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ORIGINAL RESEARCH

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The design and clinical application of a new appliance to treat impacted maxillary central incisors

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Abstract

Maxillary central incisor impaction is one of the most common types of dental anomalies in children. Treatment of impacted central incisors is complicated and challenging given the position of the impacted central incisors, root development, and the complexity of the crown eruption direction. This study aimed to describe the use of a new multifunctional appliance for the treatment of impacted maxillary central incisors. This article reports the use of a novel appliance for the treatment of impacted maxillary central incisors. We describe the cases of two young patients with labial horizontally impacted maxillary central incisors. Both patients were treated using this novel appliance. Therapeutic effects were evaluated by comparing the pretreatment results, posttreatment cone-beam computed tomography images, and posttreatment clinical examination results. At the end of the treatment period using the novel appliance, the impacted central incisors had successfully been properly aligned in the dental arch, and the tooth roots had not resorbed. Both patients exhibited good dental alignment, with restored function and acceptable aesthetics. This article demonstrates that the new appliance was comfortable, convenient, safe, and effective in the treatment of impacted maxillary central incisors and that its clinical use should be promoted in the future.

Keywords

Impacted teeth; Oral appliance; Orthodontic treatment

1. Introduction

A maxillary incisor is considered impacted if it fails to reach the occlusal plane by the normal age of eruption, if its contralateral tooth has already been erupted for at least six months, or if a deviation from the normal sequence of eruption occurs [1]. The incidence of impacted maxillary incisors is approximately 0.06%–1.4%, which is lower than that of permanent canines [2]. In a study by Tan *et al*. [3], impacted permanent maxillary central incisors represented 70.6% of all impacted incisors in Chinese orthodontic patients. In a study by Hui *et al*. [4], the rates of labial impaction were higher among patients with vertical or palatal impaction. Unlike impacted canines, which are caused by genetics, absence of lateral incisors, and abnormal dental germ positioning [5], maxillary central incisor eruption may be blocked by supernumerary teeth, odontomas, dental trauma of primary teeth, follicular cysts and crown-root dilacerations [6, 7]. The normal eruption, position, and morphology of maxillary central incisors are important factors of facial esthetics and function of the oral cavity [8]. Maxillary incisor impaction is often observed at an early age, so it can cause an unaesthetic appearance and deterioration of mastication and speech. Moreover, maxillary central incisor impaction may cause rotated tooth malpositioning, shifting of adjacent teeth, root resorption, loss of eruption space, underdevelopment of the anterior part of the maxilla, and crossbite. Therefore, early treatment is essential. Shi *et al*. [9] indicated that early treatment might help shorten the treatment time of impacted immature incisors with dilaceration.

Numerous methods are available to treat impacted maxillary incisors: (1) surgical exposure of the tooth and its orthodontic traction into the dental arch [6, 10]; (2) repositioning the impacted central incisor via surgery [8]; and (3) extraction of the tooth and maintenance of the space followed by prosthodontic rehabilitation [11]. The most conservative management involves surgical exposure of impacted incisors followed by orthodontically induced tooth eruption, and some authors have demonstrated relatively good treatment results following orthodonticsurgical management [12–14]. Both the position and direction of the impacted tooth are considered in clinical practice when determining whether an impacted tooth can be successfully aligned in its correct position [15]. Although some methods have been used to treat impacted maxillary anterior teeth, children lack compliance due to the movable appliances and the elastic traction band, which compresses the mucosa. In addition, sufficient eruption space is often lacking, and other problems can occur. Thus, more effective and safer appliances are needed.

In this study, we report a multifunctional appliance for treating impacted maxillary central incisors via orthodontic-

surgical management. The appliance can be used to expand the eruption gap of the impacted maxillary central incisor and simultaneously force eruption of the impacted tooth. The appliance can be kept in place to maintain the stability of the palatal expansion combined with the 2 × 4 technique to align the teeth.

2. Methods

2.1 Appliance design

The device included a Nance arch, a traction hook, an M bracket, and molar bands with a buccal tube (Fig. 1). Because the child is in the early stage of mixed dentition, the molar bands are fixed to the first molars as anchors. The bands are connected to the Nance arch using a welding rod. The buccal tube is welded on the molar bands, which are used for subsequent 2 × 4 orthodontic appliances. According to the patient's condition, the Nance arch can be replaced by a palatal expander, which is used to create arch expansion to regain the lost anterior space. The appliance can also be kept in place to maintain the expansion (Fig. 2). Moreover, the traction hook is attached to the appliance, and the location can be adjusted based on the position of the impacted teeth to ensure that the direction of force is suitable for the teeth. The M bracket is placed near the incisor region, avoiding the mechanical irritation of the oral mucosa caused by the rubber band during orthodontic correction. The M bracket can be used to adjust the direction of traction according to the position of the impacted tooth.

The participants met the following inclusion criteria: (1) labial and horizontal impacted maxillary central incisor; (2) tooth root formation of approximately 1/2–2/3; (3) crown-root dilaceration $\leq 20°$; and (3) no systemic disease. The following exclusion criteria were employed: (1) lateral palatal impacted teeth; (2) dental malformation; (3) no tooth root formation; (4) complete tooth root development; (5) other oral or maxillary facial disease; and (6) any systemic disease.

2.2 Case presentation

We report the effects of treatment with the new appliance in two very young patients with impacted incisors. The details are presented below.

2.2.1 Case one

An 8-year-old girl was referred to the Department of Pediatric Dentistry, Stomatological Hospital (Haizhu Square), Southern Medical University (Guangzhou, China) for orthodontic evaluation with a complaint about delayed eruption of her right maxillary central incisor.

