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WJCC mainly publishes articles reporting research results and findings obtained in the field of clinical medicine and covering a wide range of topics, including case control studies, retrospective cohort studies, retrospective studies, clinical trials studies, observational studies, prospective studies, randomized controlled trials, randomized clinical trials, systematic reviews, meta-analysis, and case reports.

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Different endodontic treatments induced root development of two nonvital immature teeth in the same patient: A case report

Rong Chai, Xiu Yang, An-Sheng Zhang

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Abstract

BACKGROUND

Pulp revascularization is a novel way to treat immature teeth with periapical disease, and the technique has become increasingly well established in recent years. By puncturing the periapical tissue, bleeding is induced, and a blood clot is formed in the root canal. The blood clot acts as a natural bioscaffold onto which mesenchymal stem cells from periapical tissue can be seeded and restore pulp vascularity, thus promoting root development as well as apical closure. Although the effect of pulp revascularization is ideal, there are certain requirements for the apical condition of the teeth. The apical barrier technique and apexification are still indispensable for teeth that cannot achieve ideal blood clot formation. In addition, a meta-analysis of several clinical studies concluded that pulp revascularization has no significant advantages over other treatments.

CASE SUMMARY

A 10-year-old girl complained of pain in the right upper and lower posterior teeth for 2 d. Clinical and radiological examinations revealed that both the right maxillary and mandibular second premolars were immature with periapical radiolucency. The right maxillary second premolar was treated by pulp revascularization, while the right mandibular second premolar was treated by conventional apical barrier surgery after revascularization failed. The purpose of this report is to compare the different root maturation processes induced by the pulp revascularization and apical barrier techniques in the same patient in homonymous teeth from different jaws. Twelve months of follow-up showed that the apical foramen of both teeth presented a clear tendency to close; however, the tooth treated with pulp revascularization showed a significant increase in root length as well as root canal wall thickness.

CONCLUSION

For the treatment of nonvital immature teeth, pulp revascularization showed a

superior therapeutic effect in comparison with the apical barrier technique.

Key Words: Nonvital immature tooth; Central cusp deformity; Pulp revascularization; Apical barrier technique; Root canal; Case report

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Core Tip: This report presents a case where pulp revascularization and the apical barrier technique were performed in the right maxillary and mandibular premolars. Twelve months of follow-up showed that both teeth were asymptomatic; however, the tooth treated with pulp revascularization showed a better outcome in root development.

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INTRODUCTION

Young permanent teeth take 3-5 years to complete root development and form the apical foramen after eruption. During this process, pulp or periapical tissue disease caused by infection or trauma may hinder or even stop root development. Flared and wide apical foramens have always been a great challenge for dental clinicians. Pulp revascularization is a novel therapeutic method that has been proven to be a clinically successful application of regenerative medicine. Numerous reports in recent years have demonstrated that revascularization is undoubtedly an ideal treatment for nonvital teeth with wide-open apices. Sterilized drug irrigation replaces the conventional mechanical root canal preparation and maximizes the preservation of root apical tissue to provide conditions for subsequent tissue regeneration in the root canal. Previous studies have suggested that secondary hard tissue may be derived from residual pulp tissue at the root apex, Hertwig's epithelial root sheath cells and periapical stem cells[1]. These cells adhere to the autologous scaffold formed by the blood clot in the root canal; induce the formation of hard tissues, such as reparative dentin, cementoid tissue and bone-like tissue at the root apex; or directly induce the ingrowth of periapical hard tissue[2-5]. In this report, we describe a case of pulp revascularization use for the treatment of apical periodontitis in a young permanent tooth with a wide-open apex. After revascularization, the apical foramen closed, and the thickness of the dentinal wall increased significantly.

Although the therapeutic effect of pulp revascularization is satisfactory, if the apical blood supply of the affected tooth is poor, sufficient blood cannot be delivered during the treatment, which makes it difficult to conduct blood-clot induced revascularization. In our report, pulp revascularization was successfully performed on the maxillary second premolar, but microscopy did not reveal obvious blood inflow into the root canal of the mandibular second premolar, so we resorted to the use of the apical barrier technique. Both techniques are important treatments for nonvital teeth with wide-open apices, and this case was a rare opportunity to evaluate and compare the therapeutic effect of pulp revascularization and the apical barrier technique in the same individual. A case report is presented to compare the different root maturation processes of pulp revascularization and the apical barrier technique in the same patient in homonymous teeth from different jaws.

