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# Evaluation of Postoperative Pain Following Adult Pulpotomy in Symptomatic Irreversible Pulpitis using MTA, Bioceramic Material, and Nanohydroxyapetite

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## ABSTRACT

**Introduction:** Adult pulpotomy is a novel approach for the management of symptomatic irreversible pulpitis in mature permanent teeth. The type of pulp-capping agent significantly influences postoperative pain and pulpal healing. This study evaluated postoperative pain following adult pulpotomy in diabetic patients using three different pulp capping materials: mineral tri-oxide aggregate (MTA), bioceramic putty, and a newly introduced nanohydroxyapatite (nHA) material.

**Methods:** Thirty diabetic patients diagnosed with symptomatic irreversible pulpitis in vital teeth were randomly allocated into three equal groups (n = 10) according to the pulp capping material used: Group I – MTA (ProRoot, Dentsply, USA); Group II – Bioceramic putty (NeoPutty, Avalon Biomed, USA); and Group III – Nanohydroxyapatite (Sigma-Aldrich, USA). Standardized pulpotomy procedures were performed under local anesthesia and rubber dam isolation. Postoperative pain was recorded using a Visual Analogue Scale (VAS) at 24, then 48, and 72 hours. Data were analyzed using Friedman, Wilcoxon, Kruskal–Wallis, and Mann–Whitney tests at a significance level of $p \leq 0.05$.

**Results:** All groups showed a statistically significant reduction in pain intensity over time ($p = 0.002$). At each time interval, significant differences were found among materials ($p \leq 0.005$). while, Nanohydroxyapatite exhibited the lowest mean VAS scores at all intervals, followed by bioceramic and MTA. After 72 hours, the mean VAS scores were $2.00 \pm 0.00$ (MTA), $1.00 \pm 0.89$ (bioceramic), and $0.33 \pm 0.52$ (nHA).

**Conclusion:** Under the conditions of this study, all tested materials effectively reduced postoperative pain following adult pulpotomy in diabetic patients with symptomatic irreversible pulpitis. Nanohydroxyapatite demonstrated the lowest pain levels and may represent a promising bioactive alternative for vital pulp therapy in medically compromised patients.

**KEYWORDS**: vital pulp therapy, adult pulpotomy, postoperative pain, nanohydroxyapatite, bioceramic, MTA, diabetic patients.

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## INTRODUCTION

Dental caries is the most common oral disease and it has the greatest prevalence in the population of all ages and socioeconomic classes throughout the world. [1] The severity of dental caries and pulpal treatment varies between patients; however, the restorative phase is usually the most disturbing for the patients. [2,3] With the growing emphasis on a minimal intervention approach in both caries management and pulpal treatments, the concepts of caries treatment have been shifted towards selective and minimally invasive removal of carious lesions. [4]

First, the prominent manifestation faced by clinicians is teeth with advanced caries on the verge of reaching the pulp chamber. One of the most debated treatment areas is vital pulp therapy. VTP is a set of procedures to protect the vitality and integrity of the pulp and facilitate its healing after mechanical injury through trauma, dental caries, or over-filling. VTP designs are indirect and direct pulp capping, partial and full pulpotomy. [5] For a long period, vital pulp therapy was the domain of immature permanent teeth because the main goal was achieving complete root formation. Lately, the mechanism of VTP has been extended, and it is accepted as an alternative to the irreversible condition of pulpitis in permanent teeth. Currently, the American Association of Endodontists (AAE) categorizes the vital pulp into three classifications: "normal," "reversible pulpitis," or "irreversible pulpitis". Irreversible pulpitis is defined as a "clinical diagnosis based on subjective and objective findings that indicate the vital pulp is inflamed and unable to heal. [6]

Controlled diabetics manifest radiographic healing comparable to those non-diabetic patients after 12 to 24 months. [7] However, uncontrolled diabetics undergo persistent periapical radiolucency or bone regeneration delay due to microvascular changes, an

impaired inflammatory response, downregulation of odontoblastic and fibroblastic activities, and decreased growth factor expression. [8]

Irreversible pulpitis is frequently cited as one of the most painful dental conditions, largely due to the extreme inflammation and infection of the dental pulp. The pain of irreversible pulpitis can be highly excruciating, constant, and almost impossible to control without the necessary treatment, such as a root canal. Though this pain is not usually considered number one under all diseases' ranking, it is still the most painful dental situation, particularly if not endodontically treated.

Until recently, the AAE has accepted pulpotomy as a potential treatment for these mature teeth with irreversible pulpitis, particularly in the context of deep caries and pulp exposure. Given the novelty of this approach, we believe it is crucial to assess and report the effectiveness of pulpotomy using different materials in treating mature permanent teeth with irreversible pulpitis. [9]

## MATERIALS AND METHODS:

**Ethical Approval and Study Design**

This in vivo clinical study was conducted at Dental Clinic of National Research Centre (NRC), Dokki, Egypt. This study was get approved by ethics committee, Faculty of Dentistry, Cairo University (Approval No.: 36/4/24). Written informed consents from all participants were obtained.

**Sample Selection**

Thirty patients requiring VPT were automatically randomized into three different groups (n=10) Group1: MTA, Group 2: Bioceramics, Group 3: nanohydroxyapetite. All the patients received identification codes before starting the treatment

**Criteria for Patient Selection**

This study focused on diabetic patients with irreversible pulpitis and had admitted to the dental department in a National Research Center between March 2022 and March 2023

**The inclusion criteria of the study were:**

Diabetic patients above 18 years have a vital molar tooth confirmed with pulp vitality testing and a history of irreversible pulpitis — patients who agreed and signed the informed consent.

**The exclusion criteria of the study were:**

- Non-vital necrotic teeth.
- Teeth with a background of trauma or immature teeth with open apices.
- Patients having other systemic conditions that interfered with the healing of tissue.
- Pregnant women.

The inclusion criteria of a tooth in the study were conformed to be clinically diagnosed as irreversible pulpitis according to the following: Spontaneous pain, night pain, persistent pain, or pain on biting and chewing after cold and heat stimulation. The sustained pain was provoked by clinical examination in the form of dental pulp thermal test. A radiograph examination of the apical peritubular dentin gap was normal or widened, or a small area low-density shadow was detected. To be included in the study, the tooth had to meet all the inclusion criteria mentioned and at least one criterion mentioned for irreversible pulpitis.

Each patient used a 0.2% chlorhexidine mouth rinse. The clinician conducting the pulpotomy has a work experience of more than ten years. Local anesthesia was administered around the diseased tooth by injecting 1:100,000 epinephrine hydrochloride and mepivacaine 20.00 mg/ml mepivacaine hydrochloride +0.01 mg/ml epinephrine. [10] Infiltration and inferior alveolar nerve block were used for anesthesia on the upper and lower teeth. Fast emery drill was employed to remove the surface enamel, slow-speed tungsten steel ball drill or spoon excavation removed caries dentin and exposed the pulp under rubber dam protection. The status of the pulp and bleeding were noted. A sterile high-speed diamond ball drill was used for partial or total coronal pulp removal. Partial or total pulpotomy was performed depending on the bleeding of the pulp after pulpotomy, if the bleeding could not be controlled after partial pulpotomy, deeper areas of the pulp would be removed. Sodium hypochlorite 2.5% was utilized for rinsing, and a sterile saline cotton ball placed on the pulp section for compression for 10 minutes. [10] After removing the cotton ball, the pulp section without active bleeding was considered to be with adequate hemostasis.

**The MTA group:** Following the manufacturer's instructions, pulp-covering agent MTA (ProRoot, Dentsply, US) was prepared one scoop of MTA powder with one drop of the sterile saline mixed until it reached a consistent mix, then was inserted into the pulp chamber. Mild pressure was allowed to adapt MTA over the exposed pulp, the biomaterial was gently adapted on the pulpal floor and the walls with a thickness of approximately 2–3 mm. A moistened cotton pellet was placed in the pulp chamber, and the cavity was permanently filled with Glass Ionomer fuji equia within the same session.

**The Bioceramic group**: Similar to previous procedure, teeth were anaesthetized and isolated, and pulpotomy was conducted. The pulp-capping neo-putty bioceramic material (Avalon BiomedInc., Bradenton, FL, USA) was applied into the pulp chamber, the biomaterial was gently adapted on the pulpal floor and the walls with a thickness of approximately 2–3 mm. After a 5-min placement of the moistened cotton pellet, the cavity was permanently filled with Glass Ionomer fuji equia within the same session.

**The Nanohydroxyapetite group:** The same steps were done after teeth were anesthetized and isolated, and pulpotomy was performed. The pulp-capping agent Nano-hydroxyapetite powder (Sigma-Aldrich, USA) was mixed with distlled water according to manufacturer's instructions, then inserted into the pulp chamber; the biomaterial was gently adapted on the pulpal floor and the walls with a thickness of approximately 2–3 mm. The cavity was permanently filled with Glass Ionomer fuji equia within the same session after the placement of a moistened cotton pellet for 5 min.

**Pain measurement:** A Visual Analogue Scale (VAS) was provided to all the patients to mark the intensity of their pain. Visual Analogue Scales (VAS) are used in clinical research to determine the intensity of subjective symptoms such as pain to have validity for assessment of pain intensity. VAS of a straight horizontal 10 cm line, with one end indicating no pain (0), and the other indicating the worst possible pain (10). The patients were asked to make a mark on the straight line to express the pain intensity they experienced. Each patient received a value between 0 and 10 on a VAS script to measure the pain, where 0 showed no pain, 1–3 mild pain, 4–6 moderate pain, 7–9 severe pain, and 10 worst possible pain. Patients were recalled at 24, 48 and 72 h to record pain levels they experienced on VAS forms.

## RESULTS:

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, pain data showed non-parametric (not-normal) distribution (Scores). Friedman was used to compare more than two groups in related samples. Wilcoxon was used to compare two groups in related samples. The Kruskal-Wallis test was used to compare more than two groups in non-related samples. The Mann-Whitney test was used to compare two groups in non-related samples. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

**I) Effect of time:**

a) MTA:

A statistically significant difference was found between (After 24hrs), (After 48hrs), and (After 72hrs), where (p=0.002). A statistically significant difference was found between (After 24hrs) and each of (After 48hrs) and (After 72hrs), where (p=0.023) and (p=0.023). Also, a statistically significant difference was found between (After 48hrs) and (After 72hrs), where (p=0.026). The highest mean score was found (After 24hrs), while the lowest mean score was found (After 72hrs).

b) Bioceramics:

A statistically significant difference was found between (After 24hrs), (After 48hrs) and (After 72hrs), where (p=0.002). A statistically significant difference was found between (After 24hrs) and each of (After 48hrs) and (After 72hrs), where (p=0.026) and (p=0.023). Also, a statistically significant difference was found between (After 48hrs) and (After 72hrs) where (p=0.023). The highest mean score was found (After 24hrs), while the lowest mean score was found (After 72hrs).

c) Nanohydroxyapetite:

A statistically significant difference was found between (After 24hrs), (After 48hrs), and (After 72hrs) where (p=0.002). A statistically significant difference was found between (After 24hrs) and each of (After 48hrs) and (After 72hrs) where (p=0.014) and (p=0.014). A statistically significant difference was found between (After 48hrs) and (After 72hrs) where (p=0.014). The highest mean score was found (After 24hrs), while the lowest mean score was found (After 72hrs).

**II) Effect of groups:**

a) After 24hrs:

There was a statistically significant difference between (MTA), (Bioceramics) and (Nanohydroxyapetite) where (p=0.001). A statistically significant difference was found between (MTA) and each of (Bioceramics) and (Nanohydroxyapetite), where (p=0.014) and (p=0.003). Also, a statistically significant difference was found between (Bioceramics) and (Nanohydroxyapetite), where (p=0.007). The highest mean score was found in (MTA), while the least mean value was found in (Nanohydroxyapatite).

b) After 48hrs:

There was a statistically significant difference between (MTA), (Bioceramics), and (Nanohydroxyapatite) where (p=0.001). A statistically significant difference was found between (MTA) and each of (Bioceramics) and (Nanohydroxyapetite) where (p=0.016) and (p=0.003). Also, a statistically significant difference was found between (Bioceramics) and (Nanohydroxyapatite) where (p=0.007). The highest mean score was found in (MTA), while the least mean value was found in (Nanohydroxyapatite).

c) After 72hrs:

There was a statistically significant difference between (MTA), (Bioceramics) and (Nanohydroxyapetite) where (p=0.005). A statistically significant difference was found between (MTA) and each of (Bioceramics) and (Nanohydroxyapetite) where (p=0.022) and (p=0.002). No statistically significant difference was found between (Bioceramics) and (Nanohydroxyapetite) where (p=0.162). The highest mean score was found in (MTA), while the least mean value was found in (Nanohydroxyapetite).

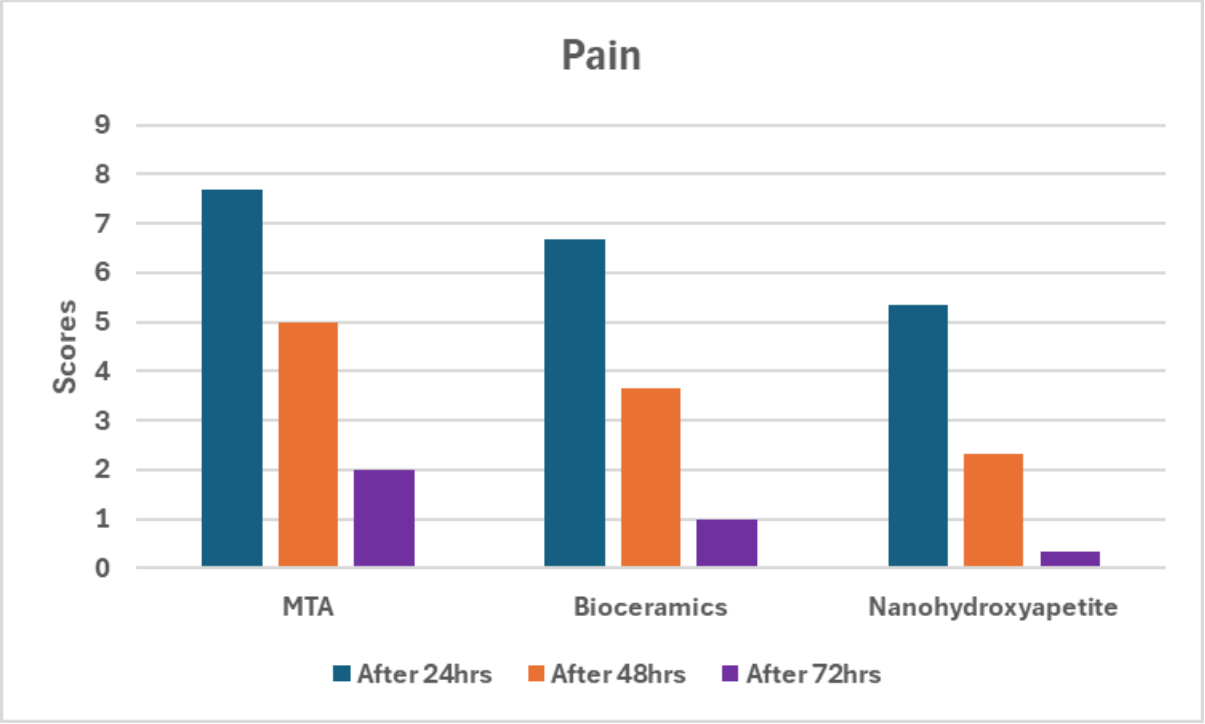
**Table (1): The mean, standard deviation (SD) values of Pain of different groups.**

| Variables | Pain |
|---|---|

| | MTA | | | | Bioceramics | | | | Nanohydroxyapetite | | | | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Median | Range | Mean | SD | Median | Range | Mean | SD | Median | Range | |
| After 24hrs | 7.67 $^{aA}$ | 0.52 | 8.00 | 1.00 | 6.67 $^{aB}$ | 0.52 | 7.00 | 1.00 | 5.33 $^{aC}$ | 0.52 | 5.00 | 1.00 | 0.001* |
| After 48hrs | 5.00 $^{bA}$ | 0.89 | 5.00 | 2.00 | 3.67 $^{bB}$ | 0.52 | 4.00 | 1.00 | 2.33 $^{bC}$ | 0.52 | 2.00 | 1.00 | 0.001* |
| After 72hrs | 2.00 $^{cA}$ | 0.00 | 2.00 | 0.00 | 1.00 $^{cB}$ | 0.89 | 1.00 | 2.00 | 0.33 $^{cB}$ | 0.52 | 0.00 | 1.00 | 0.005* |
| p-value | 0.002* | | | | 0.002* | | | | 0.002* | | | | |

*; significant ($p<0.05$)

Means with different small letters indicates significant difference in the same column, means with different capital letters indicates significant difference in the same row.



**(A)**
**(B)**

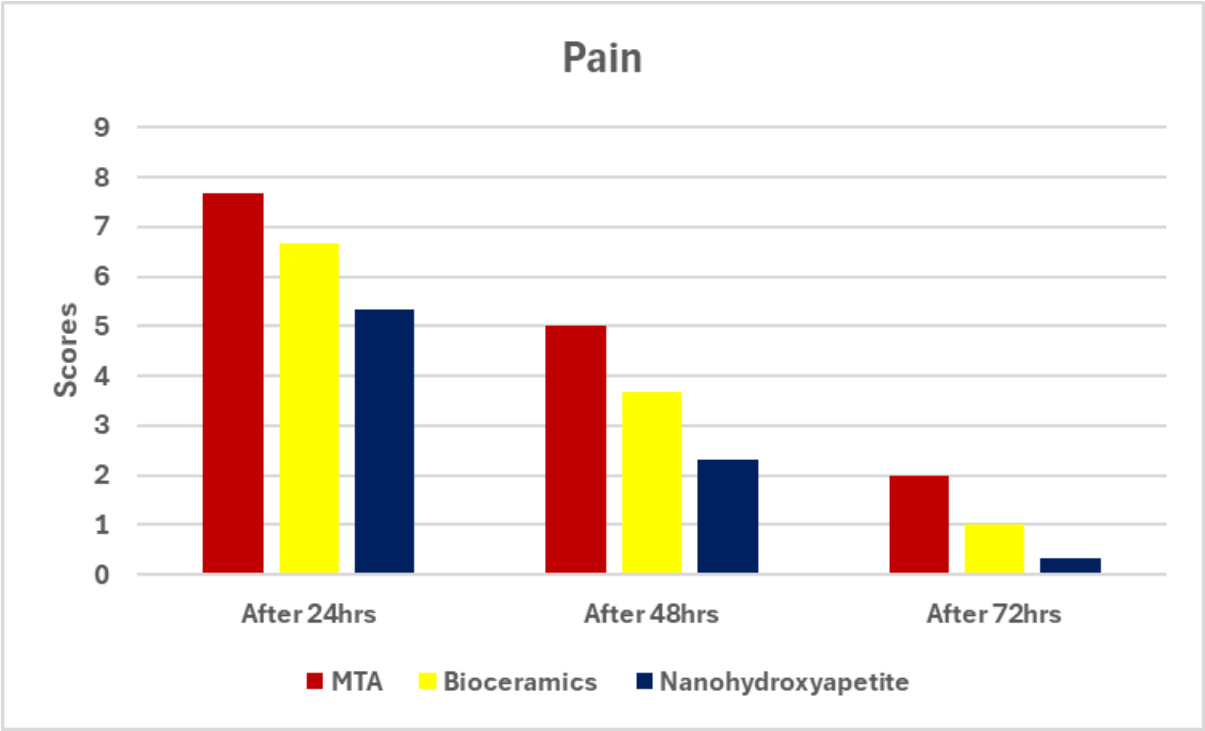



**Figure (1): Bar chart representing Pain for different groups**

## DISCUSSION

**Irreversible pulpitis & healing**

Lingering pain in a tooth is often associated with irreversible pulpitis, a condition where the pulp becomes severely inflamed and cannot heal on its own. However, it is essential to consider that the pain as a symptom of irreversible pulpitis may not denote the complete irreversible injury in the pulp. In some cases, the inflammation may be localized to the coronal pulp while the root pulp may not be affected.

In essence, it means that even though the patient experiences lingering pain, which is typically a sign of severe inflammation, the damage may not be uniform throughout the pulp. Thus, depending on the extent of coronal and radicular of pulpal damage. If the root pulp remains healthy or less damaged, more conservative treatments like pulpotomy (removal of the coronal pulp) may be possible, instead of a full root canal treatment, which involves removing the entire pulp. This distinction highlights the importance of accurate diagnosis and careful assessment of the pulp's condition by clinical examination and diagnostic vitality tests like thermal or electrical pulp testing. [11]

Many studies concerning the outcomes of coronal pulpotomy have focused on teeth with deep caries, without specifically including only those with symptoms of irreversible pulpitis. [12, 13] This article focused exclusively on diabetic patients with teeth exhibiting signs and symptoms of irreversible pulpitis. The clear inclusion and exclusion criteria enabled a targeted literature search, also accurate diagnosing pulpal conditions can be challenging due to the reliance on unreliable methods. Therefore, great care was taken to ensure that the included cases met the established criteria for clinically diagnosing irreversible pulpitis. [14]

The proper choice of the material for pulp capping substantially influences the efficiency of VPT. An optimum material for pulp capping should have high biocompatibility and potent anti-bacterial action and stimulate the development of reparative dentin. [15] Calcium hydroxide stayed the standard pulp capping material in human and veterinary dental preparation based on it is anti-bacterial, and its optimum pH of 12.5 induces 1.5-mm of pulp liquefaction necrosis. The healthy pulp counteracts the toxic effect of Calcium hydroxide and trigger an inflammatory response resulting in a hard tissue barrier, or “dentin bridge,” building between the pulp and Calcium hydroxide . Bacterial-secure restoration may be the most crucial factor impacting the performance of vital pulp therapy. [16]

MTA was selected to used in this study as it considered a golden standard for VPT. MTA induces reparative dentin formation through the adhesion, differentiation and activation of cells forming hard tissue barrier, and contribute to matrix formation and mineralization. [17] It can also solubilize the cytokines embedded in the surrounding dentine and separate growth factors in the extracellular matrix, thus stimulates reparative hard tissue formation. [18] MTA induced the migration of progenitor cells from the central pulp of injury called fibroblasts, proliferation of progenitor cells without cell apoptosis and differentiation into odontoblast-like cells. [19]

Regarding mechanical properties, MTA exhibit superior marginal adaptation, with high bond strength similar to glass ionomer cement, [20] Moreover, it creates a sticky interface layer during mineral nucleation on the surface of dentine, [21] promotes biocompatibility, non-cytotoxic, antibacterial environment and surface morphology that is favorable for the formation of reparative calcific bridge. [22] Although all that advantages, it has a delayed setting time, poor handling characteristics and high cost. [23]

With the moving back to nature, a paradigm shift from medicaments to natural remedies. Hydroxyapatite nanoparticles powder, [24] a synthetic version of the naturally occurring bone and tooth mineral hydroxyapatite, have a particle diameter of less than 200 nm as measured by the BET (Brunauer-Emmett-Teller) surface area method and therefore has more reactivity, surface area, and bioactivity in comparison to large size particles. The nanohydroxyapatite material benefits from complete synthesis, allowing optimal control of the end material products such as uniformity, and is used in various biomedical applications such as bone tissue engineering, drug delivery systems and dental implants and considerably larger areas are used as drug delivery. Its nanoscale size increases the material's interaction with biological tissue, resulting in improved cell adhesion and bone regeneration and enhances nanosized adhesion to the materials.

**Regarding the effect of time:**
The observed reduction in mean scores from 24 to 72 hours for MTA, bioceramics, and nanohydroxyapatite can be attributed to material-related physicochemical changes over time. [25-27] MTA and bioceramics undergo continuous hydration reactions, resulting in improved setting and marginal adaptation but reduced initial bioactivity. [22, 23] Similarly, nanohydroxyapatite exhibits time-dependent ionic release and surface interactions, [24] which initially stimulate cellular response but may plateau or decline as surface reactivity decreases. These temporal changes reflect the dynamic nature of these materials' interaction with the environment and surrounding tissues. These time-based changes indicate a dynamic relationship with the set of materials and their environment.

**Regarding the effect of groups:**
The effect of MTA across all time points with the highest pain level may be attributed to its robust calcium ion release, high alkalinity, and strong bioactivity that promote early tissue response and hard tissue formation. [23] Bioceramics, while similar in composition, often contains additives that slightly delay initial reactivity compared to MTA. [23] On the other hand, Nanohydroxyapatite, despite its excellent biocompatibility, has limited early biological activity due to slower dissolution and lower ion exchange rates, which may explain its consistently lower scores. [24] These differences reflect the intrinsic material properties and how they influence early biological interactions. [28,29]

**Regarding patient selection**: The high correlation of diabetes mellitus with the intensity and time span of postoperative pain following VPT found in this study can be explained by the pathophysiological effects of diabