Root Resorption

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Introduction

Root resorption has been a fascinating and intriguing entity for dental professionals for many years. It is a dental condition characterized by a physiologic or a pathologic process resulting in the loss of dentin and/or cementum which begins either in the periodontal ligament areas or within the pulpal tissues. Root resorption has generally been divided into two broad categories which are based on where the identified resorptive process has originated from — either internal or external. Bates (1) is credited with an early report of root resorption ("absorption") which he described in 1856 in the orthodontic literature. In 1894, Gaskill (2) presented one of the earliest case studies on "internal root resorption" describing a central incisor with an internal resorptive lesion with no external opening. Henry and Weinman (3) published a histological study of extracted teeth in 1951 and found that greater than 90% of the teeth they looked at showed some evidence related to external root resorption. During this 100-year period (1856-1951), many other reports of root resorption can also be found primarily in the orthodontic and periodontic literature.

Jens Andreasen (4,5) published a series of studies in the 1960's describing three types of external root resorption that were specifically related to traumatic dental injuries — surface root resorption, inflammatory root resorption and replacement root resorption (ankylosis) thus linking the endodontic specialty to root resorption. In 1979, Harrington and Natkin (6) were the first to describe post-bleaching cervical resorption in their case series report. Their report consisted of four cases involving young patients with a history of dental trauma, subsequent root canal therapy and internal bleaching that all resulted in a cervical resorptive lesion developing. Two years later, Al Frank (7) first described "extracanal invasive resorption" in another case series report. Since then, there have been many case reports and studies on root resorption that have both expanded our knowledge base in this area as well as introducing many more questions that remain to be answered.

Mechanisms of Resorption

It is important to note that when deciduous teeth undergo root resorption in children, it is a normal physiological process. However, when permanent teeth undergo root resorption, it is almost always a pathological process. Under normal circumstances, the mineralized tissues of permanent teeth are resistant to resorption. Two things need to occur before root resorption will develop. The first is that there must be a loss or alteration of the protective unmineralized surface layers of the tooth adjacent to dentin, either internally and/or externally. These protective layers consist of the pre-dentin layer internally and the pre-cementum layer externally. Clastic cells (both odontoclasts and osteoclasts) are attracted to specific proteins present on calcium salt crystals in all mineralized tissues such as bone and dentin. However, these clastic cells are unable to attach to unmineralized layers. With teeth, these unmineralized layers are the pre-cementum and the pre-dentin. Without attachment of the clastic cells to the root surface, resorption on the mineralized dentin will not occur. (Figures 1-A and 1-B)

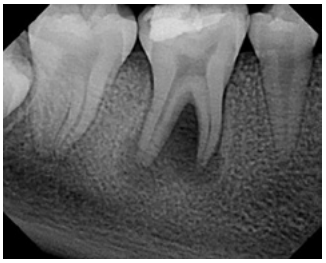


Figure 1-A. The unmineralized cementum layer protects the dentin from the ongoing inflammatory resorption in the bone.

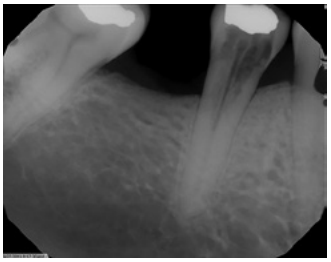


Figure 1-B. The unmineralized pre-dentin layer protects the ongoing external invasive cervical resorption from invading the pulpal tissues.

The second aspect that needs to be in place for root resorption to occur is active, ongoing inflammation next to the exposed dentin. The inflammatory response has both destructive and reparative phases. Root resorption will only occur during the more acidic environment of the destructive phase, and it will continue as long as the stimulus of the inflammation remains present. When inflammation is ongoing and exposed dentin is present, root resorption can occur (but may not necessarily occur). The four general types of stimuli that can lead to inflammation which may lead to external root resorption are: 1) microbial infection of the root canal space, 2) sulcular (periodontium) infections, 3) chemical damage secondary to bleaching and 4) pressure induced damage. In cases of inflammatory root resorption, once the etiology of the inflammatory response is removed, the inflammatory resorption will stop. (8)

