



ISSN Print: 2394-7489  
ISSN Online: 2394-7497  
IJADS 2022; 8(3): 325-330  
© 2022 IJADS  
[www.oraljournal.com](http://www.oraljournal.com)  
Received: 02-05-2022  
Accepted: 08-06-2022

**Heriberto Cardenas Dominguez**  
Master's in Sciences Student,  
Universidad Autonoma de Nuevo  
Leon, Facultad de Odontologia,  
Monterrey, Nuevo Leon, Mexico

**Fanny Lopez Martinez**  
Professor, Universidad Autonoma  
de Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo  
Leon, Mexico

**Idalia Rodriguez Delgado**  
Professor, Universidad Autonoma  
de Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo  
Leon, Mexico

**Luis Martin Vargas Zuñiga**  
Professor, Universidad Autónoma  
de Guerrero, Facultad de  
Odontología, Acapulco de Juárez  
de Guerrero, México

**Juan Manuel Luna Gomez**  
Professor, Universidad Autónoma  
de Guerrero, Facultad de  
Odontología, Acapulco de Juárez  
de Guerrero, México

**David Rafael Cortes Carrillo**  
Professor, Universidad Autonoma  
de Yucatan, Facultad de  
Odontologia, Merida, Yucatan,  
Mexico

**Celia Elena del Perpetuo Socorro  
Mendiburu Zavala**  
Professor, Universidad Autonoma  
de Yucatan, Facultad de  
Odontologia, Merida, Yucatan,  
Mexico

**Juan Manuel Solis Soto**  
Professor, Universidad Autonoma  
de Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo  
Leon, Mexico

**Corresponding Author:**  
**Heriberto Cardenas Dominguez**  
Master's in Sciences Student,  
Universidad Autonoma de Nuevo  
Leon, Facultad de Odontologia,  
Monterrey, Nuevo Leon, Mexico

## Pulp vital therapy as an alternative to endodontic treatment: A review of the literature

**Heriberto Cardenas Dominguez, Fanny Lopez Martinez, Idalia Rodriguez Delgado, Luis Martin Vargas Zuñiga, Juan Manuel Luna Gomez, David Rafael Cortes Carrillo, Celia Elena del Perpetuo Socorro Mendiburu Zavala and Juan Manuel Solis Soto**

DOI: <https://doi.org/10.22271/oral.2022.v8.i3d.1607>

### Abstract

**Introduction:** Preservation of pulp tissue can extend the long-term survival of teeth through relatively simple restorative procedures.

**Objective:** To analyze the literature on the success of indirect pulp capping in primary and permanent teeth, as well as direct pulp capping and partial and complete pulpotomy in mature and immature teeth.

**Methodology:** An electronic search was performed during January 2022 in the PubMed, SCOPUS and Google Scholar databases, using Boolean logical operators AND, OR and NOT. Human or *in vitro* comparative studies were included and evaluated, the keywords used were: "vital pulp therapy", "direct pulp capping", "indirect pulp capping", "primary teeth", "partial pulpotomy", "permanent", "mature" and "immature".

**Results:** An indirect pulp capping (IPC) will depend mainly on the size of the lesion and its time of evolution, TheraCal and Biodentine can be considered as the material of choice. A direct pulp capping (DPC) has a success rate between 80% to 90% and the materials used do not differ much from each other. Partial pulpotomy has a success rate between 85% and 95% and the most used material is MTA. Complete pulpotomy has a success ranging from 85% to 93%, with MTA and Biodentine being the most used materials.

**Conclusions:** IPC, as well as partial and complete pulpotomy, have high success rates both above 85%. The material of choice will be TheraCal for IPC, and MTA and Biodentine for partial and complete pulpotomy.

**Keywords:** Vital pulp therapy, direct pulp capping, indirect pulp capping, primary teeth, partial pulpotomy, permanent, mature and immature

### 1. Introduction

Preservation of pulp tissue can extend the long-term survival of teeth through relatively simple restorative procedures [1].

Treatment with procedures aimed at maintaining the vitality of all or part of the carious or exposed pulp have not been favored by most clinicians until recently [2]. Traditionally, treatment of deep caries was destructive with complete removal of all decayed dentin, but if treated conservatively, pulp recovery occurs even in deep carious lesions [3].

