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# An Overview of Clinical Applications for Temporary Anchorage Devices (TADs)

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The advent of temporary anchorage devices (TADs) has enabled orthodontic clinicians to accomplish profound clinical solutions that were previously deemed inconceivable with traditional anchorage modalities. Orthodontic applications with TADs have come a long way since 1983 when the first clinical case demonstrated the possibility of "absolute" anchorage control in humans [1]. Various types of complex and challenging malocclusions can now be successfully treated using TADs. This chapter outlines some contemporary clinical applications for TADs to treat various orthodontic problems. The progress in TAD-related research and potential future directions for TADs are briefly discussed.

## 1.1 Corrections in the Anteroposterior Dimension

The use of TADs is a compliance-free alternative to traditional forms of anchorage control in orthodontic treatment. Of the three dimensions, TADs have been used most frequently to correct problems in the anteroposterior dimension. Typical treatment objectives include mesialization or distalization of a single tooth, multiple teeth, or maxillary/mandibular total arches.

### 1.1.1 Comparison with Conventional Methods for Anchorage Reinforcement in the Anteroposterior Dimension

A number of studies have evaluated treatment outcomes with TADs and compared them to conventional methods such as headgear, Nance appliances, reverse pull headgear, and various distalizers [2–5]. Recently, a systematic review and meta-analysis was reported that evaluated the treatment effectiveness of intraoral TADs and headgear for en-masse retraction after premolar extractions [2]. In a review of 14 articles and 616 patients, TADs effectively enabled 1.86 mm more anchorage preservation by limiting mesial movement of maxillary first molars than did conventional methods using various types of headgear. A randomized clinical trial compared the effectiveness of three different methods including TADs, Nance appliances, and headgear [3]. In terms of maximum anchorage, there were no significant outcome differences in effectiveness for the three groups. The authors found, however, that patients had a superior comfort level with TADs and Nance appliances than with headgear. Patients also reported fewer problems with TADs than with either of the other two groups. A retrospective study compared orthodontic tooth movement after treating adult patients with maxillary dentoalveolar protrusion using TADs vs. headgear [4]. The authors highlighted the superior treatment outcomes with TADs compared to headgear in terms of greater maxillary anterior tooth retraction, less maxillary molar mesial drift, and shorter treatment time. A meta-analysis compared the treatment effects of distalizers between TAD-supported pendulum appliances and conventional distalizers, such as pendulum appliances with Nance buttons [5]. Based on six studies, this meta-analysis showed a higher average molar distraction using TADs (5.1 mm), which was significantly longer than that found with conventional appliances (3.3 mm). Also, premolar distalization averaged 4.0 mm with skeletal anchorage in contrast to 2.3 mm with conventional methods.

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### 1.1.2 Functional Appliances and Auxiliaries Combined with TADs

The introduction of TADs into orthodontics not only enables effective anchorage reinforcement with individual TADs, but also enhances the functionality of conventional orthodontic appliances when they are combined with TADs. For example, pendulum appliances anchored to the maxillary bone with TADs have achieved a similar amount of maxillary molar distalization to that of conventional pendulum appliances without TADs, providing significant premolar distalization in potentially less total treatment time and without the problem of anchorage loss [6]. For correction of Class III malocclusion with dental midline discrepancy, TADs can be used with sliding jigs (Figure 1.1) [7]. TAD-supported Herbst appliances have significantly reduced unfavorable adverse treatment effects such as mandibular incisor proclination [8]. Placing a miniplate on the infrazygomatic buttress and linking it to the outer bow of a facemask has allowed protraction of the maxilla without any undesirable tooth movement that might cause unwanted arch length loss [9]. As an esthetic and simplified treatment option, a double J-hook retractor and palatal TADs can be used to close extraction spaces by retracting the maxillary anterior segment [10]. The use of a double J-hook significantly reduced treatment time with the fixed appliances. Therefore, this might be a viable treatment option for patients who are reluctant to use conventional fixed appliances (Figure 1.2).

### 1.1.3 Miniplates Combined with TADs

Orthodontic miniplate anchorage systems have been used for various clinical applications. They are attractive options since they are independent of proximity to adjacent teeth and interradicular space limitations. In addition, since miniplates can withstand heavier forces than individual TADs, they have been used for rigorous orthodontic tooth movement such as total arch distalization. Total arch distalization with a palatal anchorage plate, when combined with tooth extractions, may be a feasible treatment option to achieve better facial esthetics without orthognathic surgery. This approach has been used as a successful non-surgical correction of Class I malocclusion with severely protrusive soft tissue profiles by extracting four first premolars and applying total arch distalization (Figure 1.3) [11]. After making a series of modifications, these palatal miniplates have demonstrated successful

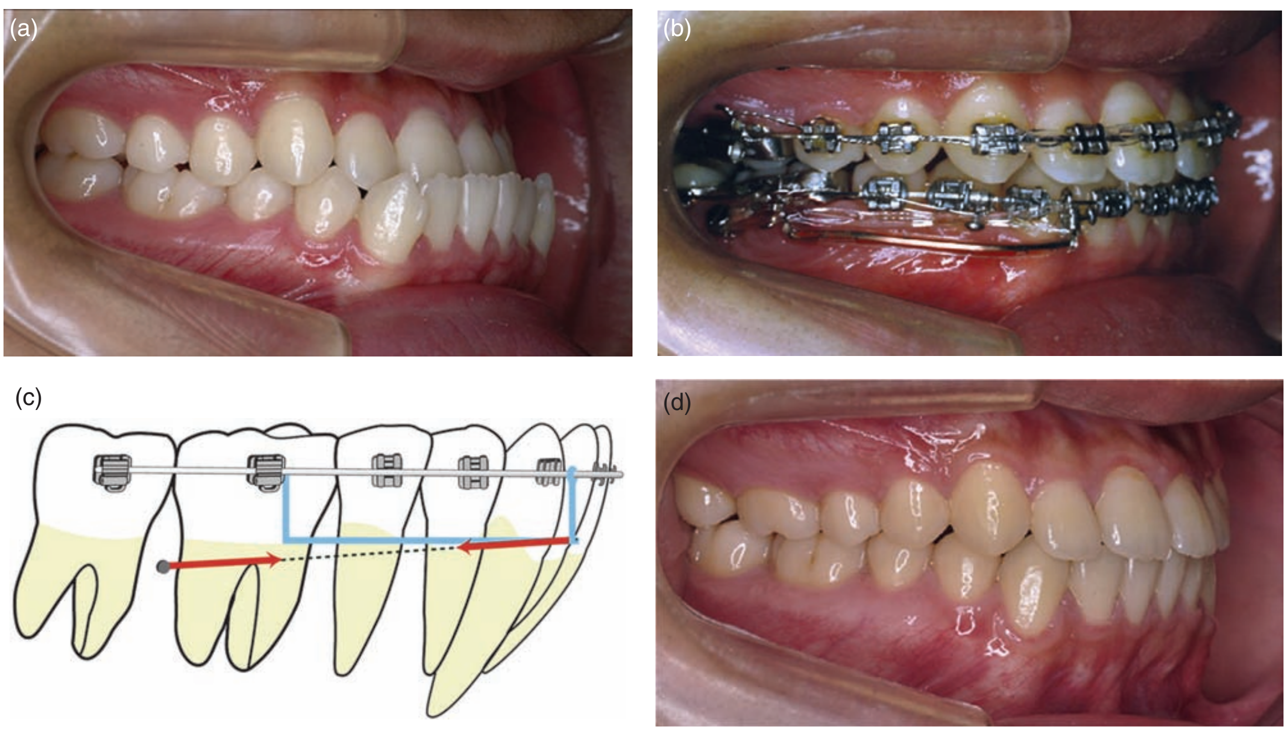


**Figure 1.1** Class III correction with TADs and sliding jigs [7]. (a) Initial examination indicated full-step Class III canine and molar relationships. (b) TADs were placed and connected with a sliding jig. (c) Schematic illustration shows a miniscrew-anchored sliding jig and the direction of the force. (d) Final examination indicated Class I canine and molar relationships. *Source:* Tai et al. [7]. Reprinted with permission from Elsevier.