Internal Root Resorption

Internal root resorption was first described in detail by Bell in 1830 (9). Gaskill (1894) and Mummery (1920) (2,10) later presented case reports of "internal resorption" in teeth showing pink spots which soon became known as the Pink Tooth of Mummery, and this became intimately associated with internal root resorption. The estimated prevalence of internal root resorption has been determined to be in the range of 0.01-1%. These teeth are generally asymptomatic, the resorptive lesion is usually a symmetrical oval size enlargement of the pulp space and part of the pulp tissue must be

vital for this resorptive process to be active. (Figure 2-A) The treatment for this type of resorption is conventional root canal therapy, often with an intracanal medicament, to eliminate the resorptive tissues and the prognosis for treating this entity is very predictable and favorable (11).

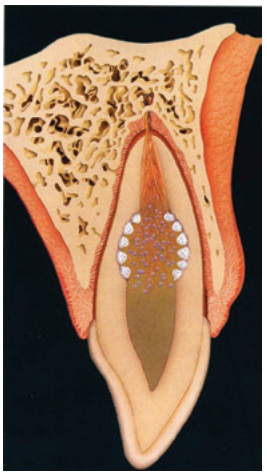


Figure 2-A. Illustration of internal root resorption confined to the canal space.

External Surface Root Resorption

In the AAE Glossary of Terms (12), external root resorption is defined as "resorption initiated in the periodontium and initially affecting the external surfaces of a tooth. This entity may be further classified as surface, inflammatory or replacement, or by location as cervical, lateral, or apical; may or may not invade the dental pulp space." External surface root resorption was one of the three types of resorption described by Andreasen in his classic 1966 study. Of the three resorption types that Andreasen described, surface root resorption was very self-limiting and was often not seen radiographically nor was it detected clinically. It occurred following a very transient stimulus which then resolved, as evidenced by cemental healing. Surface resorption was most likely what Henry and Weinmann observed in their histological study when they noted a high percentage of teeth with resorption present (3).

External Inflammatory Root Resorption

Andreasen first defined external inflammatory root resorption as "the condition where bowl-shaped areas of resorption, involving both cementum and dentin, were found in relation to areas of inflammation in the periodontal membrane. The inflammatory reaction was apparently caused by toxic products from necrotic pulp tissue and/or bacteria passing through the dentinal tubules." This observation was made during Andreasen's studies (4,5) evaluating replanted teeth that had been traumatically avulsed. At later dates, the presence of sulcular bacteria, pressure from adjacent impacted teeth and pressure from orthodontic tooth movement were also found to be associated with inflammatory root resorption. Once the etiology of the inflammatory root resorption was identified, it was found that removing this etiology would lead to an end or arrest of the active resorptive process. (Figures 3-A and 3-B) In the endodontic literature covering traumatic dental injuries, it was found that both preventive and interceptive strategies could be employed to treat/stop the inflammatory root resorption. Both strategies involve the use of calcium hydroxide as an intracanal medicament. Calcium hydroxide is antibacterial (13) and it can influence the pH in dentin (14,15). Both properties create a very favorable environment for removing the bacterial etiology stimulating active inflammatory resorption. Another medicament, Ledermix (16), has also been found to be very effective in treating inflammatory root resorption and Ledermix has been used extensively outside of the United States, however it is presently not an FDA approved medication for patient use in the United States.

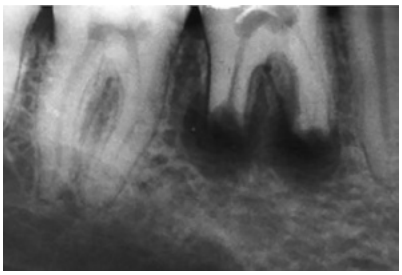


Figure 3-A. Extensive apical inflammatory root resorption from long standing necrotic pulp & bacteria.