Vital pulp therapy (VPT) techniques are means of preserving the vitality and function of the dental pulp after injury resulting from trauma, caries or restorative procedures. VPT procedures have traditionally included indirect or direct pulp capping and partial or complete pulpotomy [4]. It is commonly performed in the primary dentition (also known as deciduous teeth), as the primary dentition has not fully developed the apical root and is less commonly performed in the secondary dentition [5]. Vital pulp therapy is a reliable treatment option for permanent teeth with carious pulp exposure. However, more high-quality studies are required to corroborate this finding [6].

The indirect pulp capping (IPC) procedure is generally used in deep cavity preparations, with or without carious dentin that is in close proximity to the pulp but shows no visible pulp exposure.

Direct pulp capping (DPC) treatment is used when vital asymptomatic pulp is visibly exposed due to caries or trauma, or due to a mishap during tooth preparation or caries removal [7].

Current endodontics seeks to be more conservative and must be very punctual in removing only the damaged tissue. Vital pulp treatment considers the dental pulp as the main tissue of the tooth and seeks to preserve its vitality. It is best to keep the pulp inside the canals, since removing it completely reduces the life span of the tooth.

The aim of this article is to analyze the literature on the success of indirect pulp capping in primary and permanent teeth, as well as direct pulp capping and partial and complete pulpotomy in mature and immature teeth.

## 2. Materials and methods

Articles on the subject published through the PubMed, SCOPUS and Google Scholar databases were analyzed, with emphasis on the last 5 years. The quality of the articles was evaluated using PRISMA guidelines, i.e., identification, review, choice and inclusion. The quality of the reviews was assessed using the measurement tool for evaluating systematic reviews (AMSTAR-2) [8]. The search was performed using Boolean logical operators AND, OR and NOT. It was realized with the words “pulp capping” related with “partial pulpotomy”, “complete pulpotomy”, “indirect pulp capping”, “direct pulp capping”. The keywords were used individually, as well as each of them related to each other.

## 3. Results & Discussion

### 3.1 Indirect Pulp Capping (IPC)

IPC is described as a procedure in which non-mineralizable carious tissue is removed, a thin layer of healthy or slightly softened dentin is left in the deepest site of the cavity to prevent pulp exposure. The caries-affected dentin is coated with a biocompatible material to create a biological seal [9].

#### 3.1.1 Permanent teeth

In the first instance, the article reported that the success rate of IPC and DPC was 99.4% and 84.6%, respectively. The median survival for DPC and IPC was  $14.07 \pm 1.30$  and  $15.98 \pm 0.80$  months, respectively [10]. Another article mentions that after 16 months, 95.83% of cases of teeth treated with biodentine showed successful results both clinically and radiographically. In another group, 87.5% of cases of teeth treated with chlorhexidine gluconate and 2% followed by resin-modified glass ionomer cement (RMGIC) showed successful results. Finally, 91.66% of the cases of teeth treated with calcium hydroxide showed successful results [11]. Similarly, the success rate of stepwise caries excavation was 97.3%, which was found to be significantly higher than IPC, with 82.4% [12]. A long-term study showed that at the end of 24 months, 54 teeth were submitted for follow-up with an overall success rate of 100% for TheraCal, 94.44% for Biodentine and 77.78% for Dycal [13]. Finally, at 24 months, 15 teeth used in this study had failed to maintain vitality (6 Biodentine™, 9 Fuji IX™). The clinical success rate of IPC for both materials was 72% and is related to the intensity of reversible pulpitis symptoms [14].

#### 3.1.2 Primary teeth

It is shown that indirect pulp capping exhibited high clinical and radiographic success rates in the treatment of primary teeth, regardless of the pulp capping agent chosen [9]. A study with one year of case evolution showed that after 12 months,

the clinical and radiographic success of the group using biodentine was 100% (18/18), with chlorhexidine gluconate disinfectant solution was 2%, followed by RMGIC which was 94.4% (17/18) and calcium hydroxide (Dycal) was 94.4% (17/18). Failures included: one at 3 months with RMGIC, and one at 12 months with the calcium hydroxide group [15]. Most primary teeth treated with either approach remained asymptomatic after a follow-up period of up to 77 months, 95.3% in the conventional and 95.8% in the biological [16].