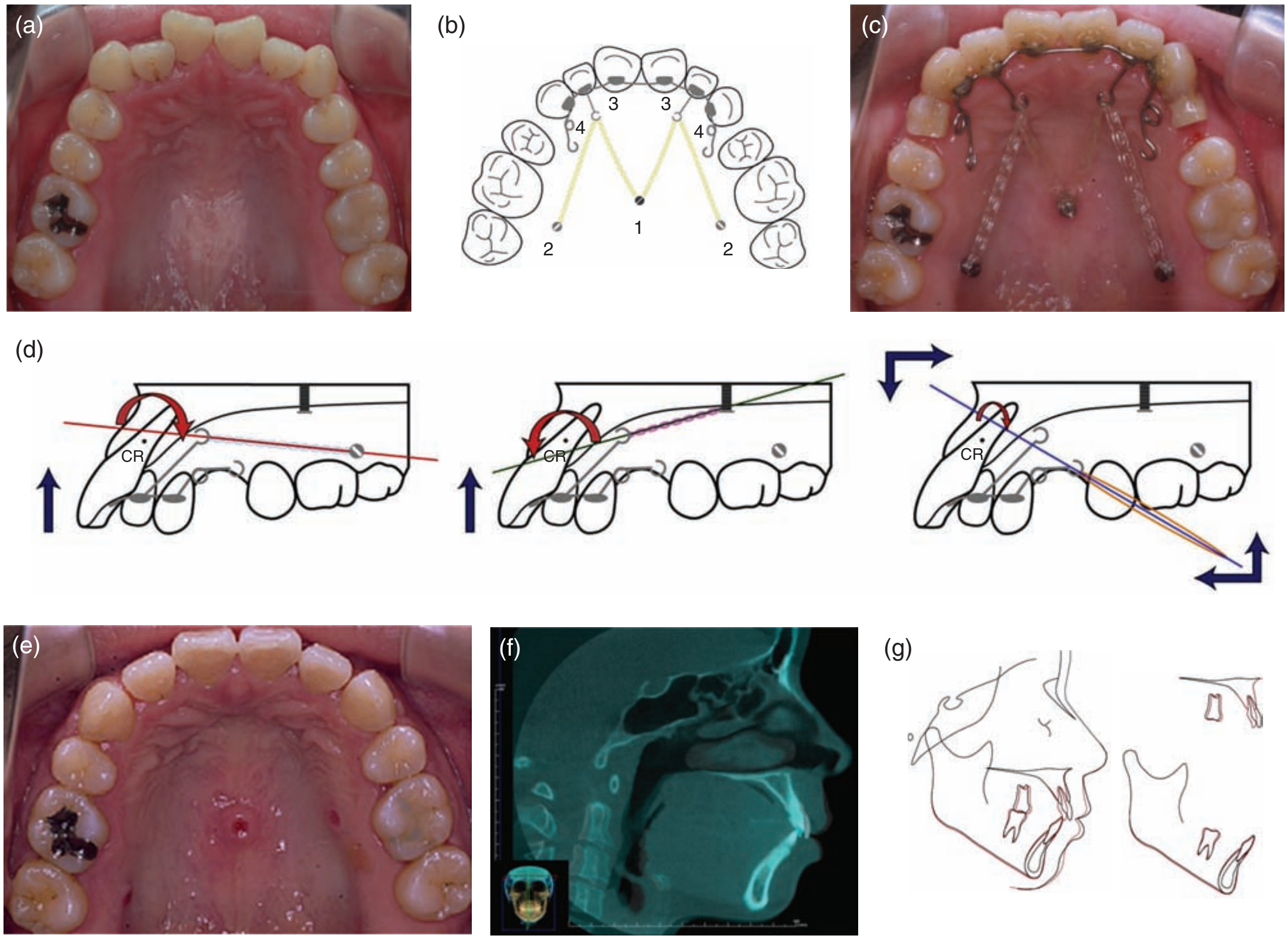


**Figure 1.2** Class II correction with a double J retractor [10]. (a) Initial examination indicated a Class II Division 1 malocclusion with anterior crowding. (b) Schematic illustration shows a double J retractor and palatal TADs: palatal TADs (1, 2); anterior lever arm hooks (3); posterior lever arm hooks (4). (c) A double J retractor was connected to the TADs with elastomeric chains to achieve bodily translation. (d) Anterior tooth tipping can be controlled by adjusting the extension line of the force. (e) Maxillary anterior teeth were retracted and the extraction spaces were completely closed. (f) Maxillary anterior teeth were retracted and slightly tipped lingually. (g) Maxillary incisors were retracted after treatment. *Source:* Park et al. [10]. Reprinted with permission from Elsevier.

treatment outcomes with Class II malocclusion cases treated without extraction or severe bimaxillary protrusion with maxillary first premolar extractions [12, 13]. These palatal miniplates also demonstrated advantages when controlling distal tipping of the maxillary posterior teeth during distalization. A comparison study provided quantitative evidence that the palatal anchorage plate provided greater distalization and intrusion with less distal tipping of the first molar compared to conventional buccal TADs (Figure 1.4a–c) [14].

A recent follow-up study evaluated the relationship between the amount of maxillary arch distalization with palatal anchorage plates and changes in the airway space. Whether the cases were treated with premolar extraction (3.4 mm of the maxillary first molar distalization) or with non-extraction (3.2 mm of the maxillary first molar distalization), there were no significant changes in airway volume or minimum cross-sectional area of the oropharynx after maxillary arch distalization (Figure 1.4d) [15]. Miniplates have been placed on mandibular bodies to treat Class III malocclusions [16]. More recently, ramal plates have been placed in the retromolar fossa as a novel approach for retracting mandibular teeth or distalizing the mandibular total arch (Figure 1.5) [17, 18]. A finite element analysis (FEA) study verified that mandibular arch distalization with a ramal plate leads to greater distal and extrusive displacement of the posterior teeth and changes counterclockwise rotation of the occlusal plane compared to the same tooth movement using TADs in the buccal shelf or interradicular regions (Figure 1.5c) [19].

