

## Total Pulpotomy with MTA in Young Permanent Teeth: Case Series

Menekşe ALİM<sup>1\*</sup>  Mehmet BANİ<sup>2</sup> 

<sup>1</sup> Res. Assist., Gazi University, School of Dentistry, Department of Pediatric Dentistry, Ankara, Türkiye, dt.alimmenekse@gmail.com

<sup>2</sup> Prof., Gazi University, School of Dentistry, Department of Pediatric Dentistry, Ankara, Türkiye, mehmetbani@gazi.edu.tr

Article Info	ABSTRACT
<b>Article History</b> <b>Received:</b> 27.06.2024 <b>Accepted:</b> 05.09.2024 <b>Published:</b> 15.10.2024 <b>Keywords:</b> Pulpotomy, Vital pulp therapy, Young permanent teeth.	Vital pulp therapy is a way to preserve the vitality and function of pulp damaged by trauma, caries or restorative procedures. Vital pulp therapy procedures include direct pulp capping, indirect pulp capping, partial and coronal pulpotomy treatments where diseased pulp tissue is removed. Over the years, the focus of vital pulp therapy has been on the preservation of the radicular pulp in immature permanent teeth to ensure the completion of root formation (apexogenesis). Today, it has been reported that vital pulp therapy can be considered as an alternative to root canal treatment, including in teeth with certain conditions that are considered to have irreversibly inflamed pulp. Coronal amputation therapy, a vital pulp treatment, involves complete removal of the coronal pulp, placement of a biologically acceptable material into the pulp chamber and restoration. The covering material must be able to relieve inflammation and initiate healing of the pulp tissue and allow new dentin tissue to form. The oldest material used in pulpotomy is calcium hydroxide. Mineral trioxide aggregate, which is a more recent material, is frequently preferred today due to its biocompatible and bioactive properties. In this case report, the results of 4 cases of coronal pulpotomy with mineral trioxide aggregate in young permanent teeth with a follow-up of 18 months are presented.

### Genç Daimi Dişlerde MTA ile Koronal Pulpotomi: Vaka Serisi

Makale Bilgisi	ÖZET
<b>Makale Geçmişi</b> <b>Geliş Tarihi:</b> 27.06.2024 <b>Kabul Tarihi:</b> 05.09.2024 <b>Yayın Tarihi:</b> 15.10.2024 <b>Anahtar Kelimeler:</b> Pulpotomi, Vital pulpa tedavisi, Genç daimi diş.	Vital pulpa tedavisi travma, çürük veya restoratif prosedürler sebebiyle hasar alan pulpanın canlılığını ve işlevini korumanın bir yoludur. Vital pulpa tedavisi prosedürleri; direkt kuafaj, indirekt kuafaj, hastalıklı pulpa dokusunun çıkarıldığı parsiyel ve koronal pulpotomi tedavilerini içermektedir. Yıllar boyunca vital pulpa tedavisinin odak noktası, kök oluşumunun (apeksogenez) tamamlanmasını sağlamak için gelişimini tamamlamamış daimi dişlerde radiküler pulpanın korunması olmuştur. Günümüzde ise vital pulpa tedavisinin, belirli şartlara sahip geri dönüşümsüz olarak inflame pulpaya sahip olduğu düşünülen dişler de dahil olmak üzere, kök kanal tedavisine alternatif olarak değerlendirilebileceği bildirilmiştir. Vital pulpa tedavilerinden olan koronal amputasyon tedavisi koronal pulpanın tamamen çıkarılması, biyolojik olarak kabul edilebilir bir materyalin pulpa odasına yerleştirilmesi ve restorasyonunu içerir. Kaplama materyali ise, pulpa dokusundaki inflamasyonu giderip iyileşmeyi başlatabilmeli ve yeni dentin dokusunun oluşabilmesini sağlamalıdır. Pulpotomide kullanılan en eski materyal kalsiyum hidroksittir. Daha güncel bir materyal olan mineral trioksit agregatı ise biyoyumlu ve biyoaktif özellikleri nedeniyle günümüzde sıklıkla tercih edilmektedir. Bu olgu raporunda genç daimi dişlerde mineral trioksit agregatı ile koronal pulpotomi uygulanan 4 olgunun 18 ay takipli tedavi sonuçları sunulmuştur.