### 3.1.3 Materials

It is necessary to consider which materials can be used for this treatment considering their success rates. ProRoot MTA, TheraCal LC and Dycal were very similar to each other. There was no statistically significant difference between primary and permanent teeth, so any of the three can be considered as a material for IPC [17]. TheraCal is considered as a new light-curing pulp capping material that initially releases high Ca<sup>2+</sup> ions and creates an ambient pH close to physiological pH after 60 days [18]. Cases with follow-up periods of 24 months show clinical and radiographic success rates of Dycal, Biodentine and TheraCal LC with high percentages [9]. There are also favorable results for other lesser-known materials such as ENDOCEM-Zr®, which together with MTA had high success rates and, in comparison between them did not have statistically significant differences [19]. This study highlights the success of IPC in young permanent molars and Biodentine is identified as the best choice of IPC material [11]. Biodentine can be used effectively as an indirect drug for pulp protection in primary teeth and has similar clinical and radiographic success to 2% chlorhexidine gluconate in conjunction with RMGIC and calcium hydroxide (CH) [15]. The clinical and radiographic results of TheraCal and Biodentine suggest their use as an alternative material for IPC in young permanent molars with greater success [13]. Finally, Biodentine and MTA showed a comparable result in terms of their internal adaptation on the dentin surface of primary teeth, and both were better than TheraCal [20].

This treatment has high success rates (over 90%), however, it will depend mainly on the size of the lesion being treated and its time of evolution, beyond the material of choice. It is emphasized that TheraCal and Biodentine can be considered as the material of choice. However, almost any of the materials used in the studies had high success rates.

### 3.2 Direct Pulp Capping (DPC)

Direct pulp capping (DPC) therapy consists of using biomaterials to protect the exposed tissues, inducing repair through the production of a mineralized barrier [21].

In general, this treatment in mature teeth usually depends on the material used, as the study mentions that the success rate using calcium hydroxide was 74% at 6 months, 65% at 1 year, 59% at 2 or 3 years, and 56% at 4 or 5 years. The success of mineral trioxide aggregate (MTA) was 91%, 86%, 84% and 81% at the same time points, similar to the success of Biodentine which was 96% at 6 months, 86% at 1 year and 86% at 2 to 3 years [22]. MTA and Biodentine show the advantage that they can induce dentin regeneration when applied on exposed pulp [23]. The success rate of novel treatments was 75% using lasers [24]. Other studies demonstrate what is mentioned above, that it is a material-independent treatment, as the article evidences that there was reparative dentin bridge formation after 9-12 weeks in all experimental teeth, both in the patient's real teeth and in the

extracted teeth [25]. Similarly, another article demonstrates that there were no significant differences between the cements CEM, MTA and Biodentine in terms of dentin bridge formation. However, the thickness of the dentin bridge formed in the Biodentine group was significantly greater than in the MTA and control groups ( $p= 0.035$  and  $p= 0.011$ , respectively) [26]. Finally, active cell proliferation is manifested, which occurred in 1 week in the MTA and CH groups, followed by differentiation of odontoblast-like cells in 2 weeks in the MTA group, while their differentiation was not facilitated in the CH group [27].

This procedure has a success rate ranging from 80% to 90% and the materials used do not differ much from each other in terms of these rates. Therefore, it cannot be considered as a procedure that can serve as a long-term treatment, however, as an emergency treatment it may be a possibility.

### 3.3 Partial Pulpotomy

Partial pulpotomy involves removal of 2 to 3 mm of the inflamed coronal pulp below the exposure, followed by placement of an appropriate agent over the remaining coronal pulp and a restoration that provides a watertight seal [28].

