Vital Pulp Therapy in Permanent Teeth

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**ABSTRACT**

This review article aimed to evaluate the outcome of vital pulp therapy procedures including indirect pulp capping (IDPC), direct pulp capping (DPC), miniature pulpotomy (MP), partial pulpotomy (PP) and full pulpotomy (FP) in permanent teeth even with signs of reversible and irreversible pulpitis. Instead of complete pulp tissue removal by pulpectomy, vital pulp therapy has been considered as an alternative approach. Articles published after 2000 were searched in PubMed and GoogleScholar online databases according to PRISMA guidelines. Forty articles were selected according to the inclusion and exclusion criteria. Eighty-five cases from case series and case report studies and also results of 20 clinical articles were included in this study. The success rate of partial and full pulpotomy in permanent teeth with signs of reversible and irreversible pulpitis was 98.8%. The success rate for both partial and full pulpotomies with mineral trioxide aggregate and calcium silicate-based cements in the current review of clinical studies was 84.6%-100% and 78.9%-100%. Partial and full pulpotomies demonstrated favourable outcomes and a high success rate in treating permanent teeth. So the vital pulp therapy procedures in permanent teeth with signs of pulpitis can be more successful, cost-effective and time-saving compared to traditional root canal treatment. However further well-designed studies with longer follow-up periods are required to validate these findings.

***Keywords***: Vital pulp therapy, Pulpotomy, Partial pulpotomy, Permanent teeth, Irreversible pulpitis

**INTRODUCTION**

Dental caries is an infectious disease and the most common cause of pulpal inflammation (Kumar et al., 2020). Pulpitis caused by caries is the main reason for root canal treatment. Instead of complete pulp tissue removal by pulpectomy, vital pulp therapy has been considered as an alternative approach (Linsuwanont et al., 2017). As a minimally-invasive approach, vital pulp therapy includes stepwise excavation of decayed tissues, direct/indirect pulp capping, partial/full pulpotomy and partial pulpectomy (Asgary et al., 2021). Direct pulp capping (DPC) involves treatment of the vital pulp exposure by sealing the pulpal wound by directly placing a biomaterial on the exposed pulp to facilitate the formation of reparative dentin and maintain the vitality of the pulp (Asgary et al., 2014). Miniature pulpotomy (MP) was defined as the procedure with gentle/limited removal of the infected dentin chips/damaged pulp tissue specially the injured odontoblast cell layer after direct exposure of the pulp tissue that would not exceed 1 mm (Asgary et al., 2014). Partial pulpotomy is the surgical removal of a small portion of the coronal pulp tissue to preserve the remaining coronal and radicular pulp (Asgary et al., 2014). Pulpotomy procedures include removal of the coronal pulp with inflammation, which is under exposure. This is followed by inserting a particular material in addition to a restoration (Hakami et al., 2020). The aim of vital pulp therapy techniques is to seal the pulp wound, induced odontoblast-like cell differentiation and stimulate dentin secretion and mineralization (Mousavi et al., 2016). Recent studies have suggested vital pulp therapy as a realistic treatment modality for pulp exposure with supposed irreversible pulpitis. They have recommended vital pulp therapy as a biological, conservative, economic and simple method with a favourable prognosis (Asgary et al, 2013). Materials used as a pulp protecting agent should be biocompatible, be able to induce hard tissue formation, bactericidal, create a long-lasting biological seal and It should maintain pulp vitality (Grosman, 2021; Nosrat et al., 2013). In many studies materials such as mineral trioxide aggregate (MTA), calcium silicate-based cements (biodentine, bioaggrigate, calcium-enriched cements) and even platelet concentrate (PRF) are recommended to use in vital pulp therapy (Grosman, 2021; Ghani & Noorani, 2021).

**MATERIAL AND METHODS**

This review of the literature was performed in compliance with the PRISMA guidelines for systematic review. Data was collected from electronic databases such as PubMed and Google scholar. Searching terms include “Vital pulp therapy”, “Pulpotomy”, “Partial pulpotomy”, “Permanent teeth”, “pulpitis” connected by a Boolean operator “AND” (e.g., PubMed search strategy: “Vital pulp therapy” AND “Pulpitis” AND “Permanent teeth”). Three textbooks were hand searched. All the titles as well as abstracts that appeared from this search, were reviewed. Specific inclusion criteria and exclusion criteria that were used to select the studies for review are mentioned in table 1.

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| Table 1. inclusion and exclusion criteria used to select studies for review | |
| Inclusion criteria | Exclusion criteria |
| Human clinical study  Procedures performed in permanent teeth  Pulp exposures and diagnosis of reversible and irreversible pulpitis  Procedures include DPC, MP, PP or FP  Full-text available  Systematic review  Clinical trials  Case reports  Case series  Cohort study | Poor data reported  Studies did not used human teeth  Procedures performed in deciduous teeth  Non-specific data reported  Narrative review  Other procedures such as apexification and apexogenesis  Unavailability of full-text article  Studies were about material used in vital pulp therapy |

When the title and abstracts were considered relevant the full-text of the article was reviewed. Full-text of eligible articles were also evaluated to ensure the article contents were relevant. All information about each case from case series and case report studies were collected and recorded in IBM SPSS. The study characteristics (year of publication), participant characteristics (age, gender, type of tooth, condition of tooth prior to treatment, pulpal and apical diagnosis), treatment (type of vital pulp therapy, materials and follow-up periods), and the outcomes (success rates) were collected from the article.

**RESULTS**

The search process resulted in a total of 309 articles. After a preliminary screening of the titles and abstracts, 193 irrelevant articles and 6 duplicates articles were excluded. The articles in which their full-text was available (61 articles) were collected and printed. Finally, after studying full-text of 40 articles were recorded according to the inclusion and exclusion criteria (Figure 1).

According to table 2: a total of 85 cases, 55.3% of which were women, were collected from case series and case report studies and the cases data were recorded in SPSS software. In 81.2% of cases, there was irreversible pulpitis and in other cases there was reversible inflammation of the pulp. In terms of diagnosis of periapical status, 42.4% had symptomatic apical periodontitis and 28.2% had also radiolucency and apical lesions. In 89.4% of cases, a full pulpotomy procedure was performed that in 71.8% MTA was used as vital pulp therapy material. Finally, the success rate of studying the total of these cases was 98.8%.

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| Figure 1. Flow chart of the search strategy and steps of this review based on PRISMA guidelines |
| PubMed (171)  Googlescholar (137)  Book (1)  Papers included  (40)  Full text articles assessed for eligibility (61)  Identification  Screening  Eligibility  Included  Records after duplicates removal (110)  Total papers screened (309)  Records excluded based on title and abstracts (193)  Exclusions (21)  Poor data reported=8  Studies did not used human teeth=2  Procedures performed in deciduous teeth=7  Non specific data reported=4  Records excluded based on title and abstracts  N=193  Exclusions (21)   * Poor data reported=8 * Studies did not used human teeth=2 * Procedures performed in deciduous teeth=7 * Non specific data reported=4 |

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| Table 2. Cases recorded from case report and case series studies | | | | | | | | | | | | | |
| **Number** | **Gender** | **Age** | **Tooth** | **Condition of tooth** | **Pulpal diagnosis** | **Apical diagnosis** | **RAD (pre-apical changes)** | **Fallow-up (Min)** | **Treatment** | **Material** | **Bleeding stoppage time** | **Result** | **Reference** |
| 1 | Male | 39 | 46 | Carious | Irreversible pulpitis | None | No | 18 | FP | MTA | 2 | Failed | (Yousef et al.) |
| 2 | Female | 19 | 36 | Carious | Irreversible pulpitis | None | No | 18 | FP | MTA | 0 | Success | (Dr.Anil Munavalli, 2018) |
| 3 | Female | 35 | 46 | Carious | Reversible pulpitis | None | No | 6 | FP | MTA | 10 | Success | (C Nandha Kumar, 2018) |
| 4 | Female | 28 | 36 | Carious | Reversible pulpitis | None | No | 6 | FP | MTA | 10 | Success | (C Nandha Kumar, 2018) |
| 5 | Female | 41 | 36 | Carious | Reversible pulpitis | None | No | 6 | FP | MTA | 10 | Success | (C Nandha Kumar, 2018) |
| 6 | Male | 14 | 47 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 0 | Success | (Shahnaz et al.) |
| 7 | Female | 37 | 44 | Carious | Reversible pulpitis | None | No | 18 | FP | MTA | 4 | Success | (Bakar, 2020) |
| 8 | Female | 37 | 45 | Carious | Irreversible pulpitis | None | No | 18 | FP | MTA | 4 | Success | (Bakar, 2020) |
| 9 | Female | 9 | 36 | Carious | Irreversible pulpitis | AAP | Yes | 60 | PP | Biodentine | 4 | Success | (Chinadet et al., 2019) |
| 10 | Female | 24 | 37 | Carious | Irreversible pulpitis | None | Yes | 15 | MP | CEM | 0 | Success | (Ramazani & Asgary, 2018) |
| 11 | Female | 38 | 37 | Carious | Irreversible pulpitis | SAP | Yes | 18 | MP | CEM | 3 | Success | (Asgary et al., 2016) |
| 12 | Male | 40 | 36 | Carious | Irreversible pulpitis | SAP | No | 18 | MP | CEM | 0 | Success | (Asgary et al., 2016) |
| 13 | Female | 9 | 36 | Carious | Irreversible pulpitis | None | Yes | 17 | FP | CEM | 1 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 14 | Female | 10 | 46 | Carious | Irreversible pulpitis | SAP | Yes | 17 | FP | CEM | 1 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 15 | Female | 14 | 46 | Carious | Irreversible pulpitis | SAP | No | 17 | FP | CEM | 2 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 16 | Male | 11 | 16 | Carious | Irreversible pulpitis | SAP | Yes | 16 | FP | CEM | 3 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 17 | Male | 15 | 36 | Carious | Irreversible pulpitis | SAP | Yes | 16 | FP | CEM | 1 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 18 | Male | 13 | 36 | Carious | Irreversible pulpitis | SAP | Yes | 17 | FP | CEM | 8 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 19 | Female | 12 | 26 | Carious | Irreversible pulpitis | SAP | No | 16 | FP | CEM | 10 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 20 | Female | 13 | 36 | Carious | Irreversible pulpitis | SAP | No | 17 | FP | CEM | 12 | Success | (M. E.-S. Sharaan & Abo Elsoud, 2017) |
| 21 | Female | 20 | 46 | Carious | Reversible pulpitis | None | Yes | 28 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 22 | Female | 20 | 45 | Carious | Reversible pulpitis | None | No | 24 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 23 | Male | 23 | 44 | Carious | Reversible pulpitis | None | No | 24 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 24 | Male | 17 | 24 | Carious | Reversible pulpitis | None | No | 26 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 25 | Male | 17 | 25 | Carious | Reversible pulpitis | None | No | 28 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 26 | Male | 26 | 28 | Carious | Reversible pulpitis | None | No | 30 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 27 | Male | 26 | 16 | Carious | Reversible pulpitis | None | No | 24 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 28 | Female | 54 | 31 | Carious | Reversible pulpitis | None | No | 26 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 29 | Female | 38 | 34 | Carious | Reversible pulpitis | None | No | 42 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 30 | Female | 42 | 36 | Carious | Reversible pulpitis | None | No | 42 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 31 | Female | 24 | 37 | Carious | Reversible pulpitis | None | No | 42 | FP | MTA | 5 | Success | (Barngkgei et al., 2013) |
| 32 | Female | 9 | 36 | Carious | Irreversible pulpitis | SAP | No | 24 | FP | MTA | 20 | Success | (Qudeimat et al., 2017) |
| 33 | Female | 10 | 46 | Carious | Irreversible pulpitis | SAP | Yes | 67 | FP | MTA | 17 | Success | (Qudeimat et al., 2017) |
| 34 | Male | 8 | 26 | Carious | Irreversible pulpitis | SAP | No | 60 | FP | MTA | 7 | Success | (Qudeimat et al., 2017) |
| 35 | Female | 9 | 26 | Carious | Irreversible pulpitis | SAP | No | 73 | FP | MTA | 5 | Success | (Qudeimat et al., 2017) |
| 36 | Male | 11 | 46 | Carious | Irreversible pulpitis | SAP | Yes | 72 | FP | MTA | 20 | Success | (Qudeimat et al., 2017) |
| 37 | Male | 11 | 36 | Carious | Irreversible pulpitis | SAP | Yes | 72 | FP | MTA | 20 | Success | (Qudeimat et al., 2017) |
| 38 | Female | 9 | 16 | Restored | Irreversible pulpitis | None | No | 68 | FP | MTA | 5 | Success | (Qudeimat et al., 2017) |
| 39 | Female | 12 | 36 | Restored | Irreversible pulpitis | SAP | No | 63 | FP | MTA | 15 | Success | (Qudeimat et al., 2017) |
| 40 | Male | 11 | 46 | Carious | Irreversible pulpitis | SAP | Yes | 19 | FP | MTA | 15 | Success | (Qudeimat et al., 2017) |
| 41 | Male | 9 | 36 | Carious | Irreversible pulpitis | SAP | No | 68 | FP | MTA | 22 | Success | (Qudeimat et al., 2017) |
| 42 | Male | 11 | 36 | Restored | Irreversible pulpitis | SAP | No | 61 | FP | MTA | 15 | Success | (Qudeimat et al., 2017) |
| 43 | Male | 11 | 16 | Carious | Irreversible pulpitis | AAP | Yes | 61 | FP | MTA | 5 | Success | (Qudeimat et al., 2017) |
| 44 | Male | 11 | 36 | Carious | Irreversible pulpitis | SAP | No | 67 | FP | MTA | 21 | Success | (Qudeimat et al., 2017) |
| 45 | Male | 10 | 36 | Carious | Irreversible pulpitis | SAP | No | 60 | FP | MTA | 20 | Success | (Qudeimat et al., 2017) |
| 46 | Male | 10 | 26 | Carious | Irreversible pulpitis | None | No | 60 | FP | MTA | 5 | Success | (Qudeimat et al., 2017) |
| 46 | Male | 10 | 16 | Carious | Irreversible pulpitis | None | No | 60 | FP | MTA | 5 | Success | (Qudeimat et al., 2017) |
| 48 | Female | 8 | 36 | Carious | Irreversible pulpitis | SAP | No | 56 | FP | MTA | 15 | Success | (Qudeimat et al., 2017) |
| 49 | Female | 13 | 26 | Carious | Irreversible pulpitis | SAP | Yes | 56 | FP | MTA | 24 | Success | (Qudeimat et al., 2017) |
| 50 | Female | 13 | 37 | Carious | Irreversible pulpitis | SAP | Yes | 55 | FP | MTA | 17 | Success | (Qudeimat et al., 2017) |
| 51 | Female | 13 | 47 | Carious | Irreversible pulpitis | SAP | No | 55 | FP | MTA | 22 | Success | (Qudeimat et al., 2017) |
| 52 | Female | 13 | 46 | Carious | Irreversible pulpitis | None | No | 55 | FP | MTA | 10 | Success | (Qudeimat et al., 2017) |
| 53 | Female | 7 | 46 | Carious | Irreversible pulpitis | SAP | No | 51 | FP | MTA | 25 | Success | (Qudeimat et al., 2017) |
| 54 | Male | 11 | 26 | Carious | Irreversible pulpitis | SAP | No | 37 | FP | MTA | 25 | Success | (Qudeimat et al., 2017) |
| 55 | Male | 12 | 46 | Carious | Irreversible pulpitis | None | No | 18 | FP | Biodentine | 5 | Success | (Soni, 2016) |