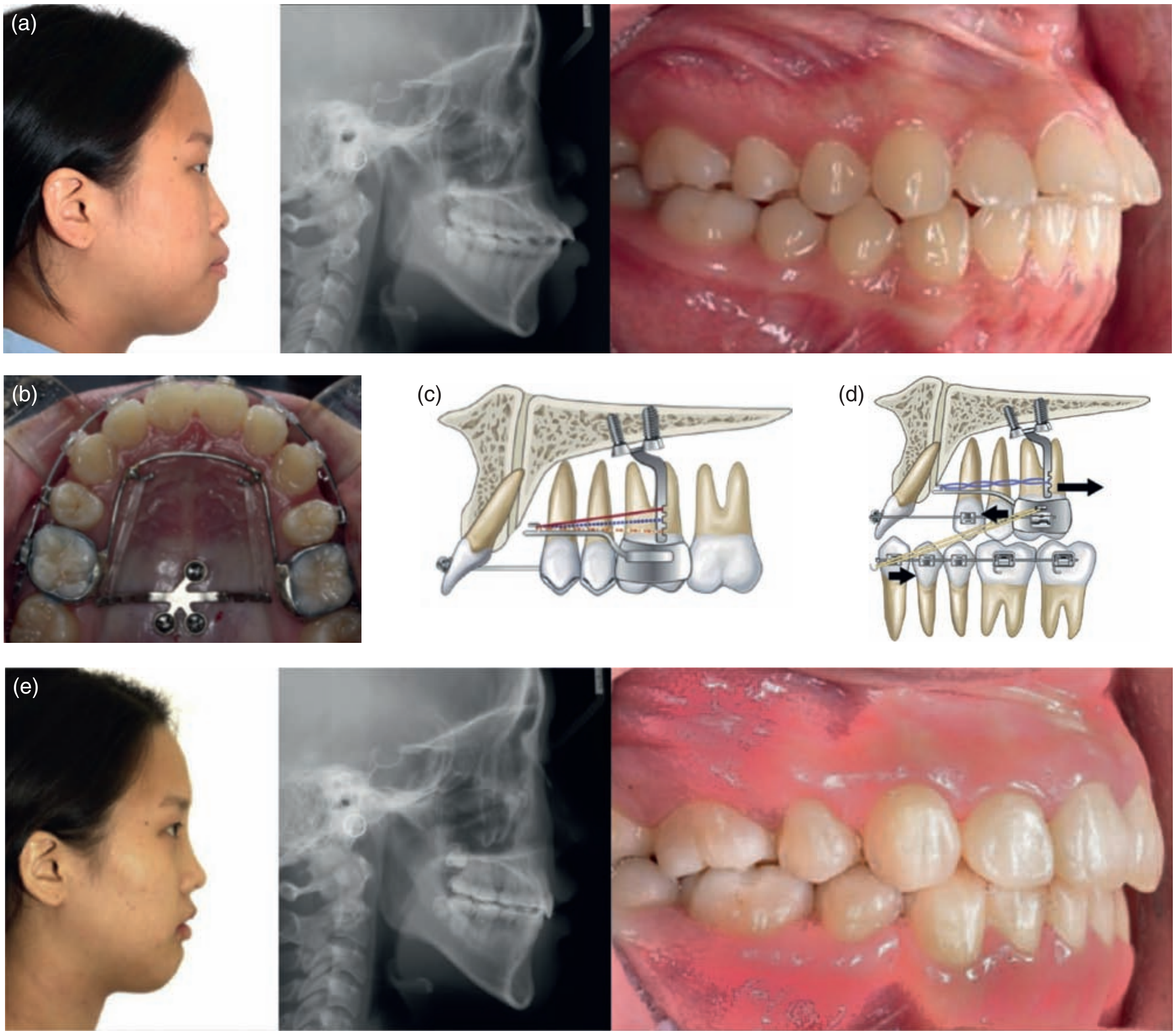


**Figure 1.3** Class I correction with a palatal plate and TADs [11, 13]. (a) Initial examination indicated Class I malocclusion with the proclined maxillary incisors and protrusive lips. (b) A palatal anchorage plate was placed. (c) Retractive force direction can be controlled by engaging elastomeric chains at different levels of the hooks. (d) The mandibular arch was retracted using Class III elastics. (e) Maxillary and mandibular anterior teeth were retracted. Facial harmony and lip support were significantly improved. *Source:* Kook et al. [11]. Reprinted with permission from Elsevier.

## 1.2 Corrections in the Vertical Dimension

### 1.2.1 Treatment for Dental and Skeletal Open Bite

A moderate to severe dental open bite, often in conjunction with a skeletal open bite, is regarded as one of the most challenging orthodontic problems to correct. The main applications of TADs for correcting anterior open bite are either intrusion of the posterior teeth or extrusion of the anterior teeth. For molar intrusion, TADs have been placed in various anatomical sites [20–22].

For open bite correction, TADs can be combined with a transpalatal arch (TPA) to provide efficient maxillary posterior tooth intrusion along with tongue exercise (Figure 1.6) [20]. Anterior open bite also can be corrected with TADs and miniplates (Figure 1.7) [21]. Miniplates were placed bilaterally in the zygomatic arch and the mandibular molar regions to provide absolute anchorage for bimaxillary molar intrusion. This approach can not only treat dentoskeletal open bite with positive overbite but can also achieve a counterclockwise rotation of the mandible. In lingual orthodontics, palatal

