

CASE REPORT

Long-term prognosis after decoronation of avulsed teeth with replacement resorption: a report of three cases

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Abstract

The complications of replacement resorption following tooth injury in growing children include infra-positioning of the tooth, tilting of the adjacent teeth, and alveolar ridge deformity. Decoronation is a conservative treatment method that facilitates bone preservation. The current case report focuses on the long-term preservation of alveolar ridge dimension following decoronation in three patients. Decoronation was performed prior to occurrence of the pubertal growth spurt, and the patients' ridge width and vertical apposition were monitored for at least 4 years. Timely intervention and regular monitoring are essential for maximization of the benefits of decoronation, a simple procedure that preserves esthetics and minimizes the need for further treatments. The importance of space management for prosthetic treatment has also been highlighted. The findings of this study show that infra-positioned teeth in growing children can be treated successfully using decoronation.

Keywords

Replacement resorption; Ankylosis-related resorption; Decoronation; Bone maintenance

1. Introduction

Tooth avulsion, defined as the complete displacement of a tooth from the alveolar bone resulting in serious damage to the pulp and periodontal tissues, has an incidence rate of 1%–16% [1–3]. Recommended treatment methods include immediate re-implantation, which has an overall success rate of 50% for permanent teeth over a period of 5.5 years [4]. Although re-implantation is typically associated with favorable functional healing, it can also result in complications such as infection-related (inflammatory) resorption or replacement resorption (RR) [5]. The latter involves induction of osteoclast differentiation from the adjacent bone marrow cavity following damage to the periodontal ligament (PDL), resulting in the resorption of the cementum and dentin in the dental root and replacement by alveolar bone [6].

RR progression can vary considerably with age, particularly in growing children where the disruption of the growth of the alveolar bone can lead to infraocclusion of the affected teeth, irregularities of the alveolar bone, tilting of adjacent teeth, and reduction of the length of the dental arch [7].

Extraction may also be selected as an alternative treatment measure, although resorption of the buccal alveolar bone may be accelerated by any injury caused to it during treatment. Furthermore, atrophy of the alveolar bone can compromise aesthetics and functionality in the long duration, indicating that conservative treatment measures may be more preferable [8].

The International Association of Dental Traumatology rec-

ommends decoronation, first introduced by Malmgren in 1984 [9], as an effective conservative treatment measure. This procedure involves the removal of the crown of the tooth, while leaving the root intact to be replaced by the alveolar bone during the resorption process. It has been found to be effective in patients who are yet to undergo the pubertal growth spurt, and has several advantages including maintenance of the buccolingual width of the alveolar bone, promotion of vertical growth of the alveolar bone, and reduction of the need for additional treatment measures such as alveolar ridge augmentation in the future [10].

This paper aimed to report the long-term prognosis in terms of alveolar bone retention that occurred when decoronation was performed before growth completion in patients who experienced RR after maxillary incisor avulsion.

2. Case presentations

2.1 Case 1

A female patient aged 8 years and 8 months and with no significant medical or dental history presented at the pediatric dental clinic with a chief complaint of an avulsed right maxillary central incisor (#11). The avulsed immature permanent tooth (Demirjian stage G of tooth development [11]) was stored extra-orally in milk for a period of 90 minutes before being replanted into the tooth socket using slight digital pressure under local anesthesia. The position of the replanted tooth was verified clinically and radiographically and then immobilized

with a flexible wire composite splint for 2 weeks (Fig. 1A). The patient was recalled after 7 days for endodontic treatment where, following pulp expiration, the canal was filled with calcium hydroxide paste to form an apical barrier and prevent root resorption. The splint was removed after 4 weeks, and clinical and radiographic examination of #11 2 months after treatment revealed no mobility, presence of a metallic sound upon percussion, and loss of PDL space (Fig. 1B). The calcium hydroxide paste was changed and the patient was monitored at 3-month intervals. Extensive progression of RR was observed 1 year and 7 months after treatment (when the patient was aged 10 years and 3 months), and infraocclusion was seen to have extended up to 1/4 of the crown size. Labioversion of the right maxillary central incisor and mesial tipping of the adjacent teeth were also observed (Figs. 1C,2A,B). After obtaining informed consent from the patient, decoronation was performed to maintain arch integrity and the alveolar bone width (Fig. 1D). A removable space maintainer was provided after 1 week, and the patient was followed up regularly to prevent the occurrence of any complications. Four years after the decoronation, the root remnants were completely replaced by alveolar bone. The alveolar bone height was at the levels similar to those of the adjacent teeth; however, the horizontal bone level was reduced (Figs. 1E,2C–F).