| 56 | Male | 36 | 14 | Carious | Irreversible pulpitis | None | No | 24 | FP | CEM | 5 | Success | (Asgary et al., 2018) |
| 57 | Male | 36 | 15 | Carious | Irreversible pulpitis | None | No | 24 | FP | CEM | 5 | Success | (Asgary et al., 2018) |
| 58 | Female | 8 | 19 | Carious | Irreversible pulpitis | SAP | Yes | 18 | PP | Biodentine | 0 | Success | (Ashraf et al., 2017) |
| 59 | Male | 8 | 9 | Carious | Irreversible pulpitis | None | No | 36 | FP | CEM | 0 | Success | (Ashraf et al., 2017) |
| 60 | Male | 35 | 36 | Carious | Irreversible pulpitis | AAP | Yes | 6 | FP | CEM | 3 | Success | (Asgary & Kemal Çalışkan, 2015) |
| 61 | Female | 40 | 45 | Carious | Irreversible pulpitis | SAP | Yes | 12 | FP | Biodentine | 2 | Success | (Tran et al., 2021) |
| 61 | Female | 25 | 36 | Carious | Irreversible pulpitis | SAP | Yes | 24 | FP | Biodentine | 0 | Success | (Tran et al., 2021) |
| 63 | Male | 13 | 46 | Carious | Irreversible pulpitis | SAP | No | 18 | FP | MTA | 2 | Success | (M. Sharaan & Ali, 2019) |
| 64 | Male | 13 | 16 | Carious | Irreversible pulpitis | None | No | 20 | FP | MTA | 1 | Success | (M. Sharaan & Ali, 2019) |
| 65 | Female | 11 | 26 | Carious | Irreversible pulpitis | None | No | 23 | FP | MTA | 2 | Success | (M. Sharaan & Ali, 2019) |
| 66 | Female | 11 | 46 | Carious | Irreversible pulpitis | None | No | 23 | FP | MTA | 2 | Success | (M. Sharaan & Ali, 2019) |
| 67 | Female | 8 | 36 | Carious | Irreversible pulpitis | SAP | Yes | 12 | FP | MTA | 2 | Success | (M. Sharaan & Ali, 2019) |
| 68 | Male | 8 | 36 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 1 | Success | (M. Sharaan & Ali, 2019) |
| 69 | Male | 13 | 46 | Carious | Irreversible pulpitis | None | No | 16 | FP | MTA | 1 | Success | (M. Sharaan & Ali, 2019) |
| 70 | Male | 8 | 16 | Carious | Irreversible pulpitis | SAP | No | 16 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 71 | Female | 9 | 46 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 72 | Female | 13 | 46 | Carious | Irreversible pulpitis | None | No | 18 | FP | MTA | 12 | Success | (M. Sharaan & Ali, 2019) |
| 73 | Male | 9 | 36 | Carious | Irreversible pulpitis | None | Yes | 12 | FP | MTA | 10 | Success | (M. Sharaan & Ali, 2019) |
| 74 | Male | 12 | 46 | Carious | Irreversible pulpitis | SAP | Yes | 12 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 75 | Male | 12 | 26 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 10 | Success | (M. Sharaan & Ali, 2019) |
| 76 | Female | 10 | 46 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 77 | Male | 11 | 16 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 78 | Female | 8 | 26 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 79 | Female | 10 | 26 | Carious | Irreversible pulpitis | None | No | 12 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 80 | Male | 10 | 36 | Carious | Irreversible pulpitis | SAP | Yes | 18 | FP | MTA | 5 | Success | (M. Sharaan & Ali, 2019) |
| 81 | Female | 9 | 46 | Carious | Irreversible pulpitis | None | No | 0 | FP | MTA | 10 | Failed | (M. Sharaan & Ali, 2019) |
| 82 | Female | 50 | 47 | Carious | Reversible pulpitis | None | No | 26 | PP | Biodentine | 5 | Success | (Owittayakul & Chuveera, 2016) |
| 83 | Female | 22 | 25 | Carious | Irreversible pulpitis | SAP | No | 12 | PP | Biodentine | 5 | Success | (Owittayakul & Chuveera, 2016) |
| 84 | Female | 37 | 14 | Carious | Irreversible pulpitis | None | No | 12 | PP | Biodentine | 0 | Success | (Owittayakul & Chuveera, 2016) |
| 85 | Female | 37 | 36 | Carious | Irreversible pulpitis | None | No | 12 | PP | Biodentine | 0 | Success | (Owittayakul & Chuveera, 2016) |