#### 3.3.1 Mature teeth

MTA is better than calcium hydroxide in terms of clinical symptoms of irreversible pulpitis after 2 years [28]. George R shows a study where cases were followed up for 6 to 24 months. Pooled data indicated that partial pulpotomy on exposed carious teeth had a success rate of 98%, 96% and 92% after 6 months and 1 and 2 years of follow-up [29]. Overall success was considered in one study where the results were 90%: with 92% for ProRoot MTA and 87% for Biodentine [30]. Another long-term study showed that at the end of the follow-up period (12 months), the success of complete pulpotomy in the occlusal and proximal caries group was 95% and 92.5%, respectively ( $p = 0.644$ ) [31]. Finally, the overall success rate in maintaining pulp vitality in this study was 89.1%, with a tooth survival of 98.4% [32].

#### 3.3.2 Immature teeth

Now in immature teeth, partial pulpotomy treatments showed a high overall success rate of 87% in one article [33]. The use of different materials for this procedure showed no intergroup differences in survival rate, survival time, root length and dentin wall thickness [34]. Using laser + MTA had a success rate of 95.5% being similar to using MTA alone with 88.8% [35]. The success rates of the primary interventions for 99 teeth (72 patients) after a median follow-up of 22 months were as follows: cervical pulpotomy 90.4% and partial pulpotomy 85.2% [36]. And finally, the overall success rate in the acemannan and MTA groups from baseline to 12 months follow-up was 90.91% and 95.65%, respectively, with no significant differences between the two groups [37].

The success rates are quite high, ranging between 85% and 95%. The material most used and appearing in the studies is MTA. For immature teeth, achieving apical closure is important and is included as part of clinical success. In mature teeth, it is mainly a matter of the patient being asymptomatic but responding to pulp sensitivity tests in a normal way.

### 3.4 Complete Pulpotomy

The objective of permanent pulpotomy is to remove the portion of the pulp that has suffered degenerative and irreversible damage leaving healthy tissue, after achieving hemostasis, ultimately preserving the vitality of the pulp [38].

#### 3.4.1 Mature teeth

Young permanent teeth with caries exposure can be successfully treated with complete pulpotomy using Biodentine, and clinical signs and symptoms of irreversible pulpitis are not a contraindication [39]. One article shows that clinical signs disappeared rapidly after treatment and at two years follow-up, the teeth were asymptomatic [40]. Parts with carious pulp exposures in asymptomatic mature permanent teeth can be predictably treated by pulpotomy using a tricalcium silicate cement [41]. Another study shows results first at 6 months with an overall success rate of 92.2%, and during 1 year 156/164 teeth attended follow-up with 12 failures (2 restorative failures and 10 endodontic failures). The overall pulpotomy success rate at 1 year was 92.3% (144/156) [42]. Finally, the revision rate ranged from 90% at 3 months to 85% at 1 year, with an overall clinical and radiographic success rate of 100% at 3 and 6 months, and a success rate of 95% at 1 year [43].

#### 3.4.2 Immature teeth

A study using MTA and Biodentine showed that there were no significant statistical differences in the radiographic results, both showing continuous root development and a higher prevalence of the H stage of root formation in both groups [44]. Using MTA and Biodentine gives a mean survival time of 17.8 and 18 months with 95% confidence interval (17.4-18.2) and 18.0-18.0 months, respectively [45]. The overall success rate in another study where 12-month follow-up was given was 92% (23/25), with no statistically significant differences between the 2 groups, where successful cases showed root development with an increase in root length and a decrease in apical foramen width [46]. At 12 months in a study using novel materials, complete apical closure was found between the MM-MTA group with 50%, the nanohydroxyapatite group with 55%, and the platelet-rich fibrin group with 60%. Some pulp canal obliteration was shown, which was observed mostly in the MM-MTA and nano-hydroxyapatite groups than in the PRF group [47]. A rather interesting clinical case used combined treatment with VPT and endodontic regeneration for immature molars with different pulp status in individual roots, being a preferable treatment option because it allows preservation of vital pulp tissues and regeneration of new vital tissues allowing continued root development and functionality [48].