CASE PRESENTATION

Chief complaints

A 10-year-old girl complained of pain in the right upper posterior teeth for 2 d before visiting; four months later, she visited again and complained of pain in the right lower posterior teeth for 2 d.

History of present illness

The patient reported that she felt discomfort in the right maxillary posterior region two days prior to visiting our department and went to see a dentist in another clinic. The diagnosis was central cusp deformity in the right maxillary and mandibular second premolars. The central cusps were partly ground off during the visit. The next day, she felt severe spontaneous pain in the right maxillary posterior region accompanied by swelling of the right maxillofacial area. Approximately 4 mo later, she

complained of paroxysmal pain in the right mandibular posterior region, and the next day, the pain became persistent.

History of past illness

The patient denied any history of previous disease.

Personal and family history

The patient denied a personal or family history of any systemic disease.

Physical examination

When the patient presented with pain in the right upper posterior teeth, the extraoral examination revealed mild swelling of the right maxillofacial region. Intraoral examination showed that the buccal gingiva around the apical region of the right maxillary premolars was swollen, the vestibular sulcus was shallow, and the residual partial central cusp deformity was visible on the occlusal surface (Figure 1A). The right maxillary second premolar was moderately loose and had a severe response to percussion.

When the patient presented with pain in the right lower posterior teeth, extraoral examination showed bilateral maxillofacial symmetry and no obvious swelling. Intraoral examination showed that the buccal gingiva around the apical area of the right mandibular premolars was red and slightly swollen. The right mandibular second premolar was slightly loose and had a severe response to percussion.

Laboratory examinations

No laboratory examination was performed.

Imaging examinations

Intraoral radiographic examination revealed a hypodense area around the apex of the right maxillary second premolar, and the root was incompletely developed with an open apex (Figure 1B).

Periapical X-ray examination showed a hypodense area around the apex of the right mandibular second premolar with an open apex (Figure 1C).

FINAL DIAGNOSIS

Based on the patient's history as well as clinical and radiographic examinations, a diagnosis of chronic apical periodontitis was made for the right maxillary second premolar and the right mandibular second premolar.

TREATMENT

Treatment options, including the use of the pulp revascularization technique and the apical barrier technique, were offered to the patient. After fully understanding the advantages and disadvantages of the two techniques, the patient chose pulp revascularization. The timelines of the treatment of the affected teeth are presented in Tables 1 and 2.

Treatment of the right maxillary second premolar

First treatment visit: Local anesthesia was performed with 2% lidocaine hydrochloride. A rubber dam was used to isolate the affected tooth. Under a microscope, pulp chamber access was performed with a diamond bur. A large amount of pus was seen in the pulp chamber. The root canal was irrigated alternately with 1.5% sodium hypochlorite solution (Longly Biotechnology, Wuhan, China) and 17% ethylene diamine tetraacetic acid (EDTA) solution (Longly Biotechnology, Wuhan, China) for five minutes. After drying the canal with sterile paper tips, calcium hydroxide paste (ApexCal®, Ivoclar Vivadent, Liechtenstein) was placed into the root canal; a sterile cotton pellet was placed in the pulp chamber, and the access cavity was sealed with a temporary sealing paste (Cavit-G, 3M ESPE, St. Paul, MN, United States).

Second treatment visit: Two weeks later, the affected tooth had no percussion pain or abnormal mobility. Local anesthesia was performed with 2% lidocaine hydrochloride, and a rubber dam was used to isolate the affected tooth. Under a microscope, the temporary sealing material was removed, and the root canal was washed with an ultrasonic apparatus (Satelec P5 Newtron XS, Acteon, France). After copious irrigation with 17% EDTA solution (Longly Biotechnology, Wuhan, China) for five minutes, the root canal was dried with sterile paper tips. The periapical tissue was penetrated with a #20 K-file to induce bleeding until blood filled the root canal (Figure 2A). The coronal third of the root canal was sealed with iRoot BP plus (iRoot® BP+, Innovative BioCeramix, Canada) (Figure 2B). The access cavity