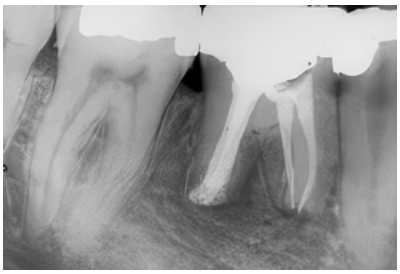


Figure 3-B. 18-month recall image following CaOH treatment and NSRCT.

External Replacement Root Resorption

The third type of external root resorption described by Andreasen (4,5) was replacement root resorption. This has also been referred to as ankylosis and dental trauma is almost always the primary etiology leading to replacement root resorption. Andreasen found that radiographically this type of resorption was "characterized by a continuous replacement of lost root structure with bone" and no radiolucency was present in relation to the area of resorption. (Figure 4-A) It has been well established in the medical literature that bone undergoes continuous remodeling throughout our lifetime. If damage occurs to the root surface of the tooth resulting in

Figure 4-A. Example of replacement root resorption #8. Note no PDL space and very little remaining root dentin on #8. Normal PDL noted on #7. (Past history of avulsions #8 & 9 eight years earlier).

exposed dentin directly adjacent to bone, the dentin may inadvertently become a part of the natural bone remodeling process. This is due in part to the fact that osteoclasts cannot differentiate dentin from bone, and with loss of the protective pre-cementum layer, the clastic cells continue to perform their normal physiological function of bone turnover, thereby invading the bone adjacent to dentinal structures of the tooth. Likewise, osteoblasts are not programmed to produce dentin, so they continue their normal function of new bone formation in the space previously occupied by dentin, ultimately resulting in ankylosis.

Can this external replacement root resorption be treated or stopped? Not without interfering with the normal process of bone remodeling. Therefore, in these cases, we attempt to manage the ankylosed teeth in a healthy state. In adults, when these teeth are asymptomatic, the teeth can be maintained, sometimes for many years. However, over time the root structures will gradually be replaced with bone ultimately resulting in the crown of the tooth fracturing away from the crestal bony ridge. In the case of children who are continuing to experience bony growth of the jaws, ankylosed teeth will likely exhibit infra-occlusion relative to the adjacent teeth since these fused teeth in the bone will not erupt normally and move forward with the developing jaws. When ankylosed teeth exhibit infra-occlusion of 1-2 mm, the tooth will not continue to erupt any further and the crestal ridge will not grow down and forward since bone/periodontal ligament will not grow onto enamel. Over time a significant periodontal bony defect will result. In these cases, when the infra-occlusion of the tooth becomes evident, the best treatment option will be a decoronation procedure (17). Since bone will not grow onto enamel, the primary goal of decoronation of an ankylosed tooth is to remove all enamel from the tooth in question. Eventually, the root structure that remains will be replaced with bone which will also allow normal growth of the osseous ridge in the area for potential future implant placement. Replacement resorption can be either a very rapid or a very slow progressive process.

External Invasive Cervical Resorption

As our understanding of external and internal root resorption became clearer, Al Frank (18) introduced a new type of resorption - "external-internal progressive resorption" - which appeared to be very distinct from both external and internal root resorption as we knew them at the time. Soon a variety of case reports were published with a wide-ranging list of resorption names that seemed similar to that which Al Frank described. In 1999 and 2004, Heithersay (19,20) introduced the term Invasive Cervical Resorption (ICR) as the primary name for this type of resorption. In his article, he proposed the following: 1) a variety of predisposing factors for ICR, 2) a classification system based on the 2-D radiographic appearance of this entity (Figure 7-A), 3) use of trichloroacetic acid in the treatment of these lesions and 4) he discussed outcomes from treatment of these lesions. Invasive cervical root resorption was typically asymptomatic, and it was initially thought to be histologically similar to other types of inflammatory resorptive lesions. The pulp tissue was found to be uninvolved in ICR, and it became evident that this resorptive process involved the cervical region of the tooth being invaded by fibro-vascular and/or fibro-osseous tissues from the PDL. (Figure 5-A) As studies rapidly increased around the globe on Invasive Cervical Resorption, the introduction of cone beam computed tomography (CBCT) to endodontics opened yet another doorway into our understanding of invasive cervical resorption. Both Nestor Cohenca (21) and Shannon Patel (22) wrote about the advantages of utilizing CBCT for the evaluation and treatment planning of external cervical resorption lesions. Patel later published a three-dimensional classification of cervical resorption based upon CBCT

Figure 5-A. Illustration of Invasive Cervical Resorption entering into dentin.