2.2 Case 2

A male patient aged 8 years and 6 months and with no significant medical and dental history presented at the pediatric dental clinic with a chief complaint of avulsion of the right maxillary central incisor (#11), left maxillary central incisor (#21), and left maxillary lateral incisor (#22). The avulsed immature permanent teeth were stored extra-orally in milk for 4 hours before being replanted (similar to Case 1; Fig. 3A). The patient was recalled for endodontic treatment after 1 week, and radiographic examination three months after treatment showed RR of #21 and #22. Additionally, accelerated root resorption was observed in #22 due to ectopic eruption of the left maxillary canine 4 months after trauma (Fig. 3B). Examination 5 years after treatment (when the patient was aged 13 years and 6 months) showed infraposition of #21 and almost complete resorption of the root of #22 (Fig. 3C). As the patient was yet to undergo a pubertal growth spurt (based on his height growth rate), decoronation of #21 and #22 was performed to prevent severe infraocclusion (Figs. 3D,4A,B). A removable space maintainer was provided immediately, and radiological and clinical examination 5 years after decoronation confirmed alveolar bone atrophy and rapid root resorption in #22. In contrast, the horizontal bone was found to be reduced in the decoronated area of #21 compared to the crown of #11, but height were maintained at the same level as those of the adjacent tooth (Figs. 3E,4C–F).

2.3 Case 3

A male patient aged 9 years and 3 months with no significant medical and dental history presented at the dental clinic with a chief complaint of an avulsed right maxillary central incisor (#11). The avulsed tooth was stored extra-orally in saline for a period of 2 hours, and clinical examination also revealed

mobility in the left maxillary central incisor (#21). The avulsed tooth was replanted and splinted for 4 weeks (Fig. 5A), and the patient was recalled after seven days for endodontic treatment. Examination 3.5 years after treatment (when the patient was aged 12 years and 9 months) showed infraposition of #11 up to a level approximately 1/8 of the height of the crown of the adjacent tooth (Fig. 5B). Decoronation was performed in the same manner as in Fig. 6 (Figs. 5C,7A,B). A removable space maintainer was provided immediately after the decoronation, and cone-beam computed-tomography (CBCT; 3D Accuitomo; J MORITA Mfg. Corp., Kyoto, Japan; voxel size: 0.125; imaging area: 4 cm × 4 cm; radiation: 80 kV, 3 mA; radiation time: 9 seconds; equivalent radiation dose: 12 μ mSv; sliced images taken at 1-mm intervals) can obtained 10 years after treatment revealed that the height and width of the alveolar bone of #11 were comparable to those of the adjacent teeth (Figs. 5D,7C,D,8A–C).

3. Discussion

Decoronation is known as an effective treatment measure for RR. It can help maintain the width and height of the alveolar bone in growing children. The three patients included in the current case series underwent replantation of avulsed teeth, and the timing of the intervention was determined during the observation.

In the three cases presented in our study, the prognosis of decoronation was observed over a long period of at least 4 years, and the labial alveolar bone demonstrated horizontal bone resorption compared to the adjacent teeth, and vertical growth was confirmed (Figs. 3C,D,6C,D,8C,D). In Case 2, a comparison of the horizontal bone width of #22 (underwent physiological root resorption) to that of #21 (exhibited RR) showed that the alveolar bone was atrophied in the former and well-maintained in the latter. This could be attributed to the fact that the conversion of the root after decoronation into a matrix during the osteogenesis process prevented the loss of labiolingual dimensions [12]. Consequently, alveolar bone loss was also prevented, thus improving conditions for orthodontic and prosthetic treatment. In Case 3, the degree of bone retention could be evaluated by comparing the alveolar bone of the adjacent teeth using CBCT examination 10 years after decoronation (Table 1). Approximately 14% of the labial bone, 91% of the palatal bone, and 78% of the alveolar bone heights were maintained. The range of alveolar bone resorption coincided with the canal space of the tooth, and this could likely be attributed to the adverse effects of prolonged extra-oral storage and delayed replantation on PDL cell vitality. Tsukiboshi *et al.* [13], found that delayed replantation failed to completely maintain the bone volume, leading to progression of buccal bone resorption up to the position of the root canal space. This could likely be because the labial roots of anterior teeth are covered by the alveolar bone derived from PDL cells after puberty, whereas the palatal bone consists of bone marrow and is therefore independent of the tooth structure. Therefore, delayed replantation decreases the proportion of viable PDL cells, resulting in severe labial bone resorption.