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**\*Corresponding Author:** Menekşe ALİM, [dt.alimmenekse@gmail.com](mailto:dt.alimmenekse@gmail.com)



## INTRODUCTION

Vital pulp therapy (VPT) consists of different treatment strategies to preserve the integrity, health and pulp vitality of teeth with deep carious lesions approaching or involving the pulp, or when pulp tissue is exposed due to mechanical causes such as trauma. VPT procedures include direct and indirect pulp capping, partial and coronal pulpotomies to remove diseased pulp tissue.<sup>1</sup>

According to common understanding, pulpotomies were limited to treating decayed deciduous teeth and traumatized permanent teeth, while root canal treatment (RCT) of caries-perforated pulp in mature permanent teeth was recommended. It has now been suggested that pulpotomy treatment may be a treatment option, even in cases of irreversible pulpitis (IP).<sup>2</sup> The goals of coronal pulpotomy treatment are to preserve pulp vitality, promote repair of remaining pulp tissue, and restore structural and functional health of the pulp dentin complex.<sup>3</sup> Traditionally, the determination of pulpal diagnosis has been based on the clinician's assessment of the patient's pain history and clinical tests such as vitality and percussion testing.<sup>4,5</sup> Historically, however, clinical test results have not accurately reflected the histological state of the pulp.<sup>6,7</sup> Histologic proof of pulpitis advancement suggests that there is no limit to which the pulp becomes irreparable.<sup>8,9</sup> Instead, pulpitis is interpreted as a graded disease, with some investigators proposing the terms "initial," "mild," "moderate," and "severe pulpitis" for grading.<sup>8,10</sup> Clinically, scrutiny of pulp tissue during and after hemostasis additional diagnostic data about the status of the pulp.<sup>11</sup> Thus, it seems that even symptomatic pulps can be treated with VPT.<sup>12</sup>

Influencing factors in the achievement of pulpotomy treatments include correct diagnosis, clinical findings, appropriate treatment method, bleeding control, use of biocompatible material,

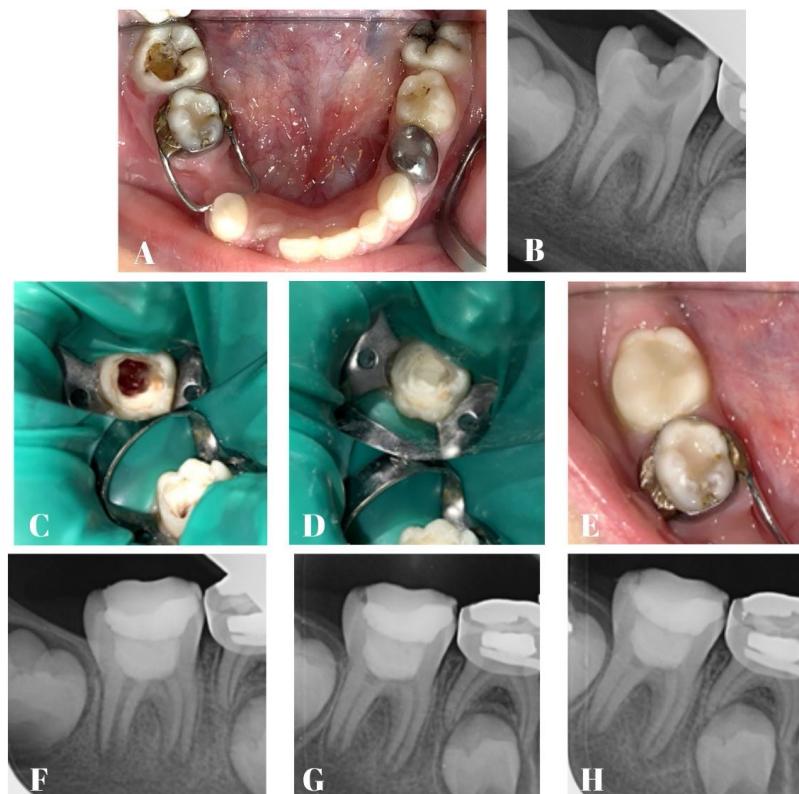
blood supply, healthy periodontal tissues, crown sealing and appropriate crown material, degree of microbial contamination and repair ability of dental tissue.<sup>13</sup> When these factors are considered, coronal pulpotomy treatments have been reported as a simple, biological, regenerative, conservative and economical method with a high achievement rate.<sup>1</sup> The oldest material used in pulpotomy is calcium hydroxide. Mineral trioxide aggregate (MTA), a more recent material, is frequently preferred today due to its biocompatible and bioactive properties.<sup>14,15</sup> Clinical investigations of cariously exposed permanent molars diagnosed with reversible pulpitis and treated with MTA have shown high success rates ranging from 82% to 100%.<sup>16-19</sup> Although few studies have investigated the use of MTA for pulpotomies of permanent molars with clinical signs and symptoms indicative of irreversibly inflamed pulp, success rates have been quite high.<sup>20-22</sup> It has been reporting that to evaluate the success of pulpotomy treatments, treated teeth should be followed up at 6 and 12 months postoperatively and then annually for four years if necessary.<sup>23</sup> The advantages of coronal pulpotomy treatment, which can be considered as an alternative to RCT, are preservation of the structural integrity of the tooth, less painful procedure, elimination of complications related to difficult root canal anatomy, and reduced cost and time spent in the clinic.<sup>10</sup> The aim of this study was to evaluate the results of coronal pulpotomy treatment with MTA in young permanent teeth diagnosed with reversible/irreversible pulpitis.