MP-miniature pulpotomy; PP-partial pulpotomy; FP-full pulpotomy; AAP-asymptomatic apical periodontitis; SAP-symptomatic apical periodontitis; MTA-mineral trioxide aggregate; CEM-calcium enriched cements.

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| Table 3. Success rate of vital pulp therapy in permanent teeth | | | | | | | | |
| **Number** | **Articles** | **Age range**  **Age mean** | **Sample size** | **Diagnosis** | **Treatment** | **Material** | **Fallow-up (Month)** | **Success rate** |
| 1 | (Aravind et al., 2022) | 16-35  25.9±4.6 | 120 | Symptomatic irreversible pulpitis  Response to vitality tests | FP | WMTA | 12 | 94.7 |
| 2 | (Linsuwanont et al., 2017) | 7-68  29 | 55 | Signs of irreversible pulpitis=45.5%  Pain to percussion=43%  Presence of radiolucency=38% | FP | MTA | 62 | 87.3 |
| 3 | (Asgary et al., 2021) | 10-60 | 147 | Curiously exposed pulp including Irreversible pulpitis cases | RCT  FP | MTA  CEM | 24 | RCT=98%  PMTA=100%  PCEM=97.9% |
| 4 | (Mousavi et al., 2016) | 18-30  24 | 40 | Intact teeth of orthodontic patients | DPC  MP | Dexamethasone+MTA | 2 | 100 |
| 5 | (Guan et al., 2021) | 6-20  11.75 | 57 | Irreversible pulpitis | DPC  PP  FP | iRoot BP+ | 36 | DPC=94.4%  PP=90.9%  FP=84.6%  Total=91.2% |
| 6 | (Asgary et al., 2013) | - | 167 | Irreversible pulpitis | VPT  RCT | CEM | 12 | VPT clinical= 97.6%  VPT radiographic=92.2%  RCT clinical=98.3%  RCT radiographic=70.3% |
| 7 | (Uyar & Alacam, 2021) | 6-13  - | 54 | Asymptomatic vital pulp | PP | CH  MTA  Biodentine | 12 | CH=72.2%  MTA=94.4%  biodentine=94.4%  total=87% |
| 8 | (Asgary et al., 2014) | -  31.7 | 94 | Irreversible pulpitis | IDPC  DPC  MP  FP | CEM | 12 | IDPC=100%  DPC=96.4%  MP=100%  FP=100%  Total=98.9% |
| 10 | (Verma et al., 2016) | 10-16 | 8 | Irreversible pulpitis | FP | MTA | 12 | 100 |
| 11 | (Kumar et al., 2020) | 22-47  30.9±7.3 | 60 | symptomatic vital pulp | FP | Biodentine  MTA | 1.5 | biodentine=82.1  MTA=75.9  total=78.9 |
| 12 | (Taha & Abdelkhader, 2018) | 19-69  33.2 |  | Irreversible pulpitis  Apical rarefaction was present in 9 teeth | FP | Biodentine | 12 | Clinical=100%  Radiographic=98.4% |
| 13 | (Suhag et al., 2019) | 15-40 | 64 | Reversible pulpitis | PP | MTA  CH | 12 | MTA=93%  CH=69% |
| 14 | (Linu et al., 2017) | 15-30 | 26 | Reversible pulpitis | PP | MTA  Biodentine | 18 | MTA=84.6%  Biodentine=92.3% |
| 15 | (Uesrichai et al., 2019) | 6-17 | 67 | Irreversible pulpitis | PP | MTA  Biodentine | 69 | MTA=92%  Biodentine=87% |
| 16 | (Taha et al., 2017) | 20-52 | 46 | Irreversible pulpitis | PP | MTA  CH | 24 | MTA=85%  CH=43% |
| 17 | (Asgary et al., 2018) | 26.8±7.6 | 76 | Irreversible pulpitis | PP | CEM | 12 | 91.4% |
| 18 | (M. Sharaan & Ali, 2019) | 9-13 | 12 | Symptomatic and asymptomatic irreversible pulpitis | FP | MTA | 12 | 100% |
| 19 | (Qudeimat et al., 2017) | 7-13 | 13 | Irreversible pulpitis and symptomatic apical periodontitis | FP | MTA | 24 | 100% |
| 20 | (Taha et al., 2017) | 10-59 | 52 | Caries exposure (8 reversible pulpitis, 44 irreversible pulpitis, 14 apical periodontitis) | FP | MTA | 24 | 92.7% |