The patient presented a straight profile (**Supplementary Fig. 1**). Intraoral examination revealed that the right maxillary central incisors had not erupted, and the right maxillary deciduous front tooth had not exfoliated. A protuberance was palpable in the apical region of the right maxillary deciduous front tooth. Midline deviation toward the left side and crowding of the maxillary arch were noted (Fig. 3A). The right maxillary lateral incisor was mesioclinated, occupying the eruption space of the right maxillary central incisor (Fig. 3B). The patient was in the early mixed dentition stage, and the molars had not established an occlusal relationship (Fig. 3B). The right maxillary permanent first molar had not erupted completely (Fig. 3C).

The panoramic radiograph showed impaction of the right maxillary central incisor, with the crown of the right maxillary central incisor located at the level of the apical third of the left incisor's root in proximity to the anterior nasal spine with a rotation of 60° (Fig. 4A, yellow arrow). Cone-beam computed tomography (CBCT) showed that the right maxillary central incisor was positioned horizontally. The root formation stage was classified as Nolla stage 7, and the crown had broken through the alveolar ridge crest. In addition, the crown and root did not exhibit a distinct bend (Fig. 4B).

The parents agreed to the treatment plan that included orthodontic traction of the impacted central incisor using the novel appliance and surgical exposure of the tooth.

2.2.1.1 Treatment progress

The special appliance was fixed to the upper second primary molar as an anchor because the right maxillary permanent first molar had not erupted completely. The impacted right maxillary central incisor was exposed using a diode laser (power, 1.5 W; energy, 50 mJ; repetition rate, 30 Hz) (Fig. 5A). Laser fenestration is convenient, with relatively little bleeding and a clear surgical field, allowing the lingual button to be immediately bonded on its labial side (Fig. 5B–C). Then, the primary front primary incisor was extracted. A rubber chain was used to connect the appliance and create orthodontic force. One month later, the crown was exposed orally with a rotation of 60°, and 2 × 4 appliances were used to correct the inclination of the right maxillary lateral incisor (Fig. 5D–E). Four months later, a lingual button was placed on the lingual side of crown 11, and the bracket was placed on the labial side. The brackets were fixed to the other anterior teeth, and a rubber band was used to correct the rotation of tooth 11. In the final stage, 2 × 4 fixed orthodontic appliances were used to correct the position of the upper front teeth (Fig. 5F). After orthodontic treatment for 14 months, the right maxillary central incisor was well aligned in the maxillary arch.

2.2.1.2 Treatment results

After surgical exposure and orthodontic traction for 14 months, the impacted tooth was well aligned in the maxillary arch (Fig. 6A–C). Radiographic examination and CBCT showed that the root had continued to develop (Fig. 6D–E). However, the apical third of the root had started to dilacerate palatally, and the labial portion of the right maxillary central incisor lacked alveolar bone (Fig. 6E, yellow arrow). The patient showed a suitable facial profile (**Supplementary Fig. 2**).

2.2.2 Case two

A 9-year-old girl was brought by her parents to the Department of Pediatric Dentistry, Stomatological Hospital (Haizhu Square), Southern Medical University (Guangzhou, China). The chief complaint was lack of right maxillary central incisor eruption during the six-month period after left maxillary central incisor eruption. Her parents denied that their daughter had experienced trauma. The child was in good physical health and

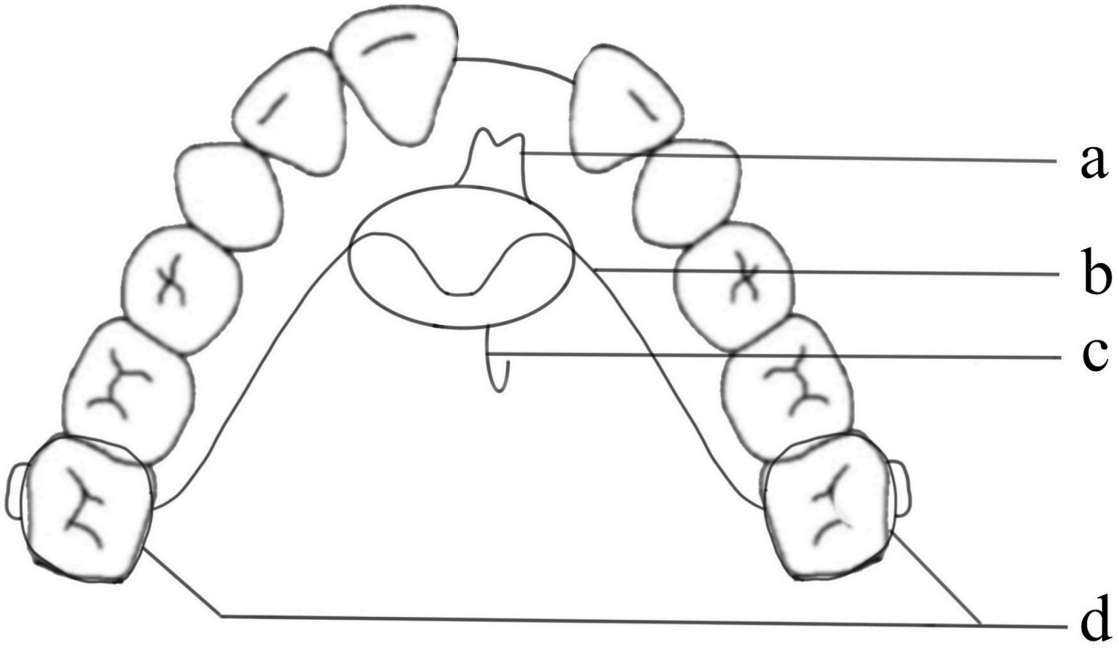

FIGURE 1. Illustration of the appliance. Note the impaction of the left maxillary incisor. a: M bracket, b: Nance arch, c: traction hook, and d: molar bands with buccal tube.