### Case 1

An 8-year-old girl patient was applied to the Pediatric Dentistry Clinic of Gazi University with pain in the lower right region. The pain started spontaneously and was persistent. Clinical examination revealed percussion sensitivity in tooth 46, which had deep dentin caries (Figure 1A). No pathologic changes were observed in the intraoral soft

tissues. Radiographic examination revealed radiolucency and loss of lamina dura in the apical and bifurcation region (Figure 1B). It was also observed that root development was incomplete and the root tips were open. A positive response was obtained to the vitality test. After clinical and radiologic examination, irreversible pulpitis was diagnosed. After removal of the coronal pulp, coronal pulpotomy/apexification preferences were planned according to the bleeding control status. Local anesthesia was applied, the caries were removed under rubber-dam isolation, and the coronal pulp tissue was removed with an aerator under water cooling. Hemostasis was achieved in 5 minutes with a cotton pellet moistened with 2.5% sodium hypochlorite (NaOCl) and the treatment was continued as a coronal pulpotomy (Figure 1C). MTA (Bio-MTA-Cerkamed) used as pulp coating material. MTA powder and liquid were mixed according to the manufacturer's instructions for 30 s until the compound reaches a consistence of soft

plasticine. A 2-3 mm MTA as placed on the pulp chamber floor (Figure 1D). After the initial hardening time of 4 minutes of MTA was completed, conventional glass ionomer cement (Nova Glass-F-Imicryl) was placed in the cavity as a base. After etching the tooth surface using phosphoric acid gel for 20 seconds, the teeth were washed with air water spray and a thin layer of universal adhesive was applied to the prepared tooth surface and cured with led light. Composite resin (Charisma-Heraus Kulzer) was applied to the tooth by layering technique and each layer was cured with led light for 20 seconds (Figure 1E). The patient was followed up for clinical and radiographic evaluation at 6, 12 and 18 months (Figure 1F, 1G, 1H). It was found that the patient's complaints were completely resolved and there was no pain on percussion. At the end of the 18th month, the disappearance of radiolucent appearance, root elongation, increase in dentin thickness and closure of the apex were observed.