These results are in accordance with the prognosis reported in previous studies. Lin *et al.* [14], followed up 12 patients

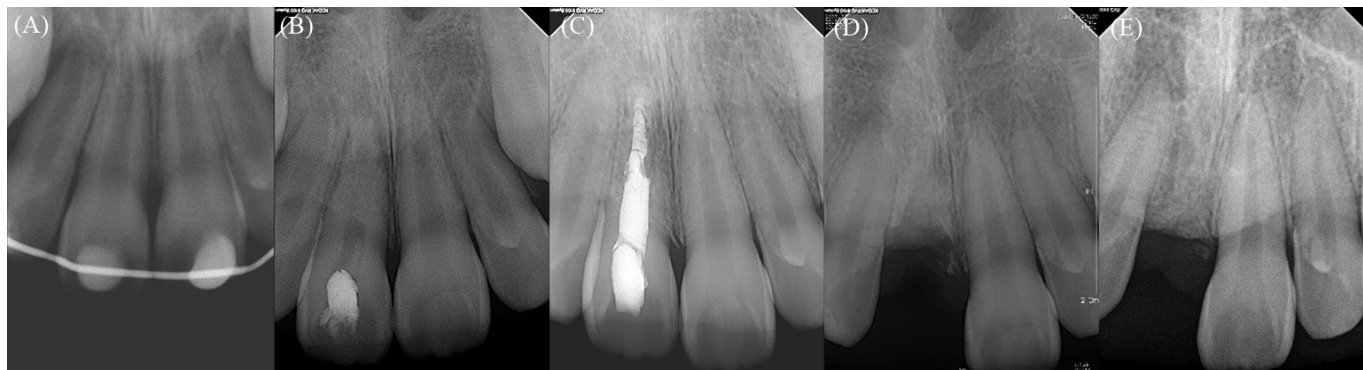


FIGURE 1. The radiographic view of #11. (A) post replantation; (B) after 2 months of follow-up; (C) after 1 year and 7 months of follow-up; (D) after decoronation; and (E) 4 years after decoronation.