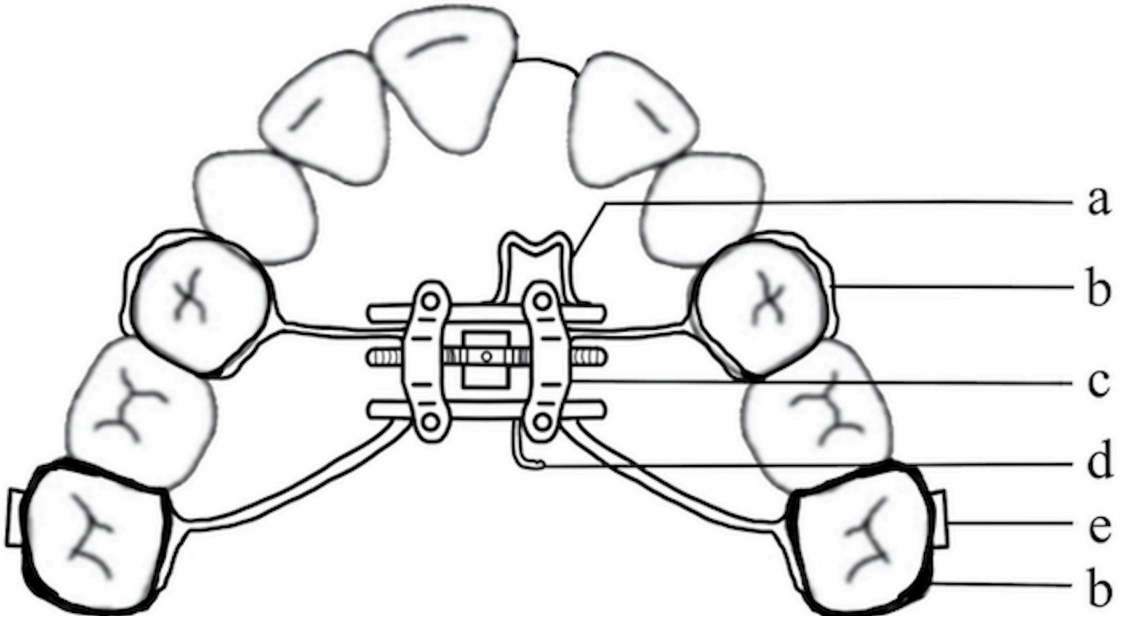

FIGURE 2. Illustration of the improved appliance. Note the impaction of the left maxillary incisor with the lack of eruption space. a: M bracket, b: molar band, c: palatal expander, d: traction hook, and e: buccal tube.

FIGURE 3. Intraoral photographs in case one. A: Nonerupted right maxillary central incisor, with a palpable protuberance in the apical region (yellow arrow). B: Molar relationship. C: Condition of the maxillary teeth and dentition.

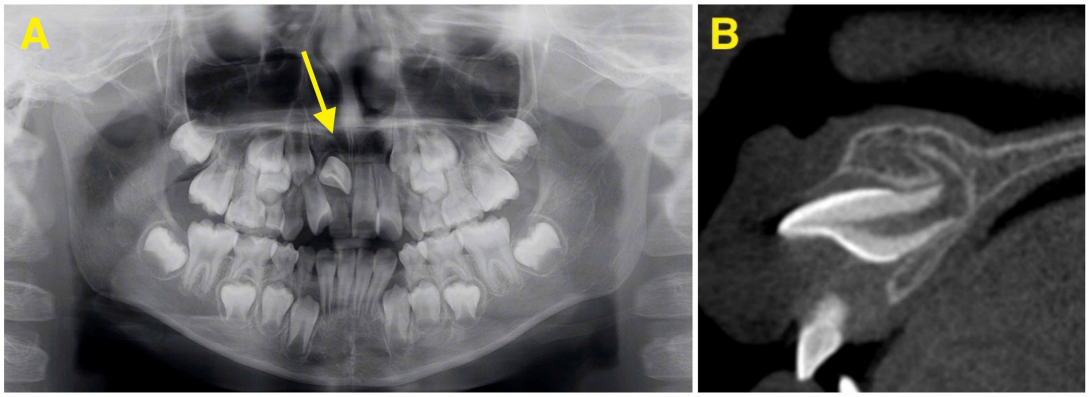

FIGURE 4. Pretreatment panoramic radiograph and CBCT image in case one. A: Horizonal impaction of the right maxillary central incisor with a crown rotation of approximately 60° (yellow arrow). B: Nolla stage 7 root formation.

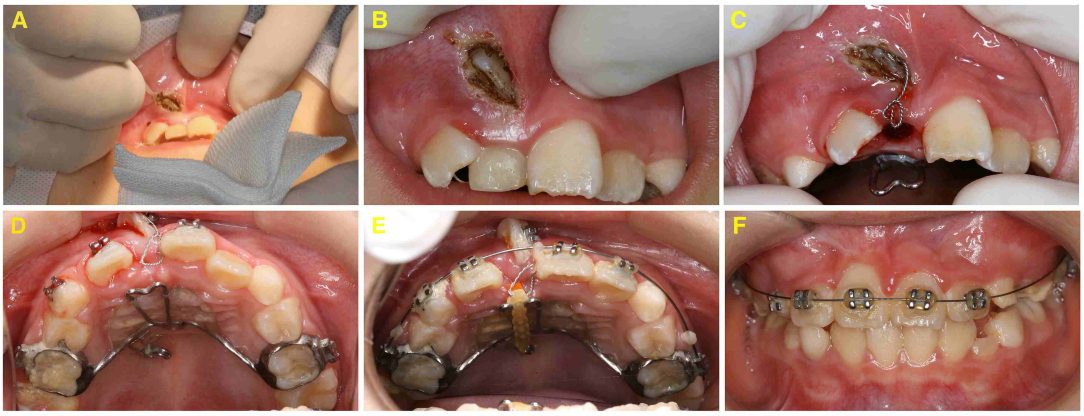

FIGURE 5. Treatment progress in case one. A: Fenestration surgery using a laser. B: Fenestration using a diode laser, with relatively little bleeding and a clear surgical field. C: Immediate bonding of the lingual button to the labial side. D: Upper occlusal intraoral view of the appliance showing oral exposure of the crown with a rotation of 60° one month later. E: Upper occlusal intraoral view of correct rotation of tooth 11 after four months. F: Two-by-four appliances after eight months.

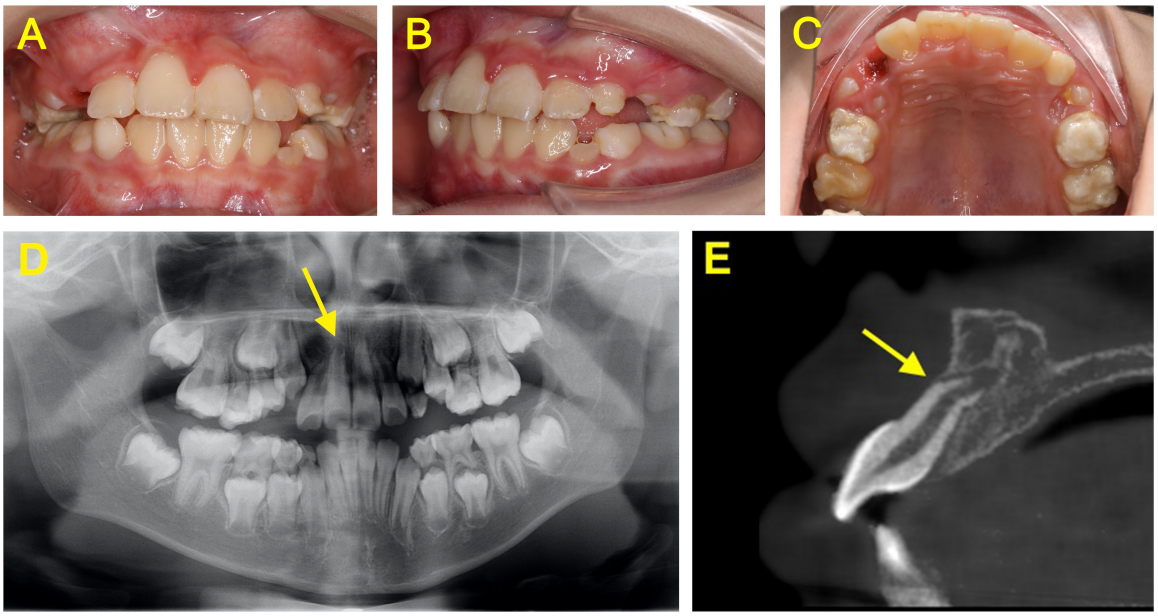

FIGURE 6. Posttreatment intraoral photographs and radiographs in case one. A: Normal positioning of the impacted tooth. B: Molar relationship. C: Upper occlusal intraoral view. D: Panoramic radiograph showing continued root development (yellow arrow). E: Palatal dilaceration of the apical third of the root (yellow arrow).

did not suffer from any medical conditions.

Facial photographs showed that the patient had a mesofacial pattern (**Supplementary Fig. 3**). Intraoral clinical examination showed that the right maxillary central incisor had not erupted. The patient was in the early mixed dentition stage with an Angle class I molar relationship. The lateral incisors on both sides exhibited a crossbite associated with maxillary constriction (Fig. 7A–B). A protuberance was observed by palpation of the buccal gingival area of the anterior teeth (Fig. 7A). Her right lateral incisor was tilted mesially toward the midline, thus occupying part of the central incisor space. The overjet and overbite were 1.5 mm and 2 mm, respectively (Fig. 7A–C).

According to CBCT, the impacted tooth was located at the level of the left incisor's dental cervix. Root formation was classified as Nolla stage 7 with no dilaceration. The contralateral tooth was classified as Nolla stage 8. The image revealed that the impacted tooth was positioned horizontally, the crown was positioned labially, and the root was positioned palatially (Fig. 7D–E).

The parents agreed to the treatment plan that included orthodontic traction of the impacted central incisor using the novel appliance and surgical exposure of the tooth using a diode laser.

2.2.2.1 Treatment progress

The aim of surgical-orthodontic management is to track the impacted tooth into proper alignment with restored function, similar to that noted for the contralateral tooth. The appliance was applied to the upper arch to create the eruption space. The protocol for rapid maxillary expansion (RME) with one-a-day activation was applied (Fig. 8D). The crown was exposed using a diode laser (power, 1.5 W; energy, 50 mJ; repetition rate, 30 Hz) (Fig. 8A–B), and a lingual button was immediately bonded on its labial side (Fig. 8C). The traction hook of the appliance was connected to the button with a rubber band (Fig. 8D). The rubber band was changed every three weeks. Three months later, the crown was completely exposed in the oral cavity, and no special mobility was noted (Fig. 8E). In addition, the eruption space was sufficient, and the expander served as a retainer to maintain the space. In the second stage (after four months), we used 2 × 4 fixed orthodontic appliances to correct the position of the impacted tooth (Fig. 8F). The molar band with the buccal tube of the appliance served as an anchor. After orthodontic treatment for alignment, the patient wore a Hawley appliance for one year.

2.2.2.2 Treatment results

The impacted tooth was well aligned in the maxillary arch after 12 months of treatment (Fig. 9A). Functional overbite and overjet were achieved at 2 mm (Fig. 9B). Radiographic examination and CBCT revealed that the root was growing, and the apex was nearly closed. No alveolar bone resorption was observed (Fig. 9D–E). The posttreatment facial photographs showed good facial aesthetics (**Supplementary Fig. 4**).

During the follow-up observation, tooth 11 was stable in the maxillary dental arch, and the level of the buccal gingival margin of tooth 11 was on the same horizontal plane as tooth 21 (Fig. 10A–C). The root of tooth 11 continued to grow, and the apex closed completely (Fig. 10D).

3. Discussion

Our new appliance demonstrated good efficacy in the surgical-orthodontic treatment of maxillary central incisors. The appliance is designed to improve patient comfort by reducing the time required for orthodontic appliance use compared to conventional methods. Specifically, our appliance can be cemented in 2 × 4 appliances after creating an eruption space and retracting the impacted tooth. Additionally, the clinical operation is more accessible than that of the traditional method.