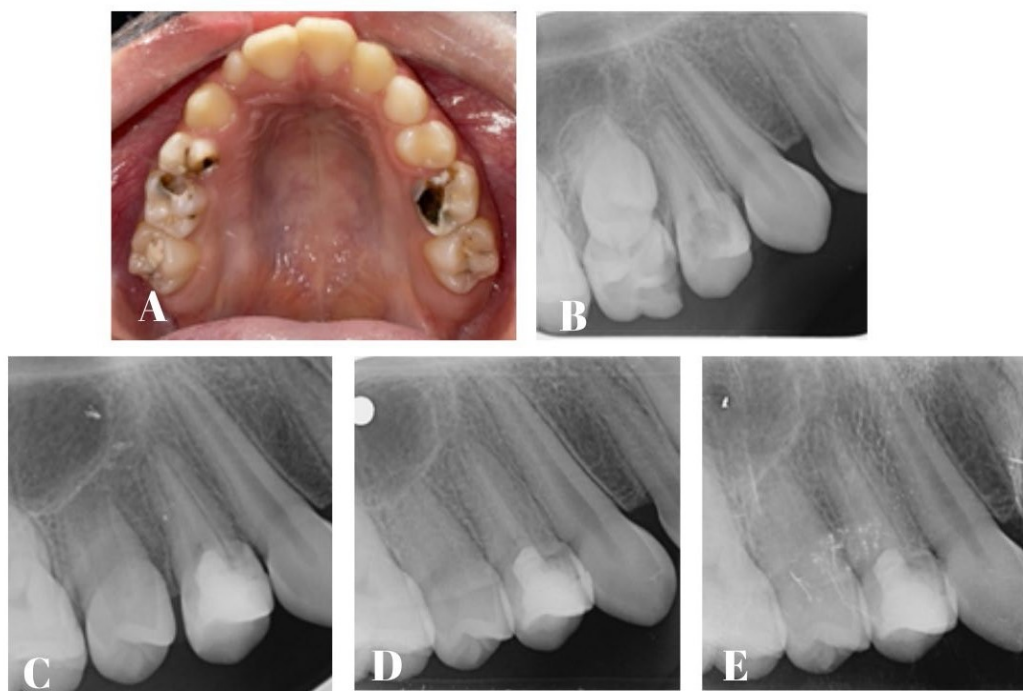


**Figure 1.** A: Preoperative photograph showing tooth 46 with deep dentin caries, B: Preoperative radiograph of tooth 46, C: Total pulpotomy performed in tooth 46, D: MTA placed over the pulp, E: Postoperative photograph, F-G-H: 6,12 and 18 months follow-up.

### Case 2

An 11-year-old girl patient presented to our clinic with pain in the right upper region. The patient stated that the pain started after eating and did not continue after the stimulus was removed. Intraoral examination showed deep dentin caries in tooth 14 (Figure 2A). No pain was detected on percussion and palpation. The radiographic examination did not reveal any negative findings in tooth number 14, which had not yet completed root development (Figure 2B). As a consequence of clinical and radiographic examination, reversible pulpitis

was diagnosed in tooth number 14. After the caries were removed under local anesthesia and rubber-dam isolation, it was decided to perform a coronal pulpotomy because the pulp was exposed to caries at multiple points. The procedure described in the other case was performed respectively. The patient was followed up for clinical and radiographic evaluation at 6, 12 and 18 months (Figure 2C, 2D, 2E). The tooth was asymptomatic and at the end of the 18th month, root elongation, increased dentin thickness and closure of the apex were observed.

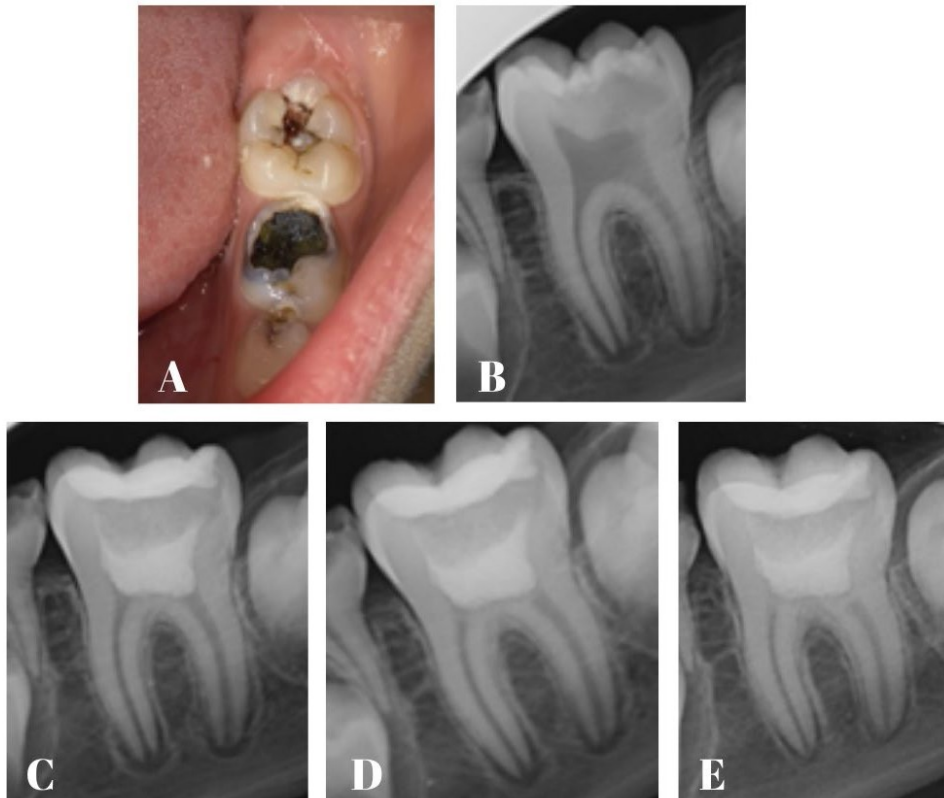


**Figure 2.** A: Preoperative photograph showing tooth 14 with deep dentin caries, B: Preoperative radiograph of tooth 14, C-D-E: 6,12 and 18 months follow-up.

### Case 3

An 8-year-old boy patient was applied to the our clinic with pain in the lower left region. The patient stated that the pain disappeared after the stimulus was removed. Intraoral examination showed deep dentin caries and percussion sensitivity in tooth 36 (Figure 3A). Radiographic examination did not reveal any negative findings in tooth 36, which had not completed root development (Figure 3B). After

clinical and radiographic examination, tooth 36 was diagnosed with reversible pulpitis. A coronal pulpotomy was performed after the caries were removed because the pulpal exposure area was more than 2 mm. Coronal pulpotomy treatment was performed according to the procedure. The tooth was asymptomatic at 6, 12 and 18 months (Figure 3C, 3D, 3E). At the end of the 18th month, root elongation, an increase in dentin thickness, closure of the apex and dentin bridge formation were observed.

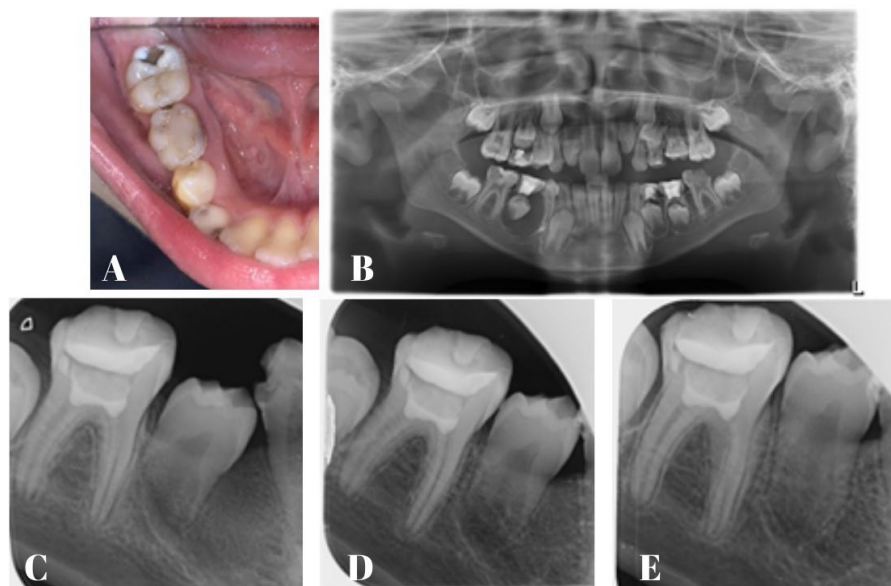


**Figure 3.** **A:** Preoperative photograph showing tooth 36 with deep dentin caries, **B:** Preoperative radiograph of tooth 36, **C-D-E:** 6,12 and 18 months follow-up.

#### Case 4

An 8-year-old boy patient was applied to our clinic with severe pain in the lower right region. The pain started spontaneously and was persistent. Intraoral examination of the patient revealed deep dentin caries in tooth 46 (Figure 4A). There was percussion sensitivity in the tooth. At the same time, hyperemia and swelling were observed in the buccal area of tooth number 85. A panoramic radiograph of the patient showed a lesion on the apical aspect of tooth 85 involving the permanent tooth germ. Deep dentin caries associated with the pulp was observed in tooth 46, which also complained of pain (Figure 4B). After clinical and radiologic examination, tooth 46 was diagnosed as symptomatic irreversible pulpitis and the lesion in the root of tooth 85 was consulted to the surgical department with a prediagnosis of inflammatory odontogenic cyst. In the first session, under local anesthesia and rubber dam

isolation, the coronal pulp was completely removed after caries removal in tooth 46. Since bleeding control was successfully achieved, coronal pulpotomy treatment was performed. The patient had no symptoms at 6, 12 and 18 months (Figure 4C, 4D, 4E). At the end of the 18th month, an increase in dentin thickness, root elongation and closure of the apex were observed.