#### 3.4.3 Materials

The long-term effect of direct pulp capping and pulpotomy is closely related to the type of pulp capping materials [49]. Calcium silicate materials can induce reparative dentinogenesis when applied on exposed pulps, with different behaviors in relation to the animal model used, pulpal inflammatory responses and the quality of dentin bridges [50]. The literature review on bioceramic materials will provide a better understanding of the properties of Biodentine and may assist in the decision-making process to maintain the vitality of exposed dental pulp with minimal intervention [51]. The clinical characteristics and effectiveness of pulpotomy on mature permanent teeth with iRoot bioceramic putty repair were similar with MTA [52]. Similarly, the novel fast-setting calcium silicate cement is a promising new biomaterial for vital pulp therapy in immature permanent molars that allows complete root formation with apexogenesis [53]. There are other materials such as melatonin, which has a similar effect on the pulp as MTA and can be used as an agent for direct pulp capping [54]. A treated dentin matrix hydrogel has a

greater potential to induce dentin bridging than Biodentine and MTA under standardized conditions<sup>[55]</sup>.

The success rates are very similar to those of the partial, (85% and 93%) with MTA and Biodentine being the most used materials. Similar to a partial pulpotomy, part of the success will consist of obtaining apical closure in immature teeth and that patients are asymptomatic and respond normally to pulp sensitivity tests.

#### 4. Conclusions

IPC treatment, as well as partial and complete pulpotomy, have high success rates, both above 85%. The material of choice will be TheraCal for IPC, and MTA and Biodentine for partial and complete pulpotomy.