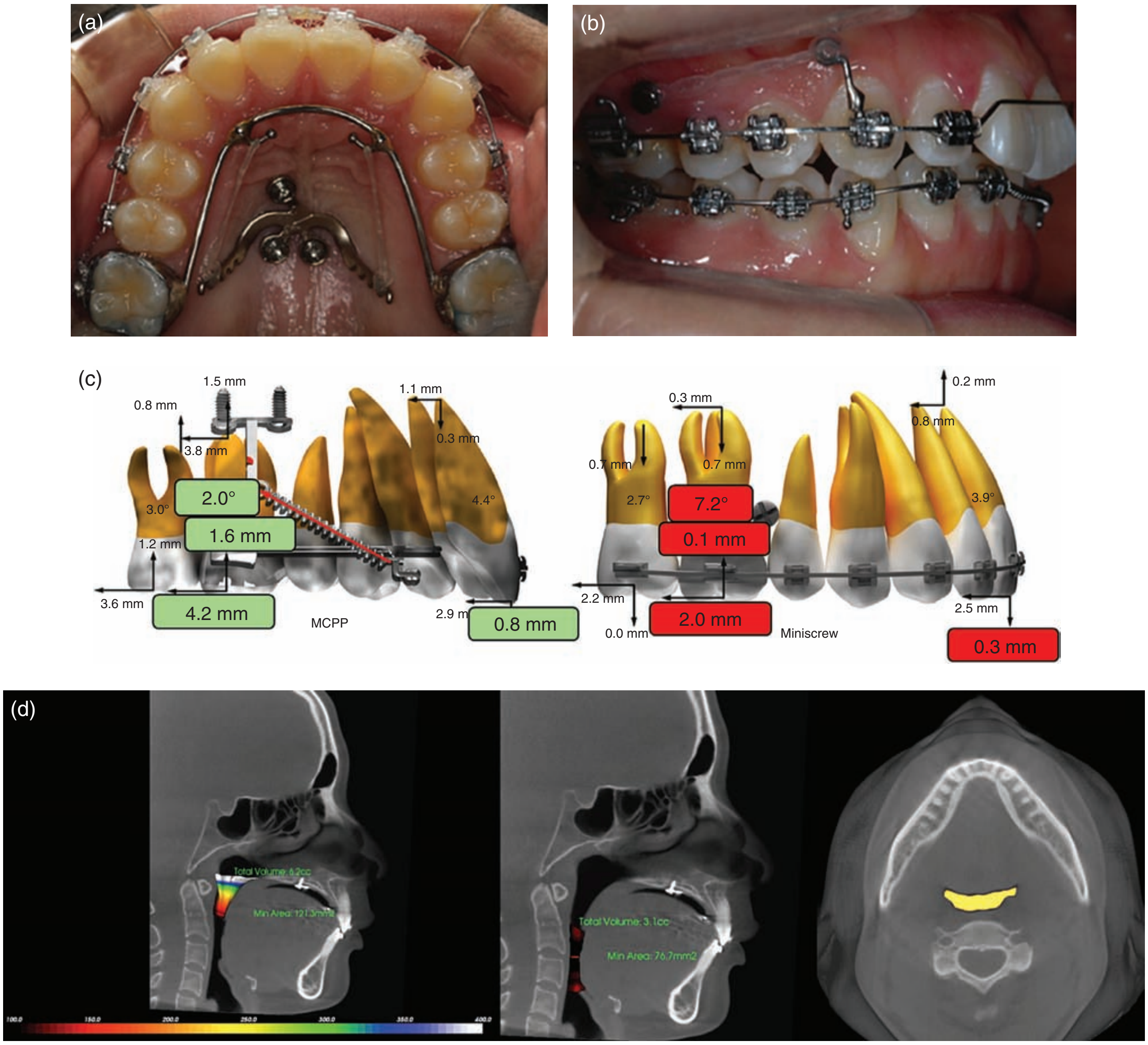


**Figure 1.4** Comparison between a palatal anchorage plate and buccal TADs [14, 15]. (a) A palatal anchorage plate was placed for maxillary total arch distalization. (b) TADs were placed on the buccal side of the posterior teeth. (c) The palatal anchorage plate group showed greater distalization and greater intrusion with less distal tipping of the maxillary first molar and more extrusion of the maxillary incisor than the buccal TAD group. (d) No significant changes were found in the airway volume or minimum cross-sectional area of the oropharynx after treatment with these two groups.

TADs can be used to retract the anterior dentition and intrude the posterior dentition to correct anterior open bite (Figure 1.8) [22]. One advantage of this modality is that the proclination and intrusion of the maxillary anterior teeth can be controlled by adjusting the length of the crimpable hooks and the vertical locations of the palatal TADs (Figure 1.8c).

### 1.2.2 Treatment for Dental and Skeletal Deep Bite

Conventional modalities for incisal intrusion have relied on archwire mechanics. These traditional methods, however, often have the undesirable effect of labial torqueing the maxillary incisors. The introduction of TADs as an anchorage has made the complex tooth movement of

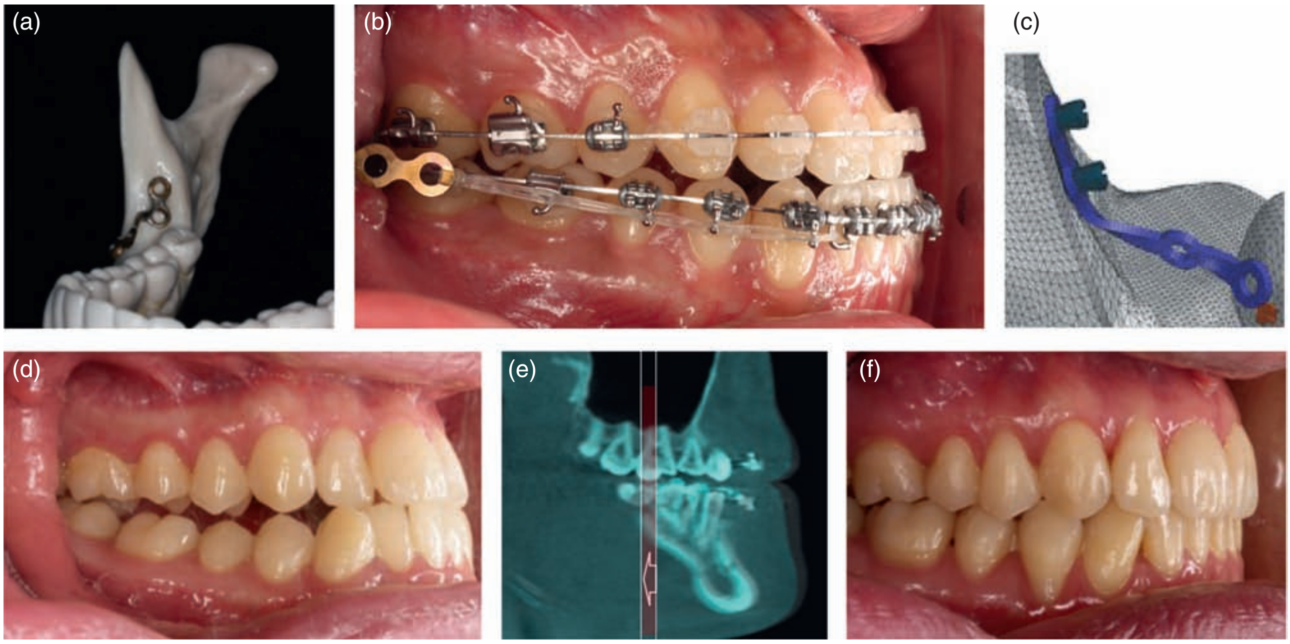


**Figure 1.5** Skeletal Class III correction with a ramal plate [17, 19]. (a) The ramal plate was located on the retromolar fossa. (b) The plate was surgically fixated with two screws and the hook extended out of the mucosa. An elastic chain was tied for mandibular total arch distalization. (c) There was greater distal and extrusive displacement of the posterior teeth with ramal plate than with buccal shelf or interradicular TADs. (d) Initial examination indicated Class III malocclusion with lateral open bite. (e) CBCT superimposition shows the magnitude of molar distalization. (f) Final examination indicated Class I canine and molar relationships. *Source:* Kook et al. [17]. Reprinted with permission from Elsevier.