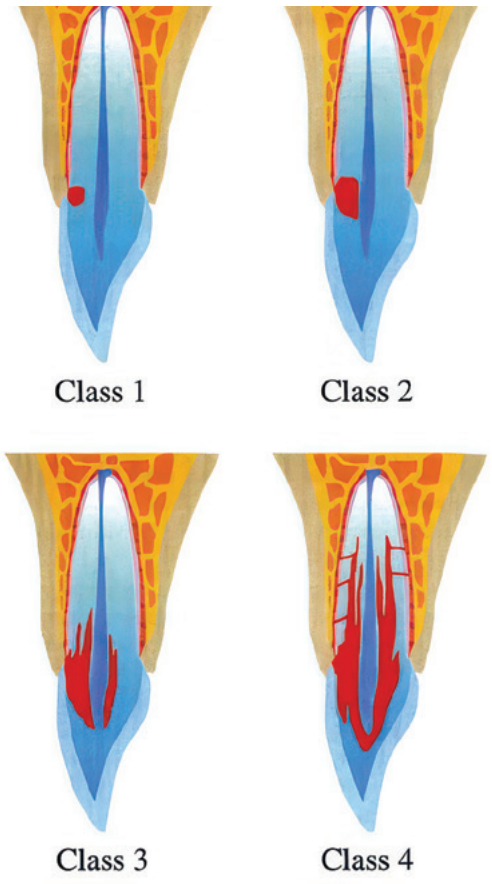
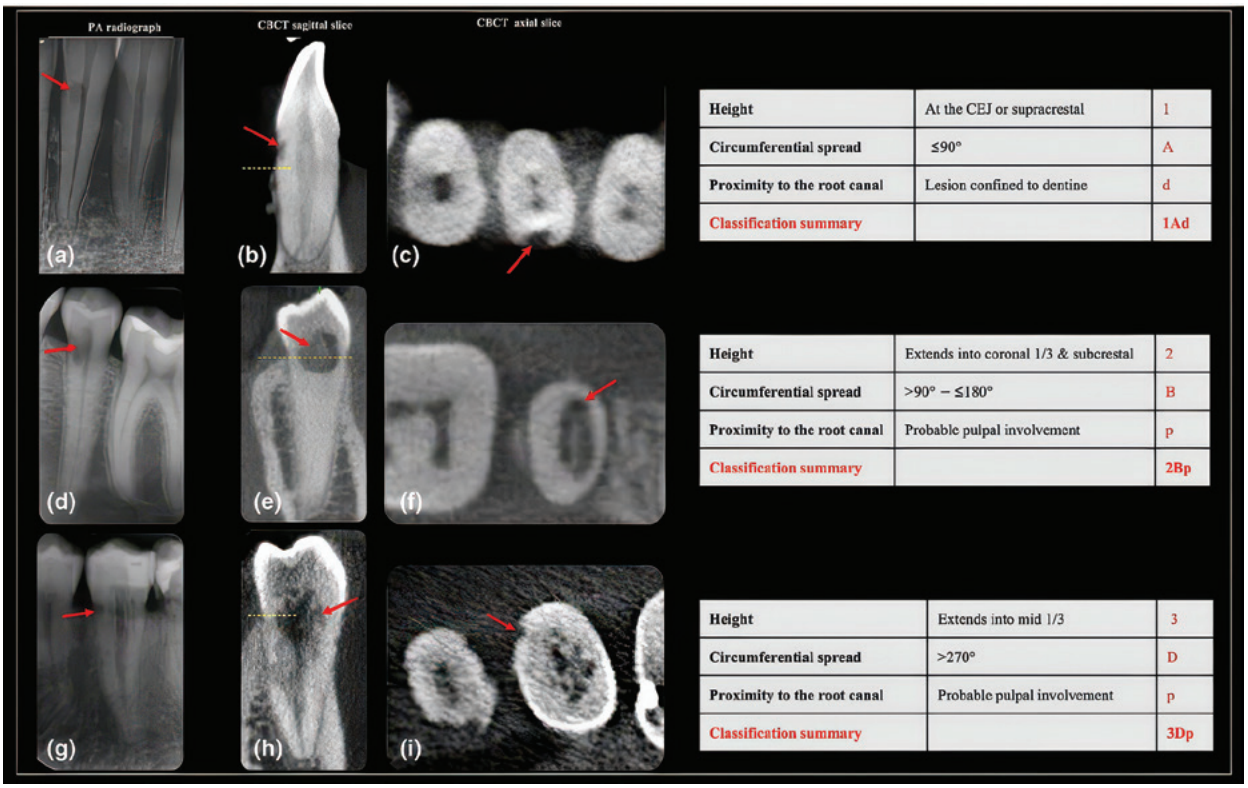