#### References

1. Yong D, Cathro P. Conservative pulp therapy in the management of reversible and irreversible pulpitis. *Aust Dent J.* 2021 Mar;66 Suppl 1:S4-S14.
2. Ricucci D, Siqueira JF Jr, Li Y, Tay FR. Vital pulp therapy: histopathology and histobacteriology-based guidelines to treat teeth with deep caries and pulp exposure. *J Dent.* 2019 Jul;86:41-52.
3. Bjørndal L, Simon S, Tomson PL, Duncan HF. Management of deep caries and the exposed pulp. *Int Endod J.* 2019 Jul;52(7):949-973.
4. AAE Position Statement on Vital Pulp Therapy. *J Endod.* 2021 Sep;47(9):1340-1344.
5. Wells C, Dulong C, McCormack S. Vital Pulp Therapy for Endodontic Treatment of Mature Teeth: A Review of Clinical Effectiveness, Cost-Effectiveness, and Guidelines [Internet]. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health; 2019 Jul 10. PMID: 31525010.
6. Leong DJX, Yap AU. Vital pulp therapy in carious pulp-exposed permanent teeth: an umbrella review. *Clin Oral Investig.* 2021 Dec;25(12):6743-6756.
7. Kunert M, Lukomska-Szymanska M. Bio-Inductive Materials in Direct and Indirect Pulp Capping-A Review Article. *Materials (Basel).* 2020 Mar 7;13(5):1204.
8. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, *et al.* AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ.* 2017;358:j4008.
9. Sahin N, Saygili S, Akcay M. Clinical, radiographic, and histological evaluation of three different pulp-capping materials in indirect pulp treatment of primary teeth: a randomized clinical trial. *Clin Oral Investig.* 2021 Jun;25(6):3945-3955.
10. Llena C, Hernández M, Melo M, Sanz JL, Forner L. Follow-up of patients subjected to direct and indirect pulp capping of young permanent teeth. A retrospective study. *Clin Exp Dent Res.* 2021 Aug;7(4):429-435.
11. Kaul S, Kumar A, Jasrotia A, Gorkha K, Kumari S, Jeri SY. Comparative Analysis of Biodentine, Calcium Hydroxide, and 2% Chlorhexidine with Resin-modified Glass Ionomer Cement as Indirect Pulp Capping Materials in Young Permanent Molars. *J Contemp Dent Pract.* 2021 May 1;22(5):511-516.
12. Manhas S, Pandit IK, Gugnani N, Gupta M. Comparative Evaluation of the Efficacy of Stepwise Caries Excavation vs Indirect Pulp Capping in Preserving the Vitality of Deep Carious Lesions in Permanent Teeth of Pediatric Patients: An *In Vivo* Study. *Int J Clin Pediatr Dent.* 2020;13(Suppl 1):S92-S97.
13. Rahman B, Goswami M. Comparative Evaluation of Indirect Pulp Therapy in Young Permanent Teeth using Biodentine and TheraCal: A Randomized Clinical Trial. *J Clin Pediatr Dent.* 2021 Jul 1;45(3):158-164.
14. Hashem D, Mannocci F, Patel S, Manoharan A, Watson TF, Banerjee A. Evaluation of the efficacy of calcium silicate vs. glass ionomer cement indirect pulp capping and restoration assessment criteria: a randomised controlled clinical trial-2-year results. *Clin Oral Investig.* 2019 Apr;23(4):1931-1939.
15. Boddeda KR, Rani CR, V Vanga NR, Chandrabhatla SK. Comparative evaluation of biodentine, 2% chlorhexidine with RMGIC and calcium hydroxide as indirect pulp capping materials in primary molars: An *in vivo* study. *J Indian Soc Pedod Prev Dent.* 2019 Jan-Mar;37(1):60-66.
16. BaniHani A, Duggal M, Toumba J, Deery C. Outcomes of the conventional and biological treatment approaches for the management of caries in the primary dentition. *Int J Paediatr Dent.* 2018 Jan;28(1):12-22.
17. Gurcan AT, Seymen F. Clinical and radiographic evaluation of indirect pulp capping with three different materials: a 2-year follow-up study. *Eur J Paediatr Dent.* 2019 Jun;20(2):105-110.
18. Beegum MSF, George S, Anandaraj S, Sumi Issac J, Khan SN, Ali Habibullah M. Comparative evaluation of diffused calcium and hydroxyl ion release from three different Indirect pulp capping agents in permanent teeth - An *in vitro* study. *Saudi Dent J.* 2021 Dec;33(8):1149-1153.
19. Sharma A, Thomas MS, Shetty N, Srikant N. Evaluation of indirect pulp capping using pozzolan-based cement (ENDOCEM-Zr®) and mineral trioxide aggregate - A randomized controlled trial. *J Conserv Dent.* 2020 Mar-Apr;23(2):152-157.
20. Al Tuwirqi AA, El Ashiry EA, Alzahrani AY, Bamashmous N, Bakhsh TA. Tomographic Evaluation of the Internal Adaptation for Recent Calcium Silicate-Based Pulp Capping Materials in Primary Teeth. *Biomed Res Int.* 2021 May 8;2021:5523145.
21. Paula AB, Laranjo M, Marto CM, Paulo S, Abrantes AM, Casalta-Lopes J, *et al.* Direct Pulp Capping: What is the Most Effective Therapy?-Systematic Review and Meta-Analysis. *J Evid Based Dent Pract.* 2018 Dec;18(4):298-314.
22. Cushley S, Duncan HF, Lappin MJ, Chua P, Elamin AD, Clarke M, *et al.* Efficacy of direct pulp capping for management of cariously exposed pulps in permanent teeth: a systematic review and meta-analysis. *Int Endod J.* 2021 Apr;54(4):556-571.
23. Nie E, Yu J, Jiang R, Liu X, Li X, Islam R, *et al.* Effectiveness of Direct Pulp Capping Bioactive Materials in Dentin Regeneration: A Systematic Review. *Materials (Basel).* 2021 Nov 11;14(22):6811.
24. Kermanshah H, Ranjbar Omrani L, Ghabraei S, Fekrazad R, Daneshparvar N, Bagheri P. Direct Pulp Capping With ProRoot MTA Alone and in Combination With Er:YAG Laser Irradiation: A Clinical Trial. *J Lasers Med Sci.* 2020 Fall;11(Suppl 1):S60-S66.
25. Bui AH, Pham KV. Evaluation of Reparative Dentine Bridge Formation after Direct Pulp Capping with Biodentine. *J Int Soc Prev Community Dent.* 2021 Jan 30;11(1):77-82.
26. Hoseinifar R, Eskandarizadeh A, Parirokh M, Torabi M, Safarian F, Rahmanian E. Histological Evaluation of Human Pulp Response to Direct Pulp Capping with