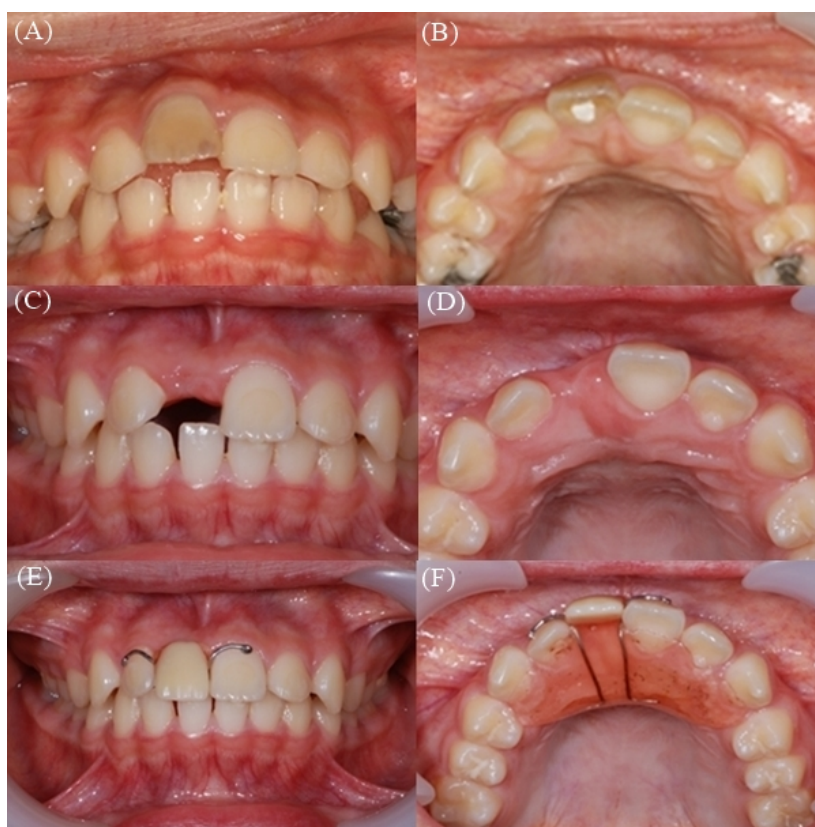


FIGURE 2. The clinical view of #11. (A,B) preoperative; (C,D) 4 years after decoronation; and (E,F) removable space maintainer.

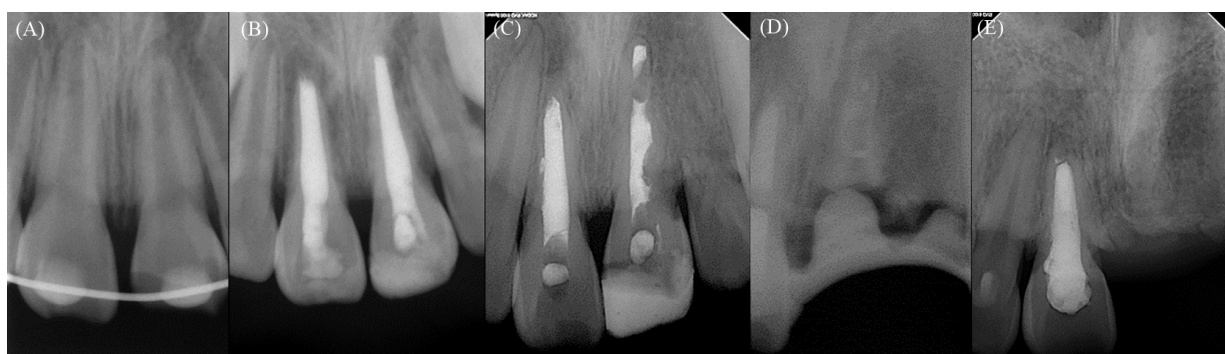


FIGURE 3. The radiographic view of #21, 22. (A) post replantation; (B) after 4 months of follow-up; (C) after 5 years of follow-up; (D) after decoronation; and (E) after 5 years of decoronation.



FIGURE 4. The clinical view of #21, 22. (A,B) 7 days after decoronation; (C,D) 5 years after decoronation; and (E,F) space maintainer.



FIGURE 5. The radiographic view of #11. (A) post replantation; (B) after 3 years and 6 months of follow-up; (C) after 1 week of decoronation; and (D) after 5 years of decoronation.