Figure 7-A. Clinical classification of Invasive Cervical Resorption (Heithersay).



Height	At the CEJ or supracrestal	1
Circumferential spread	≤90°	A
Proximity to the root canal	Lesion confined to dentine	d
Classification summary		1Ad

Height	Extends into coronal 1/3 & subcrestal	2
Circumferential spread	>90° – ≤180°	B
Proximity to the root canal	Probable pulpal involvement	p
Classification summary		2Bp

Height	Extends into mid 1/3	3
Circumferential spread	>270°	D
Proximity to the root canal	Probable pulpal involvement	p
Classification summary		3Dp

Figure 8-A. Clinical 3-D classification of Invasive Cervical Resorption (Patel)

imaging (23). (Figure 8-A) Another factor found to be important when looking at invasive cervical resorption was the anatomic configuration of the cementoenamel junction (CEJ) on teeth (24). It has been shown that there are four different configurations of the CEJ. The most common one is when the cementum slightly overlaps the enamel (60-65%) and the second most common is when the cementum meets flush with the enamel (30%). A very infrequent third type is when enamel overlaps cementum. In these three CEJ configurations, the dentin is completely protected by the overlapping cementum/enamel or the flush cementum next to the enamel. However, in 5-10% of cases, there is a natural gap between the cementum and the enamel leaving a small area of exposed dentin which may be predisposed to cervical resorption occurring. (Figure 6-A) This would certainly be an explanation of why dentin may be prone to invasive cervical resorption when there had been no prior history of trauma or surgery in the area. Other pre-disposing factors that have been proposed for invasive cervical resorption include post-bleaching resorption in teeth with a previous history of trauma at a young age (25), orthodontic treatment, history of a traumatic injury, past surgical procedures in the area and parafunctional habits (19,26). With the varied presentations of invasive cervical resorption, it has become readily apparent that the etiology for ICR is multifactorial. Several additional theories of predisposing factors have been proposed such as: playing wind instruments (27), close and/or frequent contact with cats (feline herpes virus type-1 (FeHV-1) (28) and taking medications such as Denosumab (29) used for treating bone diseases.

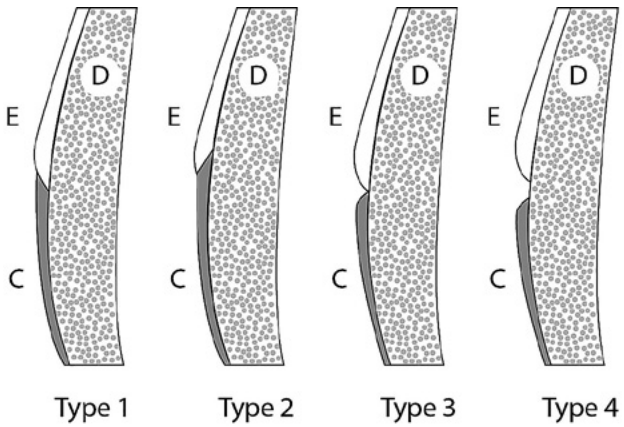


Figure 6-A. Illustration of the four types of relationships between enamel and cementum at the CEJ.