- MTA, CEM Cement, and Biodentine. *J Dent (Shiraz)*. 2020 Sep;21(3):177-183.
27. Xu D, Mutoh N, Ohshima H, Tani-Ishii N. The effect of mineral trioxide aggregate on dental pulp healing in the infected pulp by direct pulp capping. *Dent Mater J*. 2021 Dec 1;40(6):1373-1379.
  28. Taha NA, Khazali MA. Partial Pulpotomy in Mature Permanent Teeth with Clinical Signs Indicative of Irreversible Pulpitis: A Randomized Clinical Trial. *J Endod*. 2017 Sep;43(9):1417-1421.
  29. George R. Is partial pulpotomy in cariously exposed posterior permanent teeth a viable treatment option? *Evid Based Dent*. 2020 Sep;21(3):112-113.
  30. Uesrichai N, Nirunsittirat A, Chuveera P, Srisuwan T, Sastraruji T, Chompu-Inwai P. Partial pulpotomy with two bioactive cements in permanent teeth of 6- to 18-year-old patients with signs and symptoms indicative of irreversible pulpitis: a noninferiority randomized controlled trial. *Int Endod J*. 2019 Jun;52(6):749-759.
  31. R R, Aravind A, Kumar V, Sharma S, Chawla A, Logani A. Influence of occlusal and proximal caries on the outcome of full pulpotomy in permanent mandibular molar teeth with partial irreversible pulpitis: A prospective study. *Int Endod J*. 2021 Oct;54(10):1699-1707.
  32. Eggmann F, Gasser TJW, Hecker H, Amato M, Weiger R, Zaugg LK. Partial pulpotomy without age restriction: a retrospective assessment of permanent teeth with carious pulp exposure. *Clin Oral Investig*. 2022 Jan;26(1):365-373.
  33. Uyar DS, Alacam A. Evaluation of partial pulpotomy treatment in cariously exposed immature permanent molars: Randomized controlled trial. *Niger J Clin Pract*. 2021 Oct;24(10):1511-1519.
  34. Yang Y, Xia B, Xu Z, Dou G, Lei Y, Yong W. The effect of partial pulpotomy with iRoot BP Plus in traumatized immature permanent teeth: A randomized prospective controlled trial. *Dent Traumatol*. 2020 Oct;36(5):518-525.
  35. Tozar KN, Erkmén Almaz M. Evaluation of the Efficacy of Erbium, Chromium-doped Yttrium, Scandium, Gallium, and Garnet Laser in Partial Pulpotomy in Permanent Immature Molars: A Randomized Controlled Trial. *J Endod*. 2020 May;46(5):575-583.
  36. Shahmohammadi R, Sheikhezami M, Moradi S, Jafarzadeh H, Azarpazhooh A. Treatment Outcomes of Permanent Immature Teeth with Crown Fracture: A Retrospective Cohort Study. *J Endod*. 2021 Nov;47(11):1715-1723.
  37. Vu TT, Nguyen MT, Sangvanich P, Nguyen QN, Thunyakitpisal P. Acemannan Used as an Implantable Biomaterial for Vital Pulp Therapy of Immature Permanent Teeth Induced Continued Root Formation. *Pharmaceutics*. 2020 Jul 8;12(7):644.
  38. Zafar K, Nazeer MR, Ghafoor R, Khan FR. Success of pulpotomy in mature permanent teeth with irreversible pulpitis: A systematic review. *J Conserv Dent*. 2020 Mar-Apr;23(2):121-125.
  39. Taha NA, Abdulkhader SZ. Full Pulpotomy with Biodentine in Symptomatic Young Permanent Teeth with Carious Exposure. *J Endod*. 2018 Jun;44(6):932-937.
  40. Tran XV, Ngo LTQ, Boukpepsi T. Biodentine TM Full Pulpotomy in Mature Permanent Teeth with Irreversible Pulpitis and Apical Periodontitis. *Healthcare (Basel)*. 2021 Jun 12;9(6):720.
  41. Tan SY, Yu VSH, Lim KC, Tan BCK, Neo CLJ, Shen L, *et al*. Long-term Pulpal and Restorative Outcomes of Pulpotomy in Mature Permanent Teeth. *J Endod*. 2020 Mar;46(3):383-390.
