus of the mandible (blue arrows). The second molars are marked with asterisks on the right (black) and on the left (white). The lines of force for traction are red. This procedure avoids the serious surgical and restorative risks associated with extracting the deep impactions. See text for details

Conclusions

Routine malocclusions are acquired from the environmental (epigenetic) factors that are endemic in an industrialized society: refined diet, habits, and airway problems due to pollution and allergies. Most patients have the potential for near ideal morphology if the teeth and dental arches are repositioned in 3D. Bone screws for orthodontics anchorage are placed outside the alveolar process to avoid root interference as teeth and arches are moved. There are three well-established intraoral anchorage sites: mandibular buccal shelf (MBS), infrazygomatic crest (IZC), and mandibular ramus. Displaced teeth, impactions, and/or entire dental arches can be moved and rotated to reverse the etiology of a malocclusion and thereby restore optimal esthetics and function.

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Compliance with Ethical Standards

Conflict of Interest Chris Chang reports personal fees from Ormco Corporation and a patent pending for an orthodontic bone screw, issued in 2009. Joshua Lin and H.Y. Yeh declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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