**Figure 4.** **A:** Preoperative photograph showing tooth 46 with deep dentin caries, **B:** Preoperative radiograph, **C-D-E:** 6,12 and 18 months follow-up.

## DISCUSSION

Currently, it has been reported that coronal pulpotomy from VPT can be thought of as an alternative to RCT, including in teeth considered to have irreversibly inflamed pulp.<sup>24</sup> As a minimally invasive approximation to dentistry, VPT has advantages such as preservation of tooth tissue, elimination of complications associated with complex root canal anatomy, less painful procedure and reduced cost and time spent in the clinic.<sup>10</sup> The less painful and shorter duration of the clinical procedure also helps pediatric patients comply with the treatment.

Clinical signs of IP do not always indicate that the pulp has been damaged beyond repair.<sup>25</sup> Even in cases showing irreversible changes or signs of necrosis, these changes have been found to be limited to the coronal pulp tissue, with reactions less severe in the rest of the coronal tissues and normal uninflamed pulpal tissue in the roots as well as in the contralateral pulpal horn.<sup>9</sup> A meta-analysis by Ather et al. reported an 84% success rate of coronal pulpotomy in caries-exposed teeth with symptomatic IP, compared to 91.3% in teeth with asymptomatic IP, with no significant difference between them.<sup>26</sup>

The most important influencing factors for the success of coronal pulpotomy treatment are microbial contamination and bleeding status.<sup>13</sup> In this case series, a rubber dam was used to isolate the procedure site from the oral cavity and saliva. There is no reliable tool that can be used clinically to determine how deep the caries-induced inflammation has progressed into the pulp.<sup>27</sup> Researchers recommend observing and controlling bleeding rather than clinical symptoms to comment on pulp health.<sup>27,28</sup> Bleeding time has been used as an indicator of the spread of inflammation, and pulpectomy has been recommended if bleeding cannot be controlled within 5-10 minutes.<sup>29</sup> Researchers recommend NaOCl for both rapid bleeding control and disinfection of the area.<sup>23,30,31</sup> NaOCl concentration varies in different studies, and 2.5% NaOCl was used for bleeding control in the cases presented.<sup>32</sup>

It has been revealed that a vital dental pulp can be seen in a symptomatic carious tooth with a periapical lesion; therefore, apical periodontitis does not always indicate a necrotic pulp.<sup>33</sup> Only one of the 4 cases presented had periapical radiolucency. In this tooth, which was treated with coronal pulpotomy, hard tissue formation was observed at the end of the 18th month.

Studies in the literature have also revealed successful results of coronal pulpotomy in teeth with periapical radiolucency.<sup>34,35</sup> However, in the 4 cases presented, an increase in dentin thickness and root length elongation were observed after 18 months of follow-up.

The pulp capping material should create an artificial barrier between the vital pulp and the oral cavity to prevent the entry of microorganisms, be non-toxic to the pulp and have antimicrobial properties, and stimulate hard tissue regeneration. Due to its bioactive and biocompatible properties, MTA is a commonly used material with highly successful results.<sup>14,36</sup> Today, calcium silicate-containing bioceramic materials such as Biodentine and BioAggregate are also used in vital pulp treatments.<sup>37-39</sup> In our study, MTA, which is considered the gold standard, was used in all cases and successful results were obtained by determining that hard tissue regeneration occurred. It has been reporting that to evaluate the success of pulpotomy treatments, treated teeth should be followed up at 6 and 12 months postoperatively and then annually for four years if necessary.<sup>23</sup> All of the presented cases were followed up until the 18th month and no adverse findings were observed. However, long-term follow-up is still required to reveal late failures of VPT. When the study is evaluated in terms of its limitations, it is a case series conducted on 4 cases. Although the study results were successful, evidence-based clinical studies are needed.

## CONCLUSION

Within the restrictions of this case reports the 18-month follow-up results were found to be successful. According to these results, coronal pulpotomy treatment can be applied to symptomatic teeth in accordance with the minimally invasive dentistry approach.

## Ethical Approval

Since the present study did not use sources derived from humans or animals, ethics committee approval was not obtained.

## Financial Support

The authors declare that this study received no financial support.

## Conflict of Interest

The authors deny any conflicts of interest related to this study.

## Author Contributions

Design: MA, Data collection or data entry: MA, MB, Analysis and interpretation: MA, MB, Literature search: MA, Writing: MA.

## REFERENCES

1. Innes N, Frencken JE, Bjørndal L, Maltz M, Manton DJ, Ricketts D et al. Managing carious lesions: consensus recommendations on terminology. *Adv Dent Res.* 2016;28:49-57.
2. Careddu R and Duncan HF. A prospective clinical study investigating the effectiveness of partial pulpotomy after relating preoperative symptoms to a new and established classification of pulpitis. *Int Endod J.* 2021;54:2156-72.
3. Zhang W, and Yelick PC. Vital pulp therapy-current progress of dental pulp regeneration and revascularization. *Int J Dent.* 2010;856087.
4. Owatz CB, Khan AA, Schindler WG, Schwartz SA, Keiser K, and Hargreaves KM. The incidence of mechanical allodynia in patients with irreversible pulpitis. *J Endod.* 2007;33:552-6.
5. Chen E, and Abbott PV. Dental pulp testing: a review. *Int J Dent.* 2009;365785.
6. Baume LJ. Diagnosis of diseases of the pulp. *Oral Surg Oral Med, Oral Pathol.* 1970;29:102-16.
7. Dummer PMH, Hicks R, Huws D. Clinical signs and symptoms in pulp disease. *Int Endod J.* 1980;13:27-35.
8. Rechenberg DK, Zehnder M. Call for a review of diagnostic nomenclature and terminology used in endodontics. *Int Endod J.* 2020;53:1315-17.
9. Ricucci D, Siqueira Jr JF, Li Y, Tay FR. Vital pulp therapy: histopathology and histobacteriologybased guidelines to treat teeth with deep caries and pulp exposure. *J Dent.* 2019;86:41-52.

10. Wolters WJ, Duncan HF, Tomson PL, Karim IE, McKenna G, Dorri M et al. Minimally invasive endodontics: a new diagnostic system for assessing pulpitis and subsequent treatment needs. *Int Endod J.* 2017;50:825-9.
11. Bogen G, Dammaschke T, Chandler N. Vital pulp therapy. In: Berman L, Hargreaves KM, editors. *Pathways of the pulp.* 12th ed. St. Louis, MO: Elsevier; 2021. 902-38 p.
12. Lin LM, Ricucci D, Saoud TM, Sigurdsson A, Kahler, B. Vital pulp therapy of mature permanent teeth with irreversible pulpitis from the perspective of pulp biology. *Aust Endod J.* 2020;46:154-65.
13. Leong DJX, Yap AU. Vital pulp therapy in carious pulp-exposed permanent teeth: an umbrella review. *Clin Oral Investig.* 2021;25:6743-56.
14. Li Y, Sui B, Dahl C, Bergeron B, Shipman P, et al. Pulpotomy for carious pulp exposures in permanent teeth: A systematic review and meta-analysis. *J Dent.* 2019;84:1-8.
15. Camoni N, Cagetti MG, Cirio S, Esteves-Oliveira M, Campus G. Partial pulpotomy in young permanent teeth: A systematic review and meta-analysis. *Children.* 2023;10:1447.
16. El Meligy OA, Avery DR. Comparison of mineral trioxide aggregate and calcium hydroxide as pulpotomy agents in young permanent teeth (apexogenesis). *Pediatr Dent.* 2006;28:399-404.
17. Simon S, Perard M, Zanini M, Smith AJ, Charpentier E, et al. Should pulp chamber pulpotomy be seen as a permanent treatment? Some preliminary thoughts. *Int End J.* 2013;46:79-87.
18. Ghodduji J, Shahrami F, Alizadeh M, Kianoush K, Forghani M. Clinical and radiographic evaluation of vital pulp therapy in open apex teeth with MTA and ZOE. *N Y State Dent J.* 2012;78:34-8.
19. Alqaderi HE, Al-Mutawa SA, Qudeimat MA. MTA pulpotomy as an alternative to root canal treatment in children's permanent teeth in a dental public health setting. *J Dent.* 2014;42:1390-5.
20. Qudeimat MA, Alyahya A, Hasan AA, Barrieshi-Nusair KM. Mineral trioxide aggregate pulpotomy for permanent molars with clinical signs indicative of irreversible pulpitis: a preliminary study. *Int Endod J.* 2017;50:126-34.
21. Elmas S, Kotan DA, Odabaş ME. Two-year outcomes of coronal pulpotomy in young permanent molars with clinical signs indicative of irreversible pulpitis. *Pediatr Dent.* 2023;45:46-52.
22. Barngkgei IH, Halboub ES, Alboni RS. Pulpotomy of symptomatic permanent teeth with carious exposure using mineral trioxide aggregate. *Iran Endod J.* 2013;8:65-8.
23. Duncan H, Galler K, Tomson P, Simon S, El-Karim I, Kundzina R, et al. European Society of Endodontology position statement: Management of deep caries and the exposed pulp. *Int End J.* 2019;52:923-34.
24. American Association of Endodontists. AAE position statement on vital pulp therapy. Erişim tarihi: 01.06.2024, [https://www.aae.org/wp-content/uploads/2021/05/VitalPulpTherapyPositionStatement\\_v2.pdf](https://www.aae.org/wp-content/uploads/2021/05/VitalPulpTherapyPositionStatement_v2.pdf).
25. Mobarak A, Genena S, Zaazou A, Mokhless NA, Moussa SM. Regenerative pulpotomy as a novel technique for treatment of permanent mature molars diagnosed with irreversible pulpitis using platelet-rich fibrin: a case series study. *Alex Dent J.* 2021;46:129-35.
26. Ather A, Patel B, Gelfond JA, and Ruparel NB. Outcome of pulpotomy in permanent teeth with irreversible pulpitis: a systematic review and meta-analysis. *Sci Rep.* 2022;12:19664.
27. Aguilar P, Linsuwanont P. Vital pulp therapy in vital permanent teeth with cariously exposed pulp: A systematic review. *J Dent.* 2011;37:581-7.
28. Zanini M, Hennequin M, Cousson PY. A review of criteria for the evaluation of pulpotomy outcomes in mature permanent teeth. *J Endod.* 2016;42:1167-74.
29. Duncan HF, El-Karim I, Dummer PM, Whitworth J, Nagendrababu V. Factors that influence the outcome of pulpotomy in permanent teeth. *Int Endod J.* 2023;56:62-81.