  42. Taha NA, Al-Rawash MH, Imran ZA. Outcome of full pulpotomy in mature permanent molars using 3 calcium silicate-based materials: A parallel, double blind, randomized controlled trial. *Int Endod J*. 2022 May;55(5):416-429.
  43. Hussain MI, Bashar AM. Outcome of Mineral Trioxide Aggregate Pulpotomy for Mature Permanent Molars with Symptoms Indicative of Irreversible Pulpitis. *Mymensingh Med J*. 2022 Jan;31(1):223-229.
  44. Abuelniel GM, Duggal MS, Kabel N. A comparison of MTA and Biodentine as medicaments for pulpotomy in traumatized anterior immature permanent teeth: A randomized clinical trial. *Dent Traumatol*. 2020 Aug;36(4):400-410.
  45. Abuelniel GM, Duggal MS, Duggal S, Kabel NR. Evaluation of Mineral Trioxide Aggregate and Biodentine as pulpotomy agents in immature first permanent molars with carious pulp exposure: A randomised clinical trial. *Eur J Paediatr Dent*. 2021;22(1):19-25.
  46. Ahmed MI, El Hilaly Mohamed Eid G, Youssef HA. Clinical and Radiographic Assessments of Potassium Nitrate in Polycarboxylate Versus Mineral Trioxide Aggregate as Pulpotomy Biomaterials in Immature Mandibular First Permanent Molars: A Randomized Clinical Trial. *J Endod*. 2021 Nov;47(11):1672-1682.
  47. Eid A, Mancino D, Rekab MS, Haikel Y, Kharouf N. Effectiveness of Three Agents in Pulpotomy Treatment of Permanent Molars with Incomplete Root Development: A Randomized Controlled Trial. *Healthcare (Basel)*. 2022 Feb 25;10(3):431.
  48. Lee S, Park YT, Setzer FC. Combined Regenerative and Vital Pulp Therapies in an Immature Mandibular Molar: A Case Report. *J Endod*. 2020 Aug;46(8):1085-1090.
  49. Fan ML, He LB, Li JY. [Recent advances in direct pulp capping materials]. *Hua Xi Kou Qiang Yi Xue Za Zhi*. 2018 Dec 1;36(6):675-680. Chinese.
  50. Andrei M, Vacaru RP, Coricovac A, Ilinca R, Didilescu AC, Demetrescu I. The Effect of Calcium-Silicate Cements on Reparative Dentinogenesis Following Direct Pulp Capping on Animal Models. *Molecules*. 2021 May 6;26(9):2725.
  51. Arandi NZ, Thabet M. Minimal Intervention in Dentistry: A Literature Review on Biodentine as a Bioactive Pulp Capping Material. *Biomed Res Int*. 2021 Apr 3;2021:5569313.
  52. Qian K, Pan J, Zhu WH, Zhao XY, Liu C, Yong W. [Evaluation of bioceramic putty repairmen iRoot and mineral trioxide aggregate in mature permanent teeth pulpotomy]. *Beijing Da Xue Xue Bao Yi Xue Ban*. 2022 Feb 18;54(1):113-118. Chinese.
  53. Vafaei A, Nikookhesal M, Erfanparast L, Løvschall H, Ranjkesh B. Vital pulp therapy following pulpotomy in immature first permanent molars with deep caries using novel fast-setting calcium silicate cement: A retrospective clinical study. *J Dent*. 2022 Jan;116:103890.
  54. Guerrero-Gironés J, Alcaina-Lorente A, Ortiz-Ruiz C, Ortiz-Ruiz E, Pecci-Lloret MP, Rodríguez-Lozano FJ, *et al*. Melatonin as an Agent for Direct Pulp-Capping Treatment. *Int J Environ Res Public Health*. 2020 Feb 6;17(3):1043.

55. Holiel AA, Mahmoud EM, Abdel-Fattah WM. Tomographic evaluation of direct pulp capping using a novel injectable treated dentin matrix hydrogel: a 2-year randomized controlled clinical trial. Clin Oral Investig. 2021 Jul;25(7):4621-4634.