3.1 Advantages of this appliance

Surgical exposure and orthodontic traction are the most common treatments used for impacted incisors. These methods expose impacted incisors in surgical procedures and bond orthodontic attachments to the surface to apply traction to the tooth until normal dentition is achieved. Many approaches have been reported to treat impacted teeth using orthodontic-surgical approaches. Cosme-Silva *et al.* [16] reported treatment with a removable appliance. However, impacted maxillary incisors are often found at an early age, and removable appliances cause compliance issues and lack of patient cooperation. Thus, the appliance we designed is a fixed appliance that is smaller in size and more comfortable.

Impacted teeth caused a decrease in the dental arch perimeter, adjacent tooth displacement, midline shift, and narrowing of the eruption space. Most orthodontic treatments use a coil spring to create adequate space before forcing the impacted tooth to erupt or to restore the gap when the impacted tooth is exposed in the oral cavity after surgery [17]. The main approach to address the aforementioned issue is maxillary expansion via opening the midpalatal suture to create/increase the eruption space. In case two, the narrowing of the dental arch's anterior region resulted in the overbite of teeth 21 and 12. Thus, we used our appliance to restore the eruption space. The main structure of the appliance is designed as a palatal expander so that it can expand the eruption space and simultaneously provide the force that pulls the upper anterior teeth to erupt. In addition, after expansion, the expander can serve as a retainer to maintain the space without the need for additional fixed appliances. Moreover, the position of the traction hook can be changed according to the position of the impacted teeth to ensure that the magnitude and direction of the traction forces are suitable.

The M bracket can avoid compression of the buccal mucosa during orthodontic correction (**Supplementary Fig. 5**). If the M bracket is not added, the rubber band would compress the palatal mucosa, leading to an ulcer. After forced eruption of the impacted incisor, new brackets are bonded to the tooth surface to align the maxillary incisor. The buccal tube welded to the molar band can be used as an anchor. A systematic review demonstrated that the average forced eruption duration of immature impacted maxillary incisors ranged from 10.16 ± 2.73 to 14.41 ± 4.03 months [18]. In our cases, the duration, including forced eruption and alignment, was in the range of 12 ± 1 months, representing a shorter period. However, other

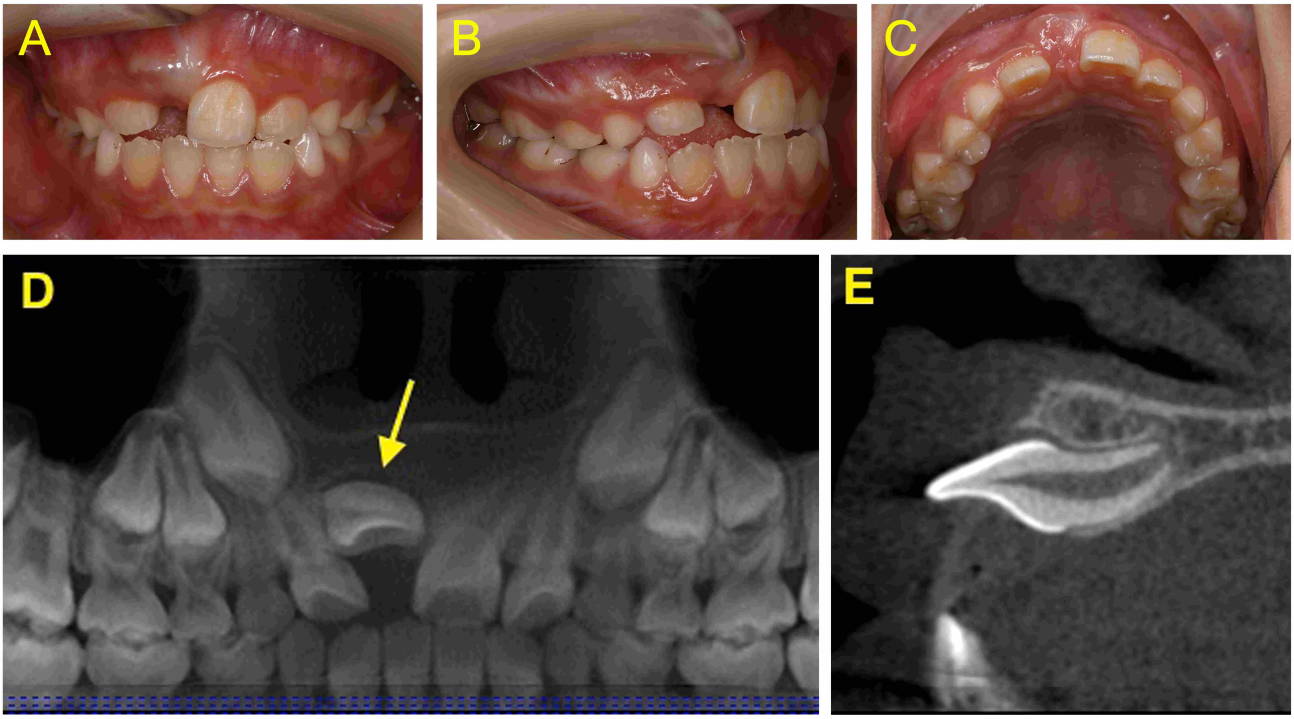

FIGURE 7. Intraoral photographs and CBCT images in case two. A: Nonerupted right maxillary central incisor with insufficient eruption space. B: Molar relationship. C: Upper occlusal intraoral view. D: CBCT showing impaction of the right maxillary incisor (yellow arrow). E: CBCT showing root formation; Nolla stage 8, with no dilaceration.

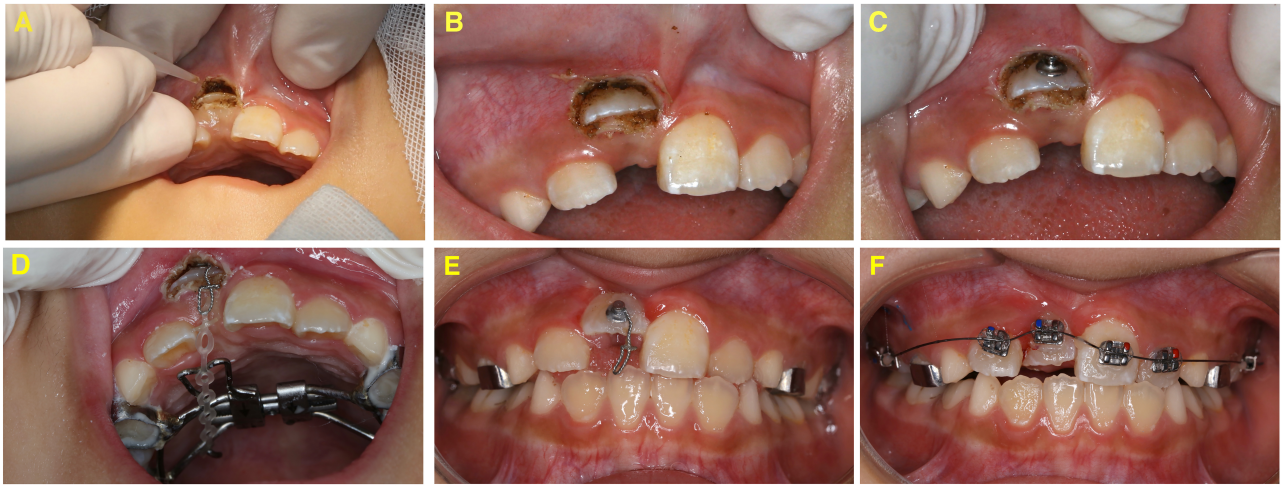

FIGURE 8. Intraoral photographs during treatment in case two. A: Surgical exposure using a diode laser. B: Labial surface of crown immediately after surgery. C: Immediate bonding of the lingual button on the labial side. D: Immediate connection of the crown and appliance by the rubber band. E: Exposure of the crown in the oral cavity three months later. F: Two × four fixed orthodontic appliances four months later.

factors influence the treatment duration, including tooth angulation, tooth position, and root formation stage. Larger sample sizes are needed to demonstrate the duration of treatment with this new appliance.

In conclusion, the appliance serves multiple functions and does not need to be replaced during treatment. Thus, the appliance is easier to use and provides a more comfortable treatment experience for patients.

3.2 Treatment timing

Although many methods have been reported for the treatment of maxillary impacted incisors, one of the common features is that early therapy is the key to success in these complicated medical situations [19]. Many patients with buccal impaction present transversely deficient maxillae, which may cause anterior crossbite [20]. The absence of teeth may result in displacement of the adjacent teeth, arch length discrepancy, and dental midline shift. These complications may cause functional problems, occlusal derangement and trauma [21].