In December of 2016, Mavridou, et al (30), published a study where they analyzed cervical invasive resorption using CBCT, nano-focus CT imaging, hard tissue histology and SEM. (Figure 9-A) From this study they proposed a three-stage mechanism of cervical invasive resorption: 1) an initiation stage, 2) a resorption stage and 3) a repair stage. (30) Several illustrations were used to highlight the results of her findings. Research continues to explore the molecular mechanisms underlying cervical root resorption, aiming to identify biomarkers and therapeutic targets.

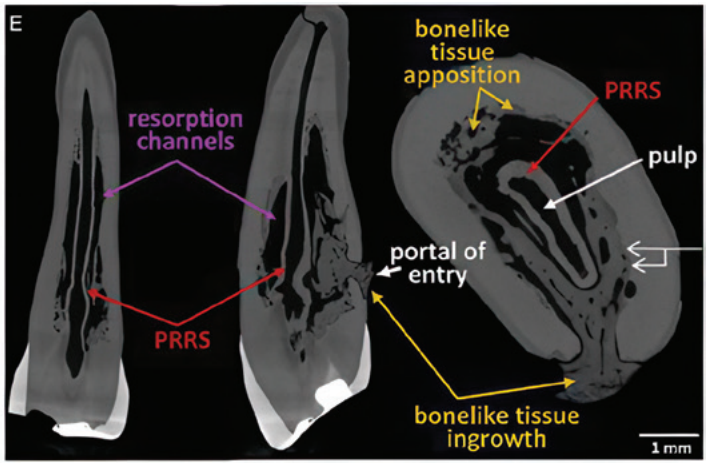


Figure 9-A. Image from Mavridou's studies on Invasive Cervical Resorption showing the repair stage of ICR.

Recent studies have examined the role of cytokines and osteoclast activity in the resorption process, providing insights that could lead to innovative treatments in the future.

With the varied presentations and varied etiologies of invasive cervical resorption, several treatment options have been utilized in managing these cases. Different approaches have included performing root canal therapy with an internal repair of the resorptive defect, using purely a surgical approach for repairing the resorptive lesion, using a combined nonsurgical and surgical approach for the treatment of these lesions and/or using orthodontic extrusion of the tooth to bring the resorptive defect above the attachment prior to the repair (31). And in some cases, the decision has been made to simply do no treatment and monitor the tooth over time. (Figures 10-A and 10-B) (19,31) In 1999 Heithersay (32), introduced the topical use of trichloroacetic acid in the treatment of invasive cervical resorption and found it to be a useful adjunct. While trichloroacetic acid is a very caustic material, with the judicial use of a topical application of this aqueous solution for 1-2 minutes, the concept was that this brief application would cause coagulation necrosis of the resorptive cells thus deactivating the resorptive process. Following three year recalls on these cases, Heithersay found that Class I and II lesions healed 100% of the time, Class III lesions healed 78% of the time, but Class IV lesions only healed 12% of the time.

Figure 10-A. Pre-operative evaluation of tooth # 20 in February, 2005.

Figure 10-B. 6 ½ year recall radiograph of tooth #20 (in August, 2011) – no change with no tx.

More recent studies have evaluated factors that contributed to successful treatment outcomes. Irinakis (33) found that tooth location and the Heithersay classification were significant factors in treatment outcomes. They also found that both root canal treatment with or without a combined repair of the resorptive defect were associated with lower failure rates. After a retrospective study of 542 teeth, Mavridou (34) proposed a three-step strategy on how to manage external cervical resorption cases. The "diagnostic step" focused on elements such as the medical and dental histories (looking for predisposing factors) along with the clinical and radiographic examinations to formulate an accurate assessment of the case in question. The "treatment planning step" was developed based on the interpretation of the diagnostic phase and each case was placed into one of three categories: 1) tooth extraction, 2) monitoring of the tooth and 3) treatment of the resorptive lesion. The "evaluation step" consisted of an assessment of the progression of the ECR, tooth survival/outcomes along with other factors. In both studies, there were several factors that could influence treatment of these teeth. In the former study, there was a 50% failure rate eight years after the initial diagnosis while in the latter, the survival rate following treatment was 70% at the five-year recall.

Two very nice review articles on External Invasive Cervical Resorption were published by Patel in 2018 — the first covering the histopathology, distribution and presentation of ICR and the second covering management of ICR. (35,36)

Final Thoughts

In conclusion, root resorption remains a complex and multifaceted condition in dentistry. A thorough understanding of the types of resorptions, the causes of and the management strategies of resorption are all critical for an accurate assessment and treatment of these lesions. Reflecting back on reports in our literature, it appears evident that resorption has been present in the dentition for many years and at times has been misunderstood and misdiagnosed. It is likely that most, if not all, pink-spots in teeth have been evidence of invasive cervical resorption, not internal resorption. While there is a distinct relationship between traumatic dental injuries and root resorption, are other concurrent etiologies also involved with the development of root resorption? With the various clinical and radiographic presentations of invasive cervical resorption, will we one day see this type of resorption divided into further classifications of cervical root resorption? Many questions remain regarding root resorption and as our knowledge base continues to grow and research studies continue to focus on resorption, we may yet gain more insight into the condition known as root resorption.

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Case Study: Root Resorption

A thirteen-year-old male and his family went on a family trip into the mountains over the Christmas holiday. On the afternoon of Christmas Eve, the 13-year-old was learning how to ice skate backwards. He fell and avulsed tooth #8. The tooth was recovered and placed in milk for the next 4 hours while the family searched for a dentist to see their son. Following is the next sequence of events:

12/24/11 – A local dentist was found, and they replanted and splinted tooth #8.

12/28/11 – The patient was seen by an endodontist who evaluated the tooth further.

1/3/12 – A pulpectomy was completed, CaOH was placed, and the splint was removed on this date.

Over the next year, this patient was seen over 3-month intervals. The patient remained asymptomatic; however, the tooth had clearly begun undergoing replacement root resorption (RRR) based on the lack of any mobility and the sound of the percussion tests on tooth #8. It was decided to watch this tooth to see how the (RRR) progressed.

Figure 1. Image dated 12/28/2011 – initial eval, 4 days post-avulsion

Figure 2. Image dated 1/3/2012 – pulpectomy/ CaOH

Figure 3. Photo dated 1/3/2012 – splint removed

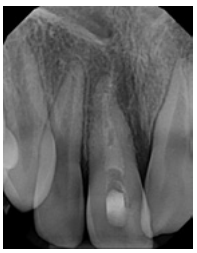

Figure 4. Image dated 7/18/2021 – 7-month follow-up

Figure 5. Image dated 9/5/2013 – 21-month follow-up

Figure 6. Image dated 9/5/2013 – 21-month follow-up, infraocclusion

9/5/13 – When the patient returned on 9/5/2013, the tooth was now in infraocclusion and a radiograph showed extensive replacement resorption after 21 months. A decoronation procedure was recommended, but the parents opted to get a second opinion instead.

The likely factor that led to this result was the time out of the mouth. This shows how quickly RRR can occur. Treatment guidelines for trauma are guidelines, but every case is unique and each needs close follow-up. Could something different have been done in this case?

Dr. Garry Myers currently serves as the graduate endodontic program director at Virginia Commonwealth University in Richmond, Va. He is an Associate Professor in Endodontics. He completed his dental school education at the University of Texas Health Science Center San Antonio in 1985. Six years later, he completed his endodontic residency program at Wilford Hall Medical Center at Lackland Air Force Base in San Antonio. He became a Diplomate of the American Board of Endodontics in 1994. After serving on active duty for 13 years, Dr. Myers left the U.S. Air Force in 1998 to enter full-time private practice in Olympia, Wash., where he practiced for the next 16 years. Dr. Myers has been active in organized dentistry, having served as the president of the Washington State Association of Endodontists in 2006-07 and as the President of the AAE in 2017-18. He served for four years as a CODA Commissioner, and he currently serves as the Treasurer of the American Board of Endodontics. He has spoken internationally at meetings in Japan, South Korea, San Diego and Guatemala.

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