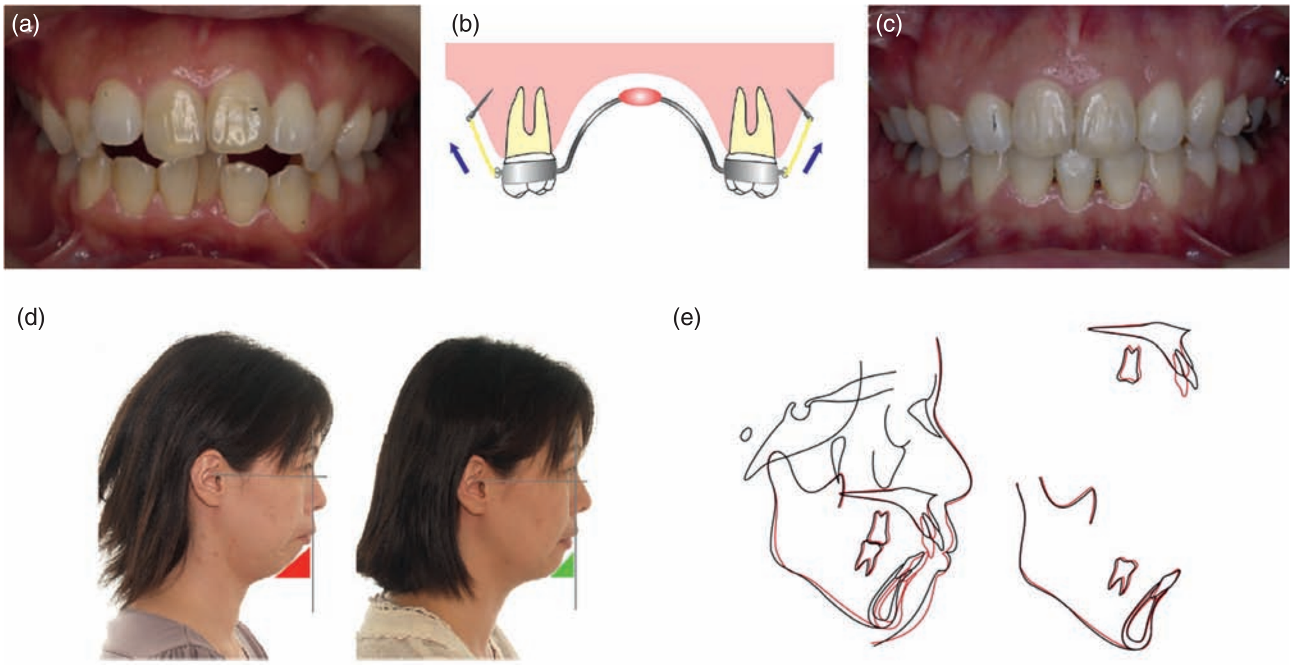


**Figure 1.6** Anterior open bite correction with TADs and a TPA [20]. (a) Initial examination indicated Class II malocclusion with anterior open bite. (b) TADs were placed on the buccal side of the maxillary first molars. Buccoversion of the posterior teeth was prevented by placing a modified TPA. (c) Optimal overbite was achieved after the maxillary first premolars and one mandibular central incisor were extracted. (d) Facial esthetic harmony was achieved. (e) Intrusion of the maxillary posterior teeth and retraction of the maxillary anterior teeth contributed to an improved overbite. *Source:* Park et al. [20]. Reprinted with permission from Elsevier.

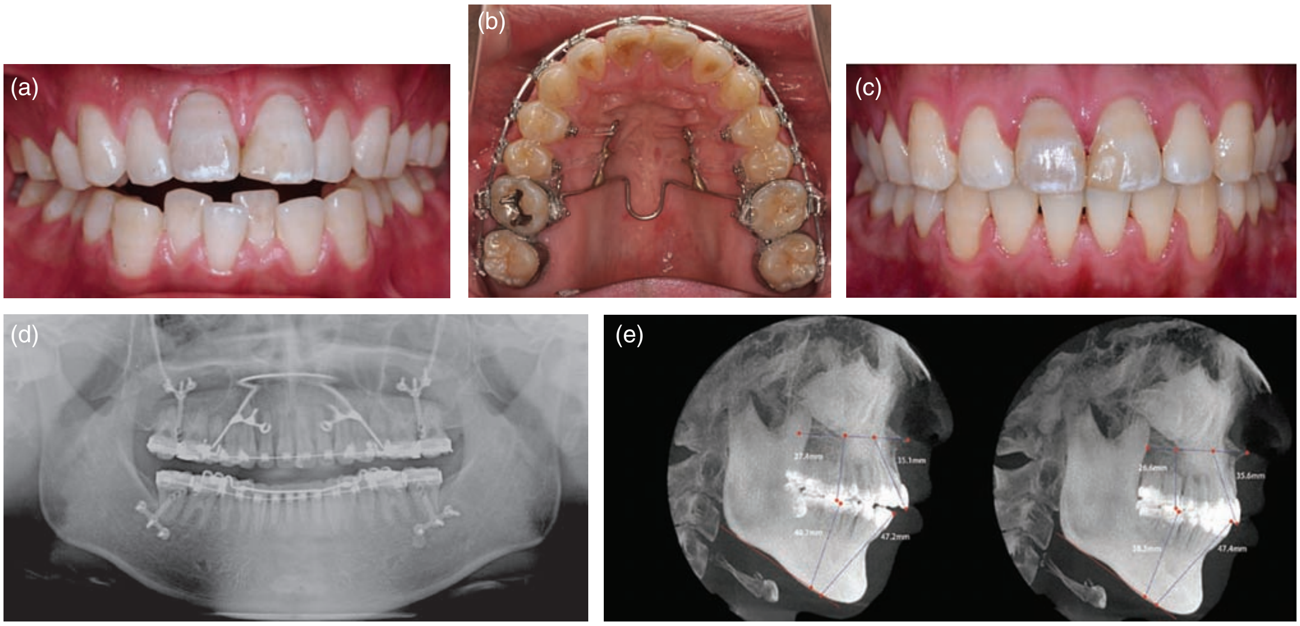


**Figure 1.7** Anterior open bite correction with TADs, miniplates, and a TPA [21]. (a) Initial examination indicated anterior open bite. (b) Extended arms from the TPA were connected to the buttons bonded on the palatal side of the maxillary premolars with elastomeric chains for intrusion. (c) Positive overbite was achieved after treatment. (d) During the treatment, miniplates were surgically placed on the infrazygomatic buttresses and mandible for intrusion of the posterior teeth. (e) Optimal overbite was achieved and the interincisal angle was increased. *Source:* Park et al. [21]. Reprinted with permission.

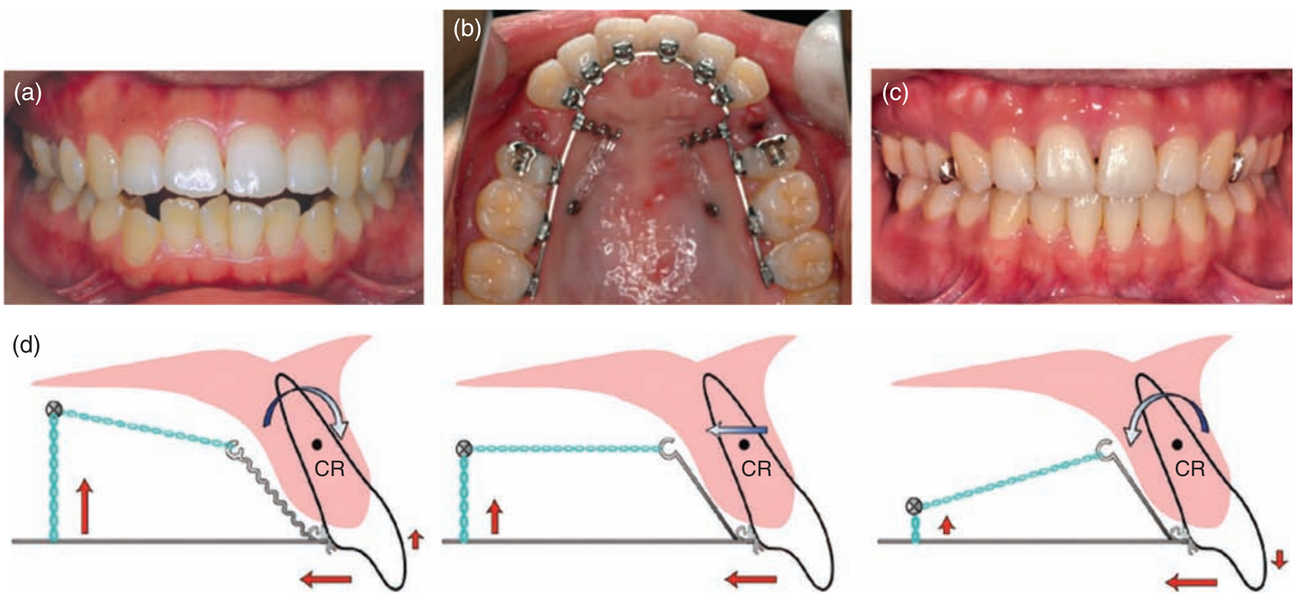


**Figure 1.8** Anterior open bite correction with TADs and maxillary lingual appliance [22]. (a) Initial examination indicated anterior open bite. (b) Lingual appliance with crimpable hooks were bonded after extraction of the maxillary first premolars. (c) Overbite was improved. (d) Torque and direction of the tooth movement were controlled by the location of TAD placement. CR, Center of resistance. *Source:* Park et al. [22]. Reprinted with permission.