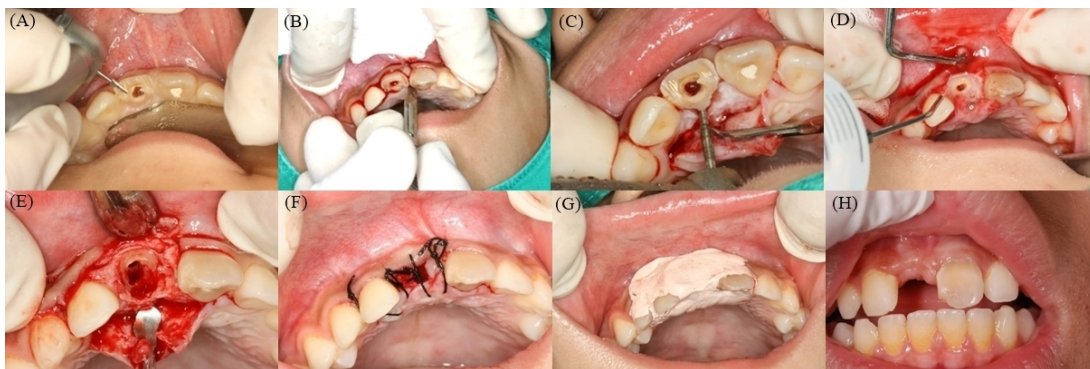


FIGURE 6. Clinical steps of decoronation. (A) Crown reduction up to 1/2 of the height of the crown, removal of the filling materials (Ca(OH)_2 paste) using a Gates-Glidden bur and endodontic files (filing the canal wall using #10 K-file with a pre-curve), and irrigation of the root canal using saline, NaOCl, and ethylenediamine tetraacetic acid (EDTA). Passive ultrasonic irrigation activation with EDTA is effective; (B) Elevation of a full thickness mucoperiosteal flap to expose the cemento-enamel junction (CEJ) of the ankylosed tooth; (C) Removal of the crown from the CEJ on the palatal side using a tapered round end diamond bur under continuous saline irrigation; (D) Obtaining image after the removal of the crown up to the CEJ; (E) Reduction of the coronal part of the root to a level 1.5–2 mm below the marginal bone using a round bur and filling the enlarged root canal with blood; (F) Placing the mucoperiosteal flap over the unsealed residual root and alveolus, followed by wound closure using single sutures; (G) Coe-Pak; and (H) Stich-out.

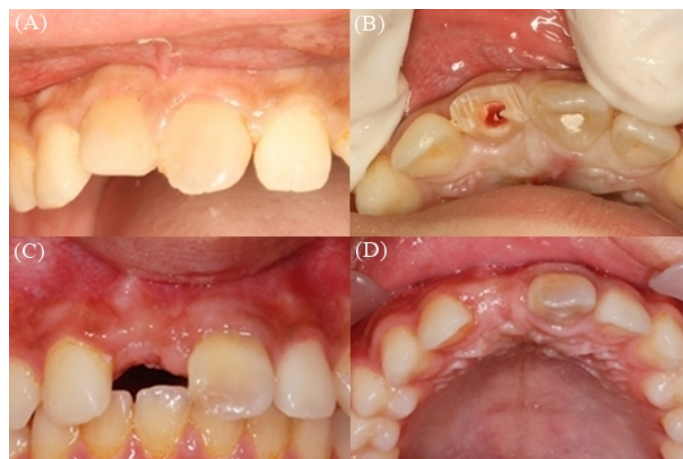


FIGURE 7. The clinical view of #11. (A) preoperative; (B) decoronation; (C,D) 5 years after decoronation.

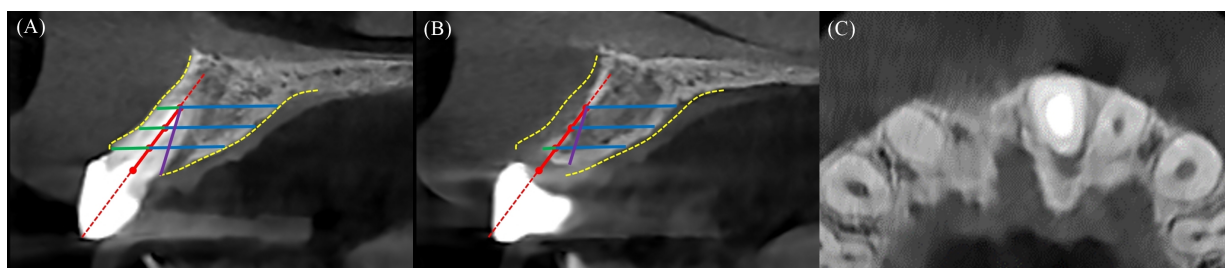


FIGURE 8. CBCT images of (A) #11 and (B) #21 10 years after surgery. Yellow: outline of alveolar bone; red: long axis of the tooth (the crestal, middle, and apical points were placed 3 mm, 6 mm, 9 mm from CEJ, respectively, and lines parallel to the FH plane were drawn at each point); green: labial bone width; blue: palatal bone width; and (C) purple: alveolar height, measured from the apical point to the palatal alveolar crest. (C) CBCT axial view.

TABLE 1. Comparison of bone volume around #11 and #21 10 years after decoronation.