Table 1 Timeline of the treatment of the right maxillary second premolar

Timeline	Events	
March 11, 2021	First treatment visit	Root canal irrigation and intracranial medication with calcium hydroxide paste
March 26, 2021	Second treatment visit	Penetration of the periapical tissue to induce bleeding, sealing of the coronal third of the root canal with iRoot BP plus
June 29, 2021	3-mo follow-up	Significant reduction of the periapical hypodense area and obvious closure of the apex
September 28, 2021	6-mo follow-up	Complete healing of the periapical lesion and slight increase in dentinal wall thickness
April 1, 2022	12-mo follow-up	Significant thickening of the dentinal wall and obvious narrowing of the root canal

Table 2 Timeline of the treatment of the right mandibular second premolar

Timeline	Events	
July 19, 2021	First treatment visit	Root canal irrigation and intracranial medication with calcium hydroxide paste
July 30, 2021	Second treatment visit	Penetration of the periapical tissue without obvious bleeding
August 6, 2021	Third treatment visit	Penetration of the periapical tissue for a second time without obvious bleeding and performance of the apical barrier technique
August 13, 2021	Fourth treatment visit	Filling of the middle and coronal third of the root canal with hot gutta-percha and filling of the access cavity with light-cured composite resin
November 10, 2021	3-mo follow-up	Significant decrease in size of the periapical hypodense area
February 11, 2022	6-mo follow-up	Complete healing of the periapical hypodense area
August 25, 2022	12-mo follow-up	Narrowing of the periodontal ligament and complete closure of the apex



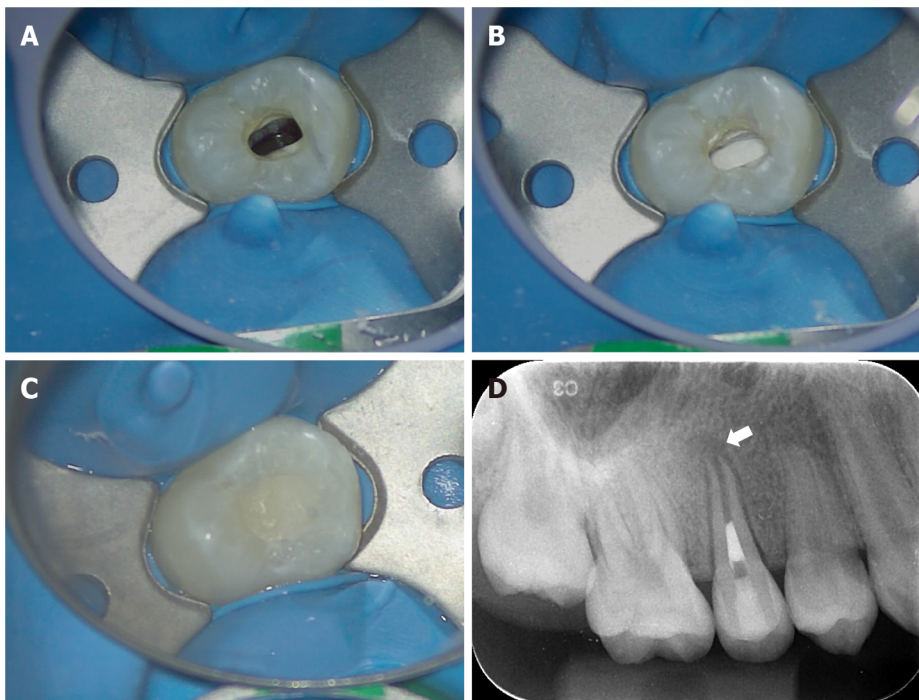
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Figure 1 Preoperative photos of the right maxillary second premolar and the right mandibular second premolar. A: Preoperative intraoral photo of the right maxillary second premolar. Note that the central cusp deformity had been polished during the patient's last visit in another clinic, and a residual part was still visible (white arrow); B: Preoperative periapical radiograph of the right maxillary second premolar. Note that the apex of the root is open (white arrow), the root canal is wide, the dentinal wall is relatively thin (black arrow), and there is a hypodense area around the root apex; C: Preoperative periapical radiograph of the right mandibular second premolar. Note that the apex of the root is not closed (white arrow), the root canal is wide, the dentinal wall is thin (black arrow), and there is a hypodense area around the root apex.

was temporarily restored with glass ionomer cement (Fuji IX GP, GC, Japan) (Figure 2C). A postoperative periapical radiograph of the right maxillary second premolar was performed (Figure 2D).

Treatment of the right mandibular second premolar

First treatment visit: Local anesthesia was performed with 2% lidocaine hydrochloride. A rubber dam was used to isolate the affected tooth. Under a microscope, pulp chamber access was performed with a diamond bur. The root canal was irrigated alternately with 1.5% sodium hypochlorite solution (Longly Biotechnology, Wuhan, China) and 17% EDTA solution (Longly Biotechnology, Wuhan, China) for five minutes. After drying the canal with sterile paper tips, calcium hydroxide paste (ApexCal®, Ivoclar Vivadent, Liechtenstein) was placed into the root canal; a sterile cotton pellet was placed in the pulp



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Figure 2 Treatment process of revascularization in the right maxillary second premolar. A: Blood filled in the root canal space after penetration of the periapical tissue by a #20 K-file; B: The coronal third of the root canal was sealed with iRoot BP plus; C: The access cavity was temporarily restored with glass ionomer cement; D: Postoperative periapical radiograph of the right maxillary second premolar. Note the obvious hypodense area around the root apex and the wide-open apex (white arrow); the root canal is wide, and the dentinal wall is relatively thin.

chamber, and the access cavity was sealed with a temporary sealing paste (Cavit-G, 3M ESPE, St. Paul, MN, United States).

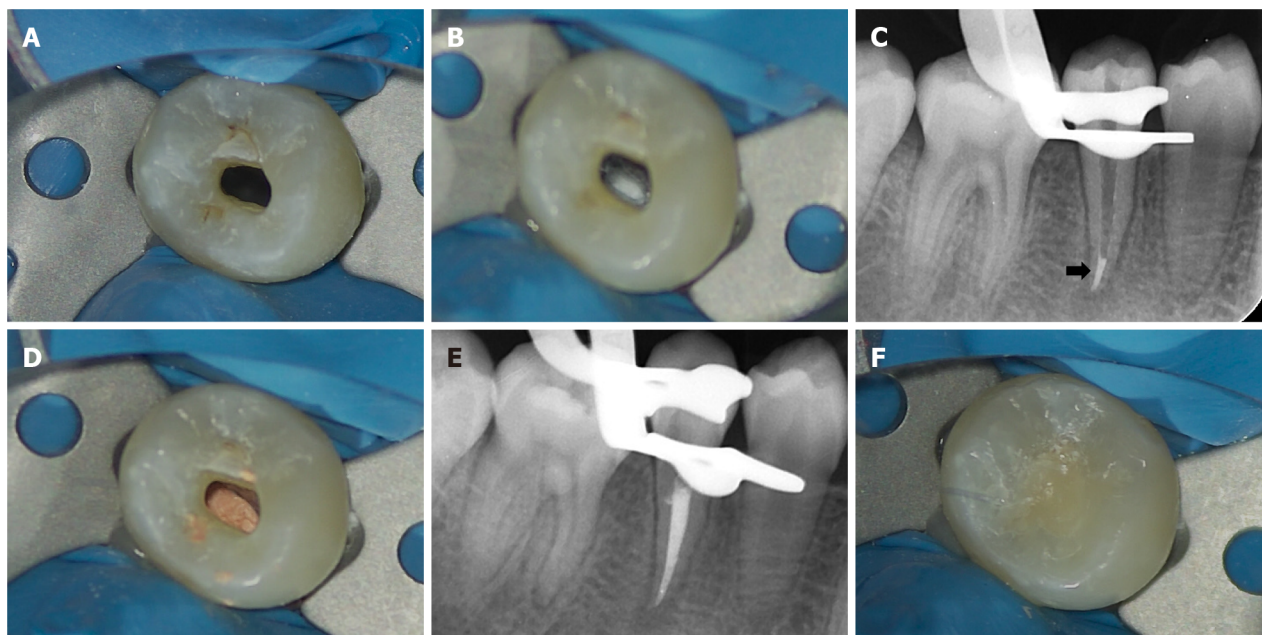
Second treatment visit: After two weeks, the affected tooth had no percussion pain or abnormal mobility. Local anesthesia was performed with 2% lidocaine hydrochloride, and a rubber dam was used to isolate the affected tooth. Under a microscope, the temporary sealing material was removed, and the root canal was washed with an ultrasonic apparatus (Satelec P5 Newtron XS, Acteon, France). After copious irrigation with 17% EDTA solution (Longly Biotechnology, Wuhan, China) for five minutes, the root canal was dried with sterile paper tips. The periapical tissue was penetrated with a #20 K-file to induce bleeding. However, after multiple attempts, there was no significant bleeding. The root canal was irrigated with 1.5% sodium hypochlorite solution (Longly Biotechnology, Wuhan, China) and then filled with calcium hydroxide paste (ApexCal®, Ivoclar Vivadent, Liechtenstein); a sterile cotton pellet was placed in the pulp chamber, and the access cavity was sealed with a temporary sealing paste (Cavit-G, 3M ESPE, St. Paul, MN, United States).

Third treatment visit

A week later, local anesthesia was performed with 2% lidocaine hydrochloride, and a rubber dam was used to isolate the affected tooth. Under a microscope, the temporary sealing material was removed, and the root canal was washed with an ultrasonic apparatus (Satelec P5 Newtron XS, Acteon, France). After copious irrigation with 17% EDTA solution (Longly Biotechnology, Wuhan, China) for five minutes, the root canal was dried with sterile paper tips. The periapical tissue was penetrated again with a #20 K-file to induce bleeding. After several attempts, there was still no obvious bleeding (Figure 3A). After discussion with the patient's parents, we decided to switch the treatment plan to the apical barrier technique. Under a microscope, an appropriate amount of iRoot BP plus was placed into the root canal and pressed repeatedly to form an apical barrier with a thickness of approximately 4 mm at the root tip (Figure 3B and C). A moist sterile cotton pellet was placed in the pulp chamber, and the access cavity was sealed with a temporary sealing paste (Cavit-G, 3M ESPE, St. Paul, MN, United States).

Fourth treatment visit

After one week, a rubber dam was used to isolate the affected tooth. Under a microscope, the temporary sealing material was removed, and the root canal was washed with an ultrasonic apparatus (Satelec P5 Newtron XS, Acteon, France). After drying with sterile paper tips, the coronal and middle third of the root canal was filled with hot gutta-percha (Figure 3D and E), and the access cavity was restored with a



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Figure 3 Treatment process of the right mandibular second premolar. A: There was no obvious blood in the root canal after penetration of the periapical tissue by a #20 K-file; B: iRoot BP plus was placed in the apical third of the root canal and pressed tightly to form an apical barrier; C: Intraoral radiograph of the right mandibular second premolar after the placement of iRoot BP plus at the apical third of the root canal (black arrow); D and E: The coronal and middle third of the root canal was filled with hot gutta-percha; F: The access cavity was restored with light-cured composite resin.

flowable light-cured resin base (Z350XT Flowable, 3M™ Filtek™, United States) and light-cured composite resin (Z350XT, 3M™ Filtek™, United States) (Figure 3F).

OUTCOME AND FOLLOW-UP

Follow-up of the right maxillary second premolar

At the 3-mo follow-up, the periapical radiograph revealed that the hypodense area around the root apex had significantly diminished, and the apex had obviously closed (Figure 4A). The glass ionomer cement was replaced by a flowable light-cured resin base (Z350XT Flowable, 3M™ Filtek™, United States) and light-cured composite resin (Z350XT, 3M™ Filtek™, United States).

At the 6-mo follow-up, there was complete healing of the periapical lesion. The thickness of the dentinal wall slightly increased, and there seemed to be some scattered calcifications in the root canal (Figure 4B).

At the 12-mo follow-up, the root canal had obviously narrowed, and the thickness of the dentinal wall had increased significantly (Figure 4C).

The affected tooth showed no response to cold, heat or electric stimulations.

Follow-up of the right mandibular second premolar

At the 3-mo follow-up, the periapical radiolucency area was significantly reduced (Figure 5A).

At the 6-mo follow-up, the periapical radiolucency area had completely healed (Figure 5B).

At the 12-mo follow-up, the periodontal ligament had narrowed, and complete closure of the apex was observed, with an obvious calcification layer generated just around the apical barrier materials (Figure 5C).

DISCUSSION

In the present case report, we described the maturation processes of homonymous teeth from different jaws after applying dental pulp revascularization and the apical barrier technique in the same patient. This was a valuable opportunity to observe the differences in the therapeutic effects between the two techniques. After 12 mo of follow-up, both teeth were asymptomatic; however, the different statuses of the roots indicated that pulp revascularization showed several advantages over the apical barrier technique. Pulp revascularization can stimulate the regeneration potential of periapical tissues, thereby promoting further development of the root, including root canal wall thickening, root elongation, and



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Figure 4 Follow-up of the right maxillary second premolar. A: 3-mo follow-up. The hypodense area around the root apex was significantly diminished, and the apex was obviously closed (white arrow); B: 6-mo follow-up. There was complete healing of the periapical hypodense area (white arrow). The thickness of the dentinal wall was slightly increased, and there seemed to be some scattered calcifications in the root canal (black arrow); C: 12-mo follow-up. The root canal was obviously narrowed, and the thickness of the dentinal wall was increased significantly (black arrow).



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Figure 5 Follow-up of the right mandibular second premolar. A: 3-mo follow-up. The hypodense area around the root apex was significantly diminished (white arrow); B: 6-mo follow-up. The periapical hypodense area was completely healed (white arrow); C: 12-mo follow-up. The periodontal ligament was narrowed (white arrow). Complete closure of the apex was observed, and there was an obvious calcification layer generated just around the apical barrier materials (black arrow).

closure of the apical foramen[6,7]. In this way, the fragile and blunderbuss-like root can be rescued, and the incidence of tooth fracture and crown-to-root ratio incompatibility can be further reduced. In addition, after pulp revascularization, the tooth does not need root canal therapy, avoiding the risk of reinfection caused by reopening the pulp cavity.

Even if pulp revascularization fails, apexification and the apical barrier technique are alternative options. Traditionally, the procedure indicated for teeth with incomplete root formation is apexification; this technique is mainly performed by placing calcium hydroxide paste into the root canal for a certain time period to induce the formation of a calcified barrier[8]. Currently, apexification is regarded as the most classical treatment; however, long-term intracanal medication may decrease root strength due to the hygroscopic and proteolytic properties of calcium hydroxide[9,10]. The key to the apical barrier technique is to seal the wide-open apex tightly with bioceramic materials, such as iRoot BP plus or mineral trioxide aggregate[11], to prevent further infections. It is often a substantial technical challenge for dentists, and if the treatment fails, it is difficult to address[12]. The current view is that the root length and dentinal wall thickness will not change after treatment; thus, this technique does not considerably enhance the strength of the root. Therefore, with a comprehensive analysis of the pros and cons of apexification and the apical barrier technique, in this case, after the failure of revascularization, we resorted to the apical barrier technique to treat the mandibular second premolar. At the 6-mo follow-up, the hypodense area around the root apex had completely healed, demonstrating that successful application of the apical barrier technique can effectively control root canal infection and promote the healing of the periapical tissue. At the 12-mo follow-up, complete closure of the apex was observed, and there was an obvious calcification layer generated just around the apical barrier materials, likely due to the mineralization induction capacity of iRoot BP plus[13].

In this case, the different maturation processes of the two teeth demonstrated that pulp revascularization showed a superior therapeutic effect in nonvital young permanent teeth because pulp revascularization offers the possibility of additional tooth development rather than simple hard tissue deposition, which may greatly reduce the incidence of future tooth fractures. According to studies in regenerative medicine, therapeutic angiogenesis is a key factor in tissue regeneration[14-16]. Both the American Association of Endodontics and the European Society of Endodontology agree that pulp

revascularization is the preferred treatment for teeth with incomplete root formation[17,18]. The blood clot-induced revascularization used in this study is the most commonly used, well-established technique. With the continuous development of regenerative medicine, revascularization can also be induced by, for example, platelet-rich fibrin, platelet-rich plasma, angiogenic peptide hydrogels, and buccal fat grafts[19-21]. Although pulp revascularization is highly recommended by many clinicians, its shortcomings, such as discoloration of the crown and root canal blockage, cannot be ignored[22-24]. Nicoloso *et al*[25] conducted a meta-analysis of several clinical studies and concluded that pulp revascularization has no significant advantages over other treatments. The optimal treatment for nonvital immature teeth remains uncertain. In the future, we need to pay close attention to new trends in regenerative medicine to create more innovative points for root regeneration; we also need to carefully analyze the condition of the affected teeth in clinical practice, balance the advantages and disadvantages of various treatment methods, and try to provide the most suitable choice for patients.

CONCLUSION

In this case, pulp revascularization showed a superior outcome of inducing root development in comparison with the apical barrier technique. However, more attention should be given to regenerative endodontics to optimize treatment for nonvital immature teeth.

FOOTNOTES

Author contributions: Chai R performed the treatment, collected data, and wrote the manuscript; Yang X contributed to data collection; Zhang AS conceived the study, provided financial support, and reviewed the manuscript; and all authors read and approved the manuscript.

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