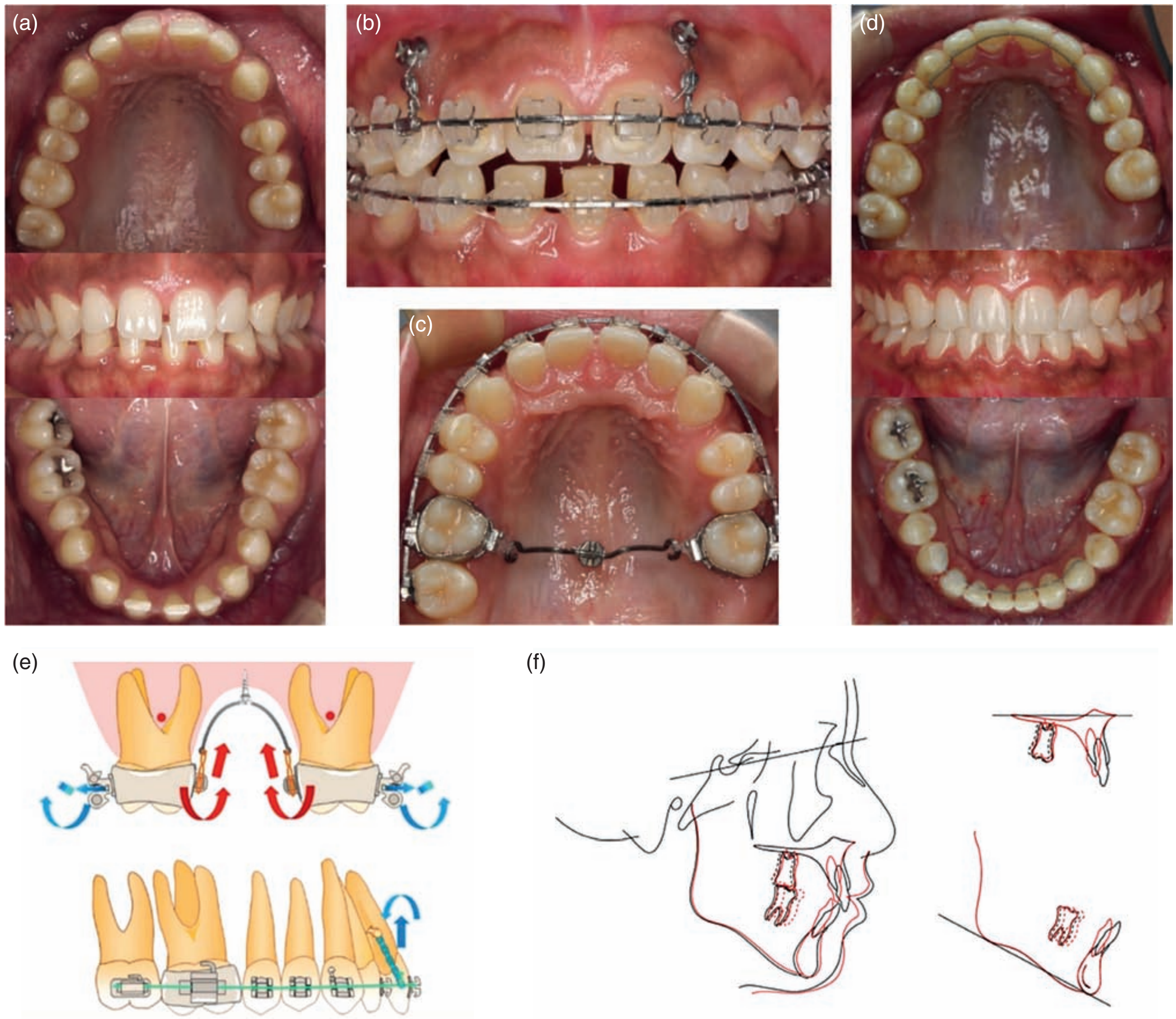


**Figure 1.9** Deep bite correction with TADs [23]. (a) Initial examination indicated deep bite and excessive gingival display on smile (gummy smile). (b) TADs were inserted in the maxillary anterior area to intrude the maxillary incisors. (c) Maxillary molars were restricted from extrusion using a TAD-supported TPA connected to the maxillary molars with elastomeric chains. (d) Optimal overbite was achieved and gingival display on smile was significantly improved. (e) The maxillary anterior teeth were intruded, while excessive molar extrusion was prevented with a TAD-supported TPA. (f) Maxillary incisors were intruded and slightly retroclined. *Source:* Uzuka et al. [23]. Reprinted with permission from Elsevier.

incisal intrusion considerably simpler. For example, in patients with "gummy smile," TADs have been inserted in the maxillary anterior and midpalatal areas to intrude the whole maxillary dentition, which results in an improved overbite and reduced excessive gingival display (Figure 1.9) [23]. Comparison studies have been performed to evaluate the effects of incisor intrusion treated with the aid of TADs or conventional utility archwires [24, 25]. These reports have commonly supported the idea that groups treated with TADs have less unfavorable tooth movements such as maxillary incisal proclination and maxillary molar tipping than do the groups treated with utility archwires alone.

## 1.3 Corrections in Transverse Dimensions

### 1.3.1 Palatal Expansion with Midpalatal Suture Split

Although tooth-borne rapid maxillary expanders (RMEs) have been most commonly used to treat adolescents with constricted maxillary arches, adverse effects have been reported with them such as undesirable tooth movement (e.g. buccal torque of the anchored teeth, limited skeletal expansion, the potential for root resorption, post-expansion