30. Taha NA, Abdelkhader SZ. Outcome of full pulpotomy using Biodentine in adult patients with symptoms indicative of irreversible pulpitis. *Int Endod J.* 2018;8:819-28.
31. Galani M, Tewari S, Sangwan P, Mittal S, Kumar V, Duhan J. Comparative evaluation of postoperative pain and success rate after pulpotomy and root canal treatment in cariously exposed mature permanent molars: A randomized controlled trial. *J Endod.* 2017;43:1953-62.
32. Hafez AA, Cox CF, Tarim B, Otsuki M, Akimoto N. An in vivo evaluation of haemorrhage control using sodium hypochlorite and direct capping with a one-or two-component adhesive system in exposed nonhuman primate pulps. *Quintessence Int.* 2002;33:261-72.
33. Abella F, Patel S, Duran-Sindreu F, Mercadé M, Bueno R, Roig M. Evaluating the periapical status of teeth with irreversible pulpitis by using cone-beam computed tomography scanning and periapical radiographs. *J Endod.* 2012;38:1588-91.
34. Taha NA, and Abdulkhader SZ. Full pulpotomy with biodentine in symptomatic young permanent teeth with carious exposure. *J Endod.* 2018;44:932-7.
35. Qudeimat M, Alyahya A, Hasan A, and Barrieshi-Nusair K. Mineral trioxide aggregate pulpotomy for permanent molars with clinical signs indicative of irreversible pulpitis: a preliminary study. *Int Endod J.* 2017;50:126-34.
36. Chen Y, Chen X, Zhang Y, Zhou F, Deng J, et. all. Materials for pulpotomy in immature permanent teeth: a systematic review and meta-analysis. *BMC Oral Health.* 2019;19:227.
37. Parirokh M, Torabinejad M, Dummer PMH. Mineral trioxide aggregate and other bioactive endodontic cements: An updated overview - part I: Vital pulp therapy. *Int Endod J.* 2018;51:177-205.
38. Dawood AE, Parashos P, Wong RHK, Reynolds EC, Manton DJ. Calcium silicate-based cements: Composition, properties, and clinical applications. *J Investig Clin Dent.* 2017;8:e12195.
39. Cho SY, Seo DG, Lee SJ, Lee J, Lee SJ, Jung IY. Prognostic factors for clinical outcomes according to time after direct pulp capping. *J Endod.* 2013;39:327-31.