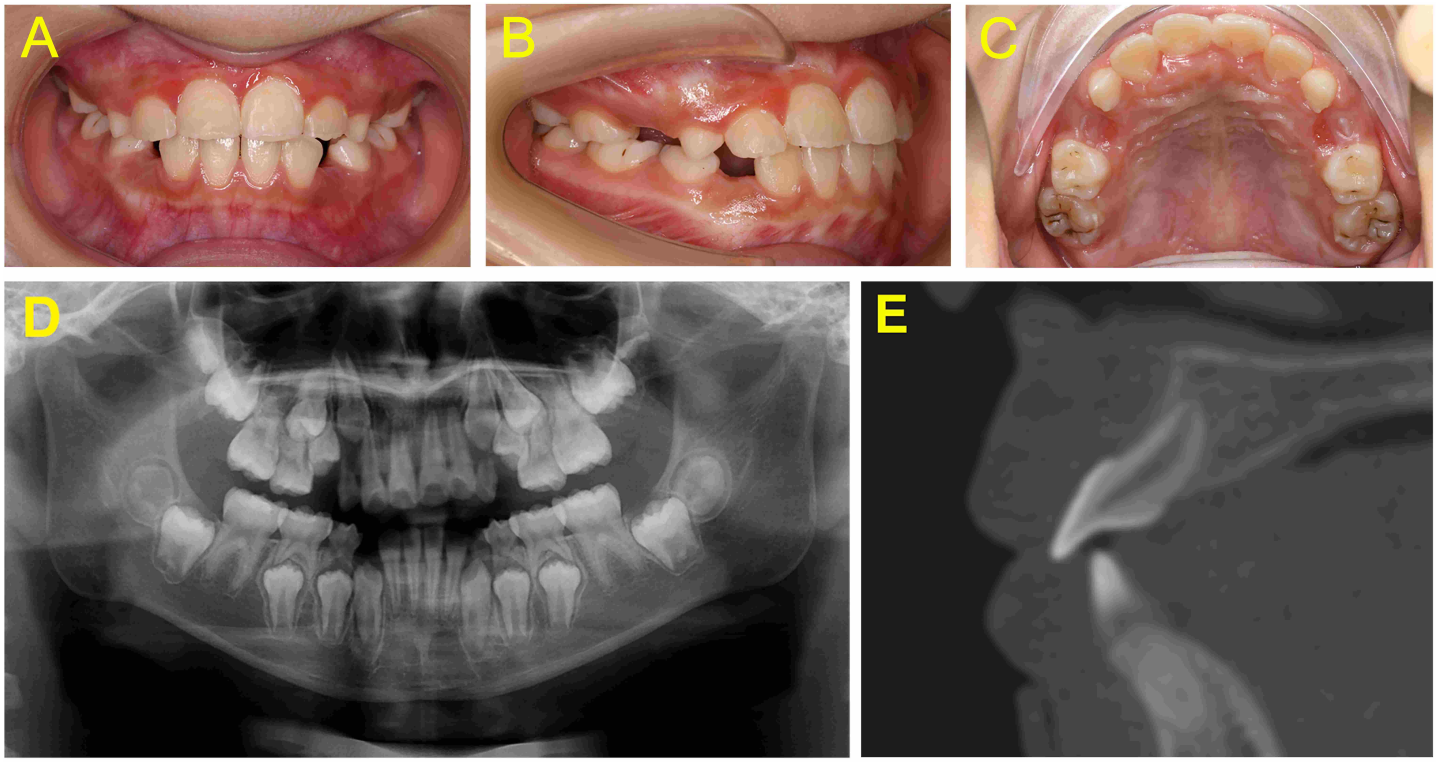

FIGURE 9. Posttreatment intraoral photographs and radiographs in case two. A: Normal positioning of the impacted incisor. B: Molar relationship; functional overbite and overjet at 2 mm. C: Upper occlusal intraoral view at the end of treatment. D: Panoramic radiograph showing nearly complete apical closure of tooth 11. E: CBCT image showing no dilaceration of the root of tooth 11.

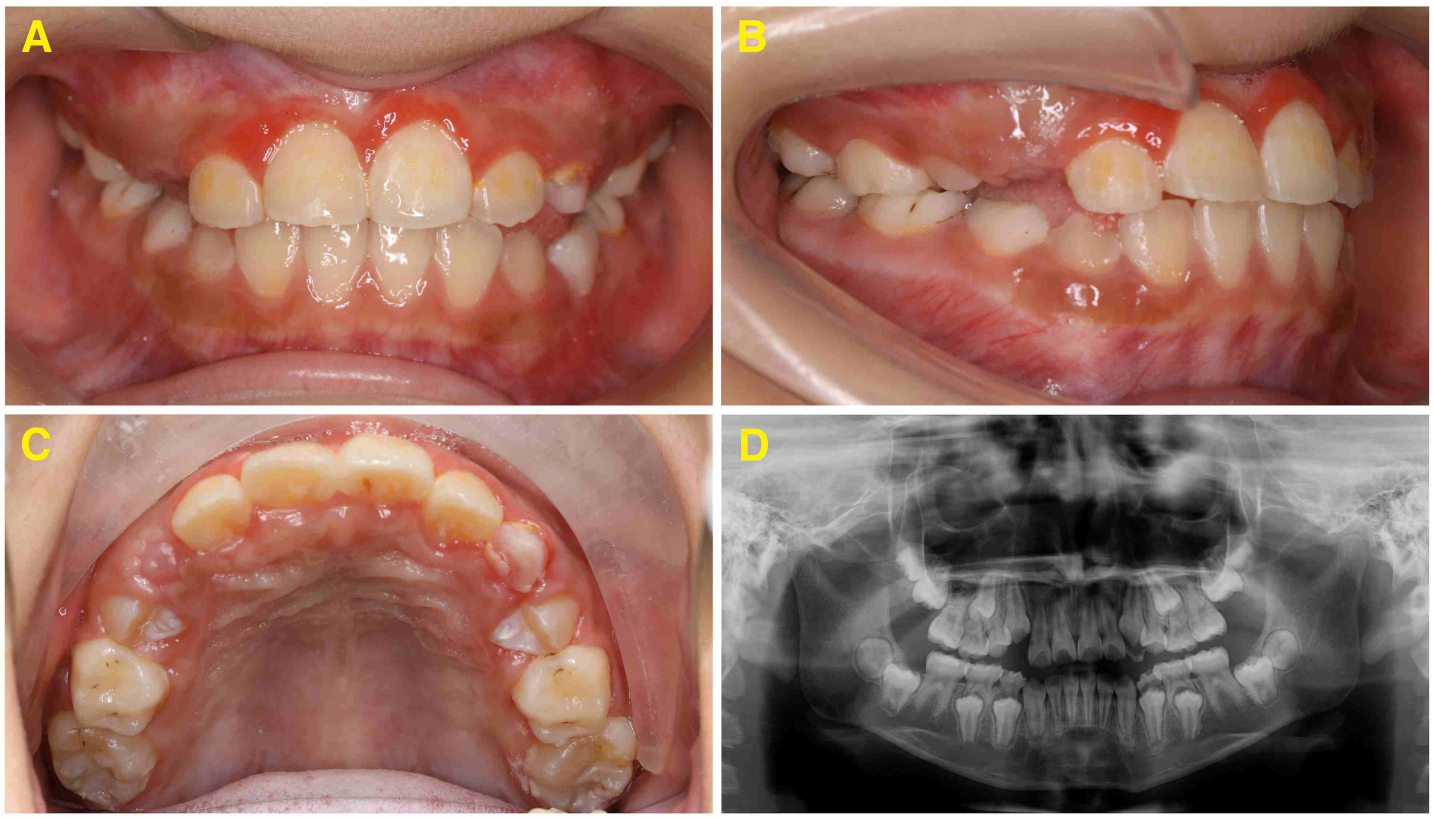

FIGURE 10. One-year follow-up in case two. A: Frontal intraoral view at the one-year follow-up. B: Molar relationship. C: Condition of the maxillary teeth and dentition. D: Panoramic radiograph showing complete closure of the apex of tooth 11.

Muscle strength imbalance due to deleterious oral habits may cause underdevelopment of the maxillae and crossbite, which may lead to maxillary central tooth impaction. Therefore, early intervention is essential.

When approximately two-thirds of the root has formed, the permanent tooth erupts from the alveolar bone. Then, the tooth erupts into the oral cavity with a wide-open apex when approximately three-fourths of the root has formed [22, 23]. Root development starts with the formation of an epithelial root sheath [24]. In early orthodontic treatment, the root apex of the underdeveloped tooth is wide-open and still has the potential for formation. Furthermore, the force exerted on the teeth may improve the impacted teeth for further growth and development during orthodontic traction. A prospective study showed that root development was promoted in the early treatment group (Nolla stages 7 and 8), and an improved root apex morphology and a reduced risk of alveolar bone loss on the labial side were noted compared with the later treatment group (Nolla stages 9 and 10) [25]. Once impacted teeth with root development that occurs at an early age receive early treatment, it is possible for the immature teeth to grow normally in the original direction. A normal length is eventually obtained, and the tooth achieves the same executive function as the contralateral tooth. A literature review has suggested that intervention for impacted teeth should be provided until more than 2/3 of the root has formed [26]. If early intervention is not provided, complete development of the root apex will lead to tooth dilaceration, which will increase the difficulty of subsequent treatment and may lead to complications, such as bone fenestration and adjacent tooth resorption. When the root has not formed, premature intervention may cause the undeveloped tooth to be unable to withstand the occlusal forces and may even cause tooth loss. Regular inspections are required to diagnose impacted maxillary central incisors early, especially if the contralateral tooth has already been erupted for at least six months, and a panoramic radiograph is needed for the investigation.

Topouzelis *et al*. [19] indicated that in the early treatment stage, the root apex was immature, and Hartwig's epithelial root sheath has growth potential and continues to develop until completely formed. In addition, Hartwig's epithelium is able to withstand trauma, so it could continue to produce new dentin at the same rate as preinjury during treatment. Early treatment could cause calcified and not yet calcified dental tissues to be relocated relative to Hartwig's sheath, allowing the root to grow in the proper direction [27]. For some patients with root dilaceration, early treatment could free the root apices from constraints caused by adjacent anatomical structures and fully exploit the growth potential of the root [18]. In our cases, both patients were classified as Nolla stage 7 when they started orthodontic traction. After the treatment was completed, the roots continued to develop, and the root length increased. In case two, the apical fomentation was almost closed, and the root morphology was normal. In case one, the apical formation was not closed and curved toward the palatal side. The patient in case one moved abroad, so follow-up was not possible. According to previous studies [25, 28], Hartwig's sheath has directional memory properties and growth regularity. We suspect that although the formed part of the tooth rotates during orthodontic traction, Hartwig's sheath still has the ability to form roots in the original growth direction. This notion could explain the dilaceration of the apical 1/3 of the root in case one.

3.3 Alveolar bone loss

Evidence shows that orthodontic treatment may result in the loss of alveolar bone around the roots [29]. The labial side of the alveolar bone is thinner and more susceptible to orthodontic traction than the lingual side of the incisors [30]. In case one, CBCT after treatment showed that the level and thickness of labial alveolar bone of the treated tooth were lower than those of the contralateral tooth. However, Hu *et al*. [31] concluded that after orthodontic traction, the alveolar bone could achieve a certain level of regeneration based on two-year follow-up research. A prospective study showed that early treatment might reduce the risk of alveolar bone loss on the labial side [25]. The growing alveolar bone of the incisors is affected by several factors, including growth and development and the occlusal relationship. In case one, the pretreatment CBCT image revealed that the crown of the impacted tooth had broken through the bone cortex, and the initial state of the alveolar bone around the crown was not observed. With movement of the impacted tooth, the alveolar bone is not modified. Therefore, the alveolar bone on the labial side is lacking when the tooth moves into the correct alignment. The patient was young (8 years old), so we hypothesize that the alveolar bone could continue to develop with potential for growth. Therefore, long-term follow-up of the patient's alveolar bone condition is necessary.

3.4 Use of a diode laser

The closed eruption technique is the most commonly used fenestration initiation technique given its ability to achieve aesthetic and superior periodontal outcomes [32]. However, a study reported no differences in the periodontal status of impacted incisors treated using the closed-eruption technique or the opened-eruption technique, called the apically repositioned flap technique, and natural teeth [33, 34]. A diode laser is a solid laser produced by various elements, such as gallium and arsenic, which can be selectively absorbed by hemoglobin and pigment and has a good coagulation function and antibacterial effect on soft tissues [34]. Currently, diode lasers are commonly used in soft tissue surgery in dental treatment. The most prominent feature that marks a difference from surgical flap procedures is the possibility of immediately positioning the orthodontic bracket without bleeding [35]. The use of diode lasers not only avoids or reduces the use of analgesic and anti-inflammatory drugs but also reduces postoperative edema and pain through minimal damage. In our case, a diode laser was used to eliminate the mucosa overlying the crown. Intraoperative bleeding was reduced, and the child did not experience discomfort after the operation. After fenestration, the lingual buckle was bonded immediately. The traction rubber band was used to increase the force, and the lingual buckle did not detach during the correction process. After orthodontic treatment and during the one-year follow-up period, the impacted gingival margin was located at the same level as that of the contralateral tooth, and the periodontal

attachment of the impacted tooth was normal. These findings indicate that the use of a diode laser for surgical eruption and traction may also yield good aesthetic results.

4. Conclusions

The new appliance enabled successful management based on creation of the eruption space, guidance of impacted tooth eruption, and maintenance of the eruption space. The appliance was then used for anchorage in the 2 × 4 technique to correct the axial inclination. The roots continued to develop, achieving a good apical morphology. Using the laser surgical eruption technique, ideal gingival architecture aesthetics were obtained. This appliance is easier to operate and more comfortable for the child than conventional devices. Therefore, this new multifunctional appliance provides another option for the treatment of impacted maxillary central incisors.

AUTHOR CONTRIBUTIONS

YQP—analyzed the data and drafted the manuscript. ZHZ, HHQ and MML—collected the data. HCX and KC—designed the appliance and revised the manuscript. All authors have reviewed and agreed with the contents in this manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Human Research Ethics Committee of Stomatological Hospital, Southern Medical University(No 2022-20). All methods were carried out inaccordance with relevant guidelines and regulations. Informed consent was obtained from all subjects and their legal guardians.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1631490902263250944/attachment/Supplementary%20material.zip.

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