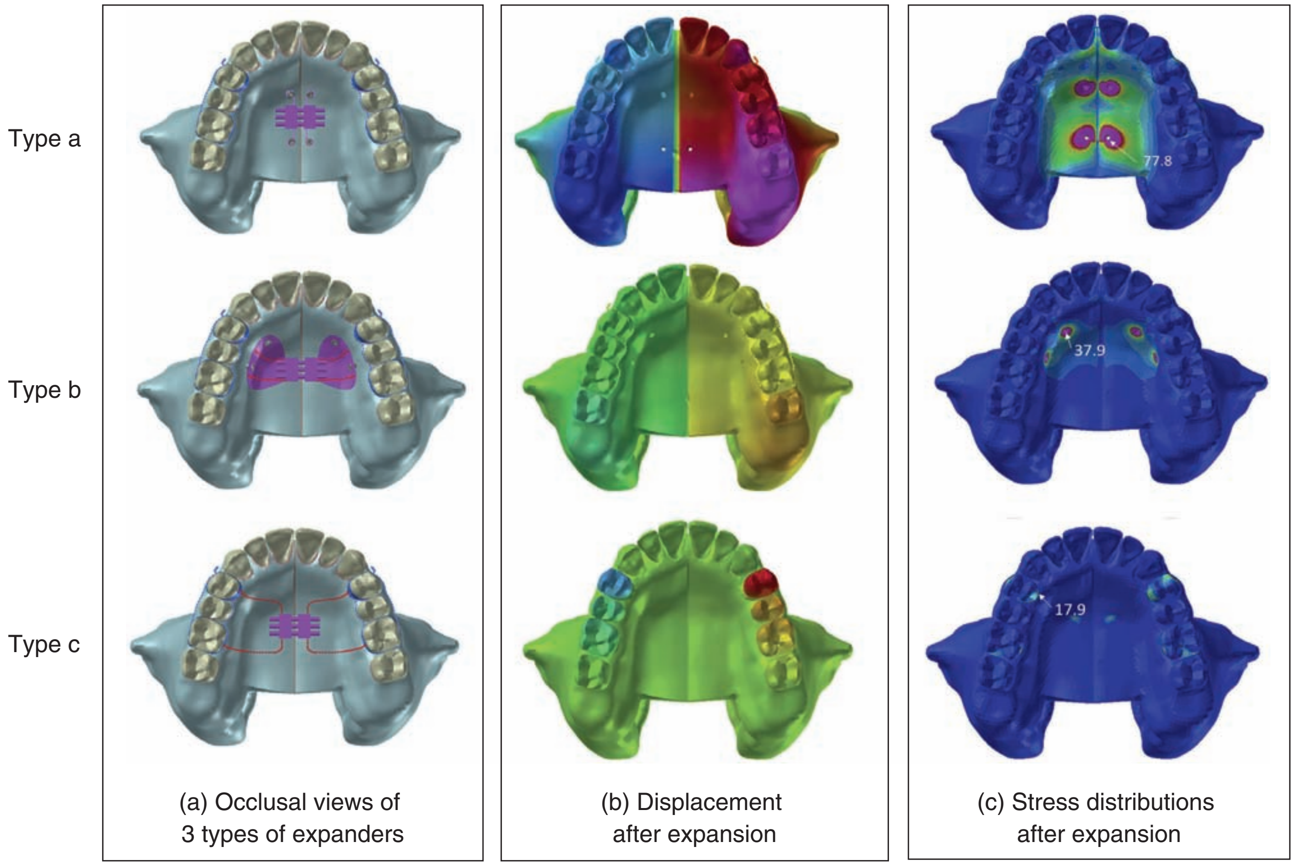


**Figure 1.10** Finite element analysis on displacement and stress distribution with different bone-borne palatal expanders [31]. (a) Occlusal views of the three types of palatal expanders: paramedian bone-borne expander (type a), palatal-slope bone-borne expander (type b), and conventional tooth-borne expander (type c). (b) Dental and skeletal displacements on the transverse plane after activation of the three different expanders. (c) Stress distributions on the maxilla and maxillary dentition after activation of the three different expanders. *Source:* Park et al. [31]. Reprinted with permission from Elsevier.

relapse, and unsuccessful midpalatal suture split) [26, 27]. Bone-anchored expanders with TADs or hybrid types (i.e. tooth- and bone-anchored expanders) are alternatives for applying direct force to the maxillary bone to overcome the limitations of the tooth-borne expanders described above [28]. Many comparative studies have stated that bone-anchored expanders with TADs achieved outcomes that are just as good as traditional tooth-borne expanders [28, 29]. Moreover, it is worth noting some studies have demonstrated successful treatment in adults with constricted maxillary arches, which used to be a very challenging treatment objective with traditional tooth-borne expanders [30]. An FEA study demonstrated the displacement and the stress distribution with different types of palatal expanders: (i) paramedian bone-borne expander, (ii) palatal-slope bone-borne expander, and (iii) conventional tooth-borne expander (Figure 1.10) [31]. Dental and skeletal displacements after the application of expansion forces widely varied with the different types of the expanders (Figure 1.10b). The magnitude and distribution of the stress after the application of the expansion forces were also determined for each expander type (Figure 1.10c). Orthodontic clinicians can take these preclinical findings into consideration when selecting the expander type.

### 1.3.2 TADs for Impacted Teeth

TADs have been used to treat difficult clinical problems which were previously deemed very challenging to impossible with traditional orthodontic modalities. Horizontally impacted mandibular molars are considered difficult to treat due to their limited access and limited anchorage support [32]. If areas distal to the second molars are available, horizontally impacted mandibular molars can be uprighted using retromolar TADs (Figure 1.11). Maxillary canine impaction is another challenging clinical problem that requires an adequate anchorage control. Palatally impacted canines, if transposed with adjacent teeth, can be even more complicated. Successful correction of a palatally impacted and transposed canine has been reported [33]. Once ideal direction of the forced eruption had been determined

