Observation of apexification and pulp revascularization results of non-vital human immature mandibular premolar

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Abstract

This article describes different results of two methods in treating non-vital human immature mandibular premolar, including the histologic findings of a human immature mandibular premolar with apexification treatment in an 8-year follow-up and the radiographic results of pulp revascularization treatment in a 2-year follow-up.

Introduction

The treatment of non-vital immature permanent teeth remains a challenge for endodontists owing to presence of thin dentin walls and lack of natural apical constriction that obturation material can be placed against⁽¹⁾. Generally, there are three treatment approaches to deal with such conditions: pulp revascularization, establishing an artificial apical barrier, and traditional apexification. The purpose of apexification is to induce calcified barrier in a root of a tooth that has an open apex, or continue apical development of an incompletely formed root in a tooth with necrotic pulp⁽²⁾. In most cases, however, apexification procedure at best results in formation of a calcified barrier at the root terminus^(3, 4). Only in a few cases, further root development can be achieved in terms of length or apical wall thickness⁽⁵⁾. In addition, the susceptibility of root fracture in prolonged exposure to Ca(OH)₂ has aroused a great attention on the shortcomings of this treatment approach⁽⁶⁾.

Pulp revascularization has been advocated as an alternative of apexification for immature permanent teeth, with the advantage of promoting the continuation of full root development and the thickening of the root walls⁽⁷⁻¹²⁾. Many cases of revascularization/revitalization/regeneration of human immature permanent teeth have been reported in the literature^(9,13,14) since Iwaya⁽¹⁵⁾ and Banchs and Trope⁽¹⁶⁾ showed the outcome of human immature permanent teeth with necrotic pulp treated by revascularization.

However, there are few clinical cases comparing the outcomes of apexification and pulp revascularization in a long time follow-up. Also very little is known about the precise histological nature of the medicine-induced maturation of the root apex in apexification. In this article, we report the outcome of two different methods treating non-vital human immature mandibular premolars. We give a histological analysis of a newly formed root tip of an immature permanent premolar after apexification in 8-year follow-up and radiographic results of pulp revascularization in 2-year follow-up.

Case 1

Diagnosis and treatment plan

An 11-year-old boy was referred to the Endodontic Department of Stomatological Hospital of Southern Medical University, presenting with severe dull pain in his left mandibular second premolar (tooth #20). He had experienced intermittent spontaneous pain in that area for the previous 3 months. Clinical examination showed that tooth #20 was free of caries. However, pinpoint defect was observed on the occlusal surface,

which seemed to be associated with a ground down dens evaginatus. The tooth was quite sensitive to percussion and palpation, and the mobility of the tooth was +1. The tooth did not respond to pulp sensitivity tests (heat, cold, and electric pulp test). Periapical radiograph revealed that the tooth had thin canal wall and an incompletely developed apex. It also showed that the apex was surrounded by well-circumscribed radiolucency (Fig. 1a). The provisional diagnosis for the tooth was pulp necrosis.

Treatment options and procedures, including apexification and revascularization were explained to the patient and his parents. An informed written consent was obtained to perform a traditional apexification procedure for treating the tooth. There was no ethical conflict.

First treatment phase

The pulp chamber was accessed for tooth #20 under a surgical microscope (Carl Zeiss Meditac Inc, Dublin, CA) with administration of anesthesia. The root canal was gently irrigated using copious amounts of sodium hypochlorite (2.5%) and normal saline in an ultrasonic unit (XO Odontogain, Denmark). After drying the canal with paper points, calcium hydroxide mixed with saline solution was packed as an intracanal medication. Fourteen days after the initial treatment, the tooth was asymptomatic. calcium hydroxide/iodoform paste (Vitapex, Tokyo, Japan) was injected into the apical portion of the canal as intracanal apexification medication, and glass ionomer cement was used as temporary filling material (Fig. 1b).

Recall visits

The patient was followed up at 3, 6, and 12 months and he reported no pain. Periodontal probing depths of tooth #20 were 2-3 mm, and the mobility of the tooth was normal. Radiographic examinations revealed narrowing of the apex and continual root lengthening of tooth #20 (Fig. 1c, d, e). Calcium hydroxide/iodoform paste was replaced at each visit.

At the 24-month recall appointment, the tooth was still asymptomatic and clinically functional. The closure of the root apex was apparent radiographically (Fig. 1f). After access to the cavity, the canal was evaluated for the presence of apical closure using a #40 file, and a hard tissue barrier was confirmed. The canal was obturated using gutta-percha (Dentsply, Germany) and AH Plus sealer (Dentsply, Germany) with warm vertical compaction. The access cavity was sealed with light-cured composite resin (3M ESPE, Irvine, CA).

The patient visited 8 years later after initial treatment complaining of intermittent localized swelling and pain on the apical mucosa of tooth 20# for the previous 2 months. The patient had accidentally bitten tiny hard objects. A clinical examination showed that the composite restoration on tooth #20 was intact, and the tooth was tender to vertical percussion. There were no signs of pathological mobility. Neither a deep periodontal pocket, nor swelling on the buccal mucosa, was detected at the follow-up visit.

A periapical radiograph showed a large periapical radiolucent area (Fig. 2a). Cone-beam computed tomographic examination barely revealed a vertical root fracture in axial scans. However, the root-filling material of the apical part deviated from the center of the root canal in the buccal direction (Fig. 2b). Flap reflection was taken to reveal a vertical root fracture on tooth #20. The apical part of the gutta-percha had extruded into the periapical tissue, due to compaction from mastication (Fig. 2c). It was thus determined that the tooth was not restorable.

During extraction, the main root was easily separated from the newly formed root apex and abandoned (Fig. 2d). The apical part of the root with attached soft granulation tissue was curetted out, fixed, sectioned longitudinally, and stained with hematoxylin and eosin (H&E) for histologic evaluation.

Tissue processing and H&E staining

Permission for histologic examination of the root endpoint of tooth #20 was obtained from the patient. The specimen was immediately immersed in a 10% neutral buffered formalin solution for 24 hours. Demineralization was performed in a 40% (v/v) formic acid aqueous solution. The specimen was washed in running water for 60 minutes, dehydrated, and embedded in paraffin (melting point, 56 °C). Longitudinal serial sections of

3-5 μm were cut on a buccolingual plane throughout the entire apical portion of the specimen. To examine specimen under light microscope for screening purposes, it was stained using hematoxylin-eosin.

Histological observations

Serial histologic sections showed that the newly formed apical portion of the root was composed of hamartomatous calcified tissue and lacking a normal root terminus structure (Fig. 3a), and with inflammatory granulation tissue attached to it. Histologically, the outermost part of the newly formed apex was comprised of randomly arranged dentinal tubules. The most apical and central portion of the canal was filled with bone-like mineralized tissue, leaving a narrow root canal without any pulp-like tissue (Fig. 3b). A patch of cementum-like tissue with incremental lines was embedded in the dentinal tissue (Fig. 3c). The demarcation between the canal dentin and the bone-like mineralized tissue could be easily recognized, because of the absence of dentinal tubules in the latter tissue (Fig. 3d).

Case 2

Diagnosis and treatment plan

A 14-year-old boy was referred to the Endodontic Department, complaining intermittent swelling on the mucosa in the area of the mandibular left premolars. Clinical examination showed that a sinus tract was present buccally in association with the mandibular second premolar. The tooth was tender to percussion and palpation, the mobility of the tooth was +1. Periapical radiographs revealed that the tooth had thin canal wall and an underdeveloped apex with a circumscribed radiolucency especially in the distal direction (Fig. 5a). The provisional diagnosis for the tooth was pulp necrosis and apical periodontitis.

Treatment options and procedures were explained to the patient and his parents. An informed written consent was obtained to perform revascularization. There was no ethical conflict.

First session

The pulp chamber was accessed for tooth #20 with administration of anesthesia. Pus and a purulent hemorrhagic exudate were discharged from the canal. The absence of vital pulp tissue in the apical one third was confirmed using a Zeiss surgical microscope (Carl Zeiss Meditac Inc, Dublin, CA). The canal was gently irrigated with 20 mL 1% sodium hypochlorite without any mechanical instrumentation. After drying the canal with sterile paper points, a triple antibiotic paste that consisted of ciprofloxacin, metronidazole, and minocycline was placed in the root canal space, and the access cavity was sealed with Cavit (3M ESPE, Seefeld, Germany) .

Second session

Two weeks after initial treatment, the tooth was asymptomatic, showing no tender to percussion or palpation. After removal of intermediated medicine of triple paste with irrigation of sterile saline, K-files were used to induce bleeding into the canal up to 3 mm below the cemento-enamel junction by irritating the periapical tissues under local anesthesia (Fig.4b,c). The blood clot was covered by a layer of CollaPlug and then by 3mm depth of ProRoot mineral trioxide aggregate (MTA) (Dentsply Tulsa Dental, Tulsa,OK) mixed with saline solution. The access was sealed with light-cured composite restoration(3M ESPE, Irvine, CA).

Recall visits

After the treatment, the patient was followed up 3, 12 and 24 months later and he reported no pain. At 3-month follow-up, the sinus tract disappeared, the mobility of the tooth returned to normal, and the radiographic result revealed a complete healing of periapical lesion(Fig.5b). At 12 and 24 -month follow-up, the thickening of the canal wall and narrowing of the apex were detected obviously (Fig.5c,d). At 12-month follow-up, the apical one third of the canal was occupied with mineralized tissue (Fig.5c).At 24-month follow-up, it became more obvious which apparently blocked the canal space in half (Fig.5d), the Cone-beam computed tomography examination showed there was normal canal image in the coronal part of root, while

it became obscure in the middle part, and it was completely calcified in the apical third(Fig.5e-h). Also, the tooth began to response to electric pulp test at 24-month follow-up.

Discussion

The lengthening of the root and narrowing of the apex was observed in an immature mandibular premolar with open apex after apexification at 2-year follow-up in Case 1. Unfortunately, the root was fractured and extracted 8 years after the initial treatment. In traditional apexification, once apical barrier is formed, root canal obturation is implemented to complete the treatment. However, the root canal wall is still thin and prone to fracture after apexification. Moreover, long-term intracanal calcium hydroxide dressing and pressure from warm gutta-percha vertical compaction, also weaken the radicular wall, leaving the tooth at high risk of root fracture^(17,18). This may explain why vertical root fracture occurred 6 years after the permanent filling.

The revascularization treatment in Case 2 facilitated the continuation of root development through strengthening of the root structure, especially in the apical one third, where the thickening of root canal wall was observed obviously. The tooth began to respond positively to the electric pulp test at 24-month follow-up, which in some certain increased the potential resistance to fracture in future. Compared with apexification, revascularization in Case 2 need less treatment time and gain more potential successful clinical result in a long run. The present case reports are accordance with some retrospective or prospective studies^(5,12), which concluded revascularization was associated with significantly greater increases in root length and thickness in comparison with calcium hydroxide apexification, as well as excellent overall survival rates.

Histologically, the calcified tissue that formed over the apical foramen after apexification was identified as an osteoid (i.e., bonelike) or cementum-like tissue^(19,20). A case report found the hard barrier of the original root appearing like osteodentin, immature cementum, or immature bone after apexification, and a separate new root tip composed of normal pulp, predentin, dentin, and cementum⁽²¹⁾. In the histologic sections of our study, the newly formed apical portion of the root showed hollow root canal with inner bone-like tissue wall and outer dentin wall containing embedded islands of cementum-like tissues. From the examples above, it appears that the type of apical development and tissue that forms subsequent to the apexification procedure is unpredictable and variable.

A recent study found that intracanal calcification has a higher frequency in the revascularized cases with induced bleeding compared those without induced bleeding⁽²²⁾. In our study, induced bleeding as a convenient method was adopted in case 2 and radiographic result in 2-year follow-up showed that apical half of canal appeared to be obliterated by the hard tissue, suggesting that the pattern of root development induced by revascularization might be different from that of physiologic maturogenesis^(23,24). This result is similar to the case report of Martin G et al. who concluded that the tissues formed in the canals were similar to cementoid/osteoid tissue and uninflamed fibrous connective tissue while no pulp-like tissue was observed histologically⁽²⁵⁾. Also, the deposition of hard tissues in the apical portion were found to be more developed than in the coronal portion after revascularization which is consistent with Altaii.M⁽²⁶⁾. Most of histological analysis either in animal or human studies of immature teeth have showed that the new tissue growing in the pulp space was cementoid/osteoid tissue and/or periodontal ligament-like tissue⁽²⁷⁻³⁰⁾ regardless with or without the introduction of stem cells and scaffold. Only in few studies⁽³¹⁻³³⁾ in which pulplike tissue was observed in a revitalized tooth. However, in these studies^(31,33), the teeth were diagnosed as reversible or irreversible pulpitis before treatment which indicated the possibility of vital pulp tissue inside the canal. Though it doesn't mean the pulplike tissue can be regenerated successful in every case with pulpitis during revascularization, it cannot be deny that the tooth with pulpitis may have a higher chance of regenerating pulplike tissue in comparison with the tooth with an obvious apical lesion, since residual vital pulp might initiate the revascularization in the former while in the latter the inflammation existed in the apex area may damage the potential stem cells from the apical papilla (SCAPs) and the Hertwig epithelial root sheath. In the present case, we have no accurate information on the specific histological biopsy of the newly formed root ending. We just inferred that the tissue inside the canal might be more likely to be cementoid/osteoid tissue and/or periodontal ligament-like tissue rather than the pulplike tissue, since there was wide radiolucency

before treatment.

Conclusion:

Compared with apexification, revascularization reduced the potential risk of root fracture in immature tooth by thickening the canal wall and lengthening the root. The nature of the apical root terminus generated by apexification would be hamartomatous calcified tissue lacking physiological structure.

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