IDPC-indirect pulp capping; DPC-direct pulp capping; MP-miniature pulpotomy; PP-partial pulpotomy; FP-full pulpotomy; MTA-mineral trioxide aggregate; CH-calcium hydroxide; CEM-calcium enriched cements

**DISCUSSION**

Endodontology is postponing or avoiding non-biological treatment and descending down the restorative spiral, which would significantly reduce the long-term prognosis for tooth retention and function (Verma et al., 2016). Through reviewing medical literature in the past decade, it is revealed that pulpotomy is a minimally-invasive strategy that is cost-effective and has better clinical as well as radiological outcomes compared to other conventional methods (Hakami et al., 2020).

This review aimed to evaluate the clinical and radiographic success rates of vital pulp therapy in permanent teeth which had the signs of reversible and irreversible pulpitis and some of the cases with preapical changes using different pulp capping medicaments. The evidence from the present review of case series and case report studies indicates 98.8% success rate and suggests that permanent teeth diagnosed with irreversible pulpitis can also be effectively treated by vital pulp therapy procedures, including miniature pulpotomy, partial pulpotomy and full pulpotomy which is in agreement with the main finding of a previously-published review that focused mainly on coronal and partial pulpotomy studies (Santos & Pereira, 2021). A pulpotomy is a widely-used technique to treat this type of pulpitis (Hakami et al., 2020). The present review also studied the success rate of vital pulp therapy procedures as an indication to treat permanent teeth with pulpitis.

The success rate for both partial and full pulpotomies with mineral trioxide aggregate and calcium silicate-based cements in the current review was within the range of 84.6%-100% and 78.9%-100%. This suggests that permanent teeth with reversible and irreversible pulpitis can be treated successfully with both coronal and partial pulpotomies, as compared to root canal therapy, which was reported to have a mean success rate of 74.7% (Ghani & Noorani, 2021).

In clinical trials by Asghary et al in 2013 and 2021, the result of clinical and radiologic success rate indicated that vital pulp therapy outcomes can be better than root canal treatment even in teeth with signs of irreversible pulpitis. Asghary et al in 2013 and 2021 Therefore, vital pulp therapy procedures could be a successful alternative treatment modality for root canal treatment (M. E.-S. Sharaan & Abo Elsoud, 2017).

According to the outcome of radiologic high success rate in cases with preapical lesions and other clinical studies, this review shows the repair of preapical radiolucency after vital pulp therapy procedures. Also, some studies noticed radiolucency resolution in addition to complete hard tissue bridge after starting the vital pulp therapy by one year (M. E.-S. Sharaan & Abo Elsoud, 2017).

Material selection is an important factor for successful vital pulp therapy. The results in this review showed a lower success rate in cases which were treated with calcium hydroxide (range=43%-72.2%). This finding is in accordance with a recently randomized controlled trail study that found vital pulp therapy for cariously exposed pulps treated with calcium hydroxide has shown poor outcomes (Uyar & Alacam, 2021). In this review, the success rate ranges of mineral trioxide aggregate, biodentine and calcium-enriched cement were 75.9%-100%, 82.1%-100% and 91.4%-98.9%. the use of these materials in vital pulp therapy indicates better results than traditionally used material calcium hydroxide (Nosrat et al., 2013; Witherspoon, 2008). Mineral trioxide aggregate has a greater long-term sealing ability and stimulates a high quality and a great amount of reparative dentine. In clinical outcomes evaluation, it has demonstrated a high success rate (Witherspoon, 2008).

The coronal seal of the permanent restoration to avoid any bacterial penetration is another important parameter for a long-term success rate of vital pulp therapy. Aa Some researchers affirmed that the coronal seal is more significant than the agent placed in pulpotomy (M. E.-S. Sharaan & Abo Elsoud, 2017).

**CONCLUSION**

The success rate of vital pulp therapy in 85 permanent teeth in which 81.2% with irreversible pulpitis and in other cases there was reversible pulpitis, was 98.8%. Also, the study of 20 researches showed favourable outcomes of partial and full pulpotomy performed in permanent teeth. So, the vital pulp therapy procedures in permanent teeth even with signs of pulpitis can be more successful, cost-effective and time-saving compared to traditional root canal treatment but further well-designed studies with longer follow-up periods are required to validate these findings.

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