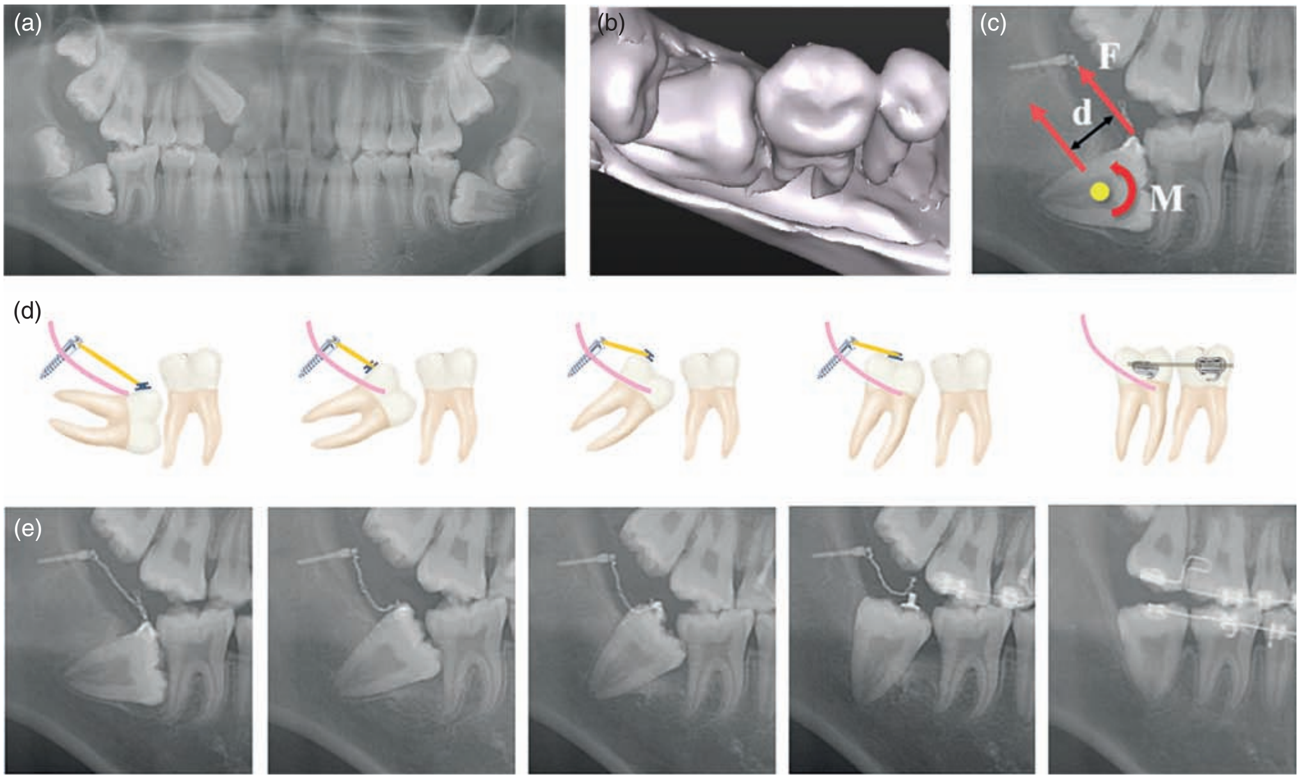


**Figure 1.11** Uprighting horizontally impacted mandibular second molars with TADs [32]. (a) Mandibular second molars were horizontally impacted. (b) Occlusal CBCT view of the horizontally impacted mandibular left second molar. (c) Biomechanical factors for uprighting impacted mandibular second molars: *F*, force; *M*, moment; *d*, distance. (d) Illustrations of biomechanical procedure for uprighting impacted mandibular second molars with retromolar TADs. (e) Treatment procedure for uprighting impacted mandibular second molars with retromolar TADs. *Source:* Kim et al. [32]. Reprinted with permission.

with cone-beam computed tomography (CBCT), the impacted and transposed canine was successfully treated with palatal TADs (Figure 1.12).

## 1.4 Future Directions

In a relatively short time, TADs have evolved extensively in both clinical applications and research perspectives [34]. In the 1980s and early 1990s, research topics focused primarily on the biomechanics of dental implants such as the preclinical evaluation of the bone–implant interface in terms of osseointegration, load bearing, and bone healing [34]. As the clinical application of TADs increased exponentially, the factors that account for their stability and success have been broadly classified as either the patient's anatomical and periodontal conditions or specifications of the TADs in conjunction with their biomechanical properties. Researchers and clinicians have substantially broadened our understanding of TADs, particularly as new technologies such as CBCT and FEA have been introduced. Recently, evidence-based clinical TAD studies have become widely available. In the past decade, an important but limited number of systemic reviews, meta-analyses, and randomized controlled trials on TADs have been published, focusing mainly on the stability of TADs and corrections in the anteroposterior dimension [34].

In recent years, TADs have introduced a new paradigm for orthodontic tooth movement, previously deemed inconceivable with traditional anchorage modalities. Post-treatment long-term stability remains unevaluated and further long-term follow-up investigations are therefore needed. In order to provide stronger evidence-based clinical guidance, many questions still need to be answered regarding TADs, with higher level hierarchy studies such as systemic reviews, meta-analyses, and randomized controlled trials, especially for newly designed TAD-supported appliances and their treatment outcomes. Combined treatment modalities with other approaches such as lingual fixed appliances and aligners have still not been investigated extensively. Just as the introduction of CBCT has considerably enriched our understanding and use of TADs, a series of new technologies (e.g. CAD/CAM, 3D bioprinting, regenerative medicine, AI machine learning) will further expand the horizon of clinical applications and research perspectives of TADs.

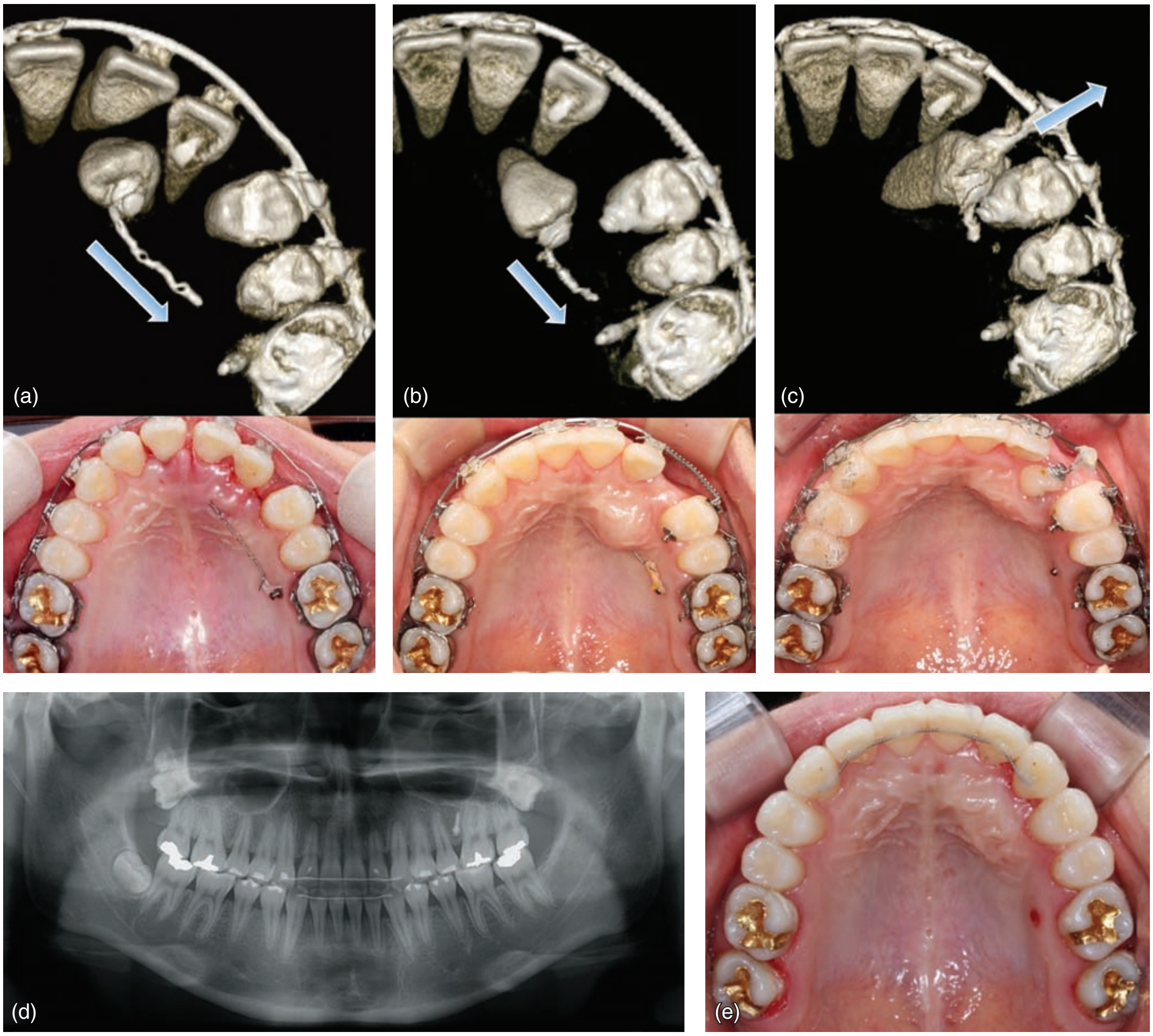


**Figure 1.12** Forced eruption of an impacted and transposed canine [33]. Three-dimensional images were taken: (a) at the time of surgery and lingual button bonding; (b) 14 months after starting retraction of the canine; and (c) 27 months after starting retraction of the canine. (d) The maxillary left canine was well positioned with proper root parallelism and without any signs of root resorption. (e) The impacted canine was well aligned and bonded with a fixed retainer. *Source:* Lee et al. [33]. Reprinted with permission from Elsevier.

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