Tooth	#11 (decoronated tooth)			#21 (adjacent tooth)		
	Labial	Palatal	Height	Labial	Palatal	Height
Apical	0	11.6		3.1	12.7	
Mid	0	10.7	8.6	3.3	11.6	10.9
Crestal	1.6	8.9		4.8	9.8	
Average	0.5	10.4		3.7	11.3	

who underwent decoronation for an average period of 4.1 years and measured the alveolar bone width of the decoronated area and adjacent teeth using a cast. Their findings showed that, when compared to the adjacent site, the alveolar bone width of the treated area decreased by 1.67 mm on average, while the vertical height remained similar. Zhang *et al.* [15], found that compared with the adjacent teeth, more than 75% of the alveolar bone was maintained after decoronation over a period of 4.2 years in boys and 4.0 years in girls.

The results of the present study confirmed that decoronation prevent alveolar bone resorption compared to tooth extraction. According to a study based on the clinical experience, the extraction of an ankylosed tooth may involve the loss of the

attached bone, particularly the thin buccal plate of the maxilla, which hampers socket healing, thereby causing bone defects in both horizontal and vertical dimensions [12]. Further, as the alveolar bone is a tooth-dependent tissue, and remarkable bone loss is induced due to tooth extraction, the alveolar bone is substantially lost within the first month after tooth extraction. On average, the bone is resorbed by 3–5 mm in 6 months, and 50% of the width of the alveolar bone is resorbed after 12 months. Moreover, in the anterior maxillary region, the loss of the width of the alveolar bone is greater than the loss of its height, and, resorption occurs faster on the labial side than on the palatal side, causing aesthetic and functional complications in prosthetic restoration [16–18].

In the relevant literature, several treatment options, such as observation, build-up using composite materials [19], surgical luxation [20], segmental osteotomy [21], distraction osteogenesis [22], extraction [23], and decoronation [9] have been reported. Because the growth is completed in adulthood, even if RR occurs, RR can be managed conservatively. However, a more immediate approach should be used for growing children. Moreover, without intervention, complications, such as submersion and space loss, develop faster and more severe in children than in adults. Notably, the composite build-up can be selected as the treatment of choice if infraposition is minimal. However, if composite restoration is performed at a young age, the clinical crown of the tooth becomes extremely elongated over time [24]. Although surgical luxation is recommended when RR is minimal, the long-term prognosis of such cases is poor because the reduced level of marginal bone does not change and the root cannot receive sufficient bone support [20]. Bone distraction should be delayed until bone growth is complete, and if attempted in a growing patient, infraposition of the affected tooth may reoccur. Moreover, this method cannot prevent root resorption [22]. Further, extraction causes both vertical and horizontal losses of the alveolar bone, and even a simple extraction can cause significant loss of alveolar bone if advanced infraocclusion occurs [12]. Therefore, after the exclusion of the previous methods, decoronation was recognized as the most recommended treatment for growing children with RR. However, it should be planned considering the period of growth and development.

Continuous monitoring of patients and timely intervention are critical to treatment success. When determining the appropriate timing of decoronation, the patient's age, sex, degree of infraocclusion, space loss, and growth patterns should be taken into consideration. Importantly, decoronation should be performed before the patient has undergone a pubertal growth spurt, usually around the age of 10 years and 11 months for girls and 12 years and 4 months for boys [25]. Treatment should be performed within 2 years in patients younger than 10 years and diagnosed with RR, while the timing of decoronation should be determined taking the degree of infraocclusion into consideration in patients diagnosed at the age of 10–12 years [9]. According to a long-term retrospective study of 103 patients in which alveolar bone level was evaluated in terms of age during surgery, the effect of the surgery decreased with aging in both boys and girls [26]. The RR progression rate can vary with growth pattern, with infraocclusion progressing faster in those exhibiting vertical growth patterns compared to those presenting with horizontal growth patterns. According to Mohadeb *et al.* [27], decoronation is appropriate when the severity of the infraposition of the ankylosed tooth is moderate, corresponding to an index score of two ($\geq 1/8$ but $< 1/4$ of the crown height of non-ankylosed adjacent teeth, whereas Díaz *et al.* [28], suggested that it should be performed when low-level occlusion progresses by 3–4 mm compared to the adjacent tooth.

In the current study, regular check-ups at 3-month intervals were performed after diagnosis of RR to allow identification of the appropriate timing of intervention (*i.e.*, before the onset of the pubertal growth spurt). In Case 1, RR occurred at the age of 8 years and infraocclusion progressed rapidly along

with labioversion of the affected tooth and inclination of the adjacent tooth. Decoronation was performed as soon as the loss of space was observed. Case 2, on the other hand, was diagnosed with RR at the age of 9 years and 5 months and, based on his height growth rate and slow progression of infraocclusion due to a horizontal growth pattern, periodic check-ups were performed until intervention at a relatively late age of 13 years and 8 months. Case three was diagnosed with RR at the age of 10 years. The patient exhibited progression of infraocclusion with growth, and decoronation was performed in #11 at the age of 12 years and 9 months when infraocclusion of the tooth had extended to approximately 1/8 of the height of the adjacent teeth. Decoronation was performed once the patient had reached the growth spurt stage, determined based on their age and height growth rate.

Decoronation has several advantages including short procedural duration and less postoperative pain compared with other procedures. The technique proposed by Malmgren [9] included removal of the filling materials from the root canal after the flap formation; however, this was modified so that the filling materials were removed before flap formation to minimize inflammation and the risk of complications. Complete removal of the filling materials is essential for prevention of inflammatory reactions. During endodontic treatment with gutta percha, RR proceeds along its surface (tunnel resorption), often leading to inflammatory reactions in the bone and failure of osseointegration of dental implants [29]. In such cases, calcium hydroxide paste can be applied prior to decoronation to prevent rapid root resorption after trauma in immature permanent teeth. This, in turn, allows complete removal of the filling materials easily during surgery.

As final restorations are usually completed several years after decoronation, space maintenance using temporary restorative methods such as movable partial dentures, lingual bars with prosthetic crowns, and bonding of crowns to the adjacent teeth is essential until growth completion. Attachment of a fixed crown has several advantages including ease of acceptance among children and less need for cooperation, although it is also aesthetically inferior as a space is left in the cervical region to allow alveolar bone growth which may be difficult to adjust for later. This technique is possible only when dental arch development and eruption have not been interrupted [9, 30]. The application of a removable space maintainer allows vertical growth of the alveolar bone and inter-canine space growth while preventing disordered eruption of the adjacent teeth. However, cooperation and regular inspection and replacement are required [31] as inadequate mounting of the device may necessitate orthodontic treatment for space creation at a later stage. As the patients included in the current study were still growing and exhibited mixed dentition, removable space maintainers were used to allow adjustments as tooth eruption and growth progressed. The patients and their parents were informed in advance that failure to comply with regular check-ups until growth completion would increase the risk of malocclusion and eruption disturbances. The appliance was checked every 4–6 months and was reconstructed, if necessary, thus allowing effective space maintenance for a longer duration.

The results of the current case report showed that although

complete maintenance of alveolar bone width following decoronation was not possible, the procedure was still beneficial in growing children as it allowed continuation of vertical alveolar bone growth, thus minimizing the need for additional treatment in the future and facilitating functional and aesthetic prosthetic treatment. To the best of our knowledge, the complications of decoronation have not been reported previously [27]. The key limitation of this study was that only photographs and post-surgical CBCTs were used for examination, and future studies should consider using CBCTs before and after the procedure along with dental casts for greater accuracy.

4. Conclusions

Longitudinal follow-up of the three patients included in this study confirmed that despite the resorption of the horizontal bone, decoronation is worthwhile for the vertical growth of the alveolar process in young children with RR of the permanent incisors.

AVAILABILITY OF DATA AND MATERIALS

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

AUTHOR CONTRIBUTIONS

JEH—written the first draft of the manuscript; JSL—provided critical feedback and was responsible for final approval of the manuscript. All authors contributed to the article. All authors commented on previous versions of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was previously approved by the Kyungbook National University Dental Hospital Institutional Review Board, under protocol no. KNUDH-2022-10-04-00. Informed consent was obtained from the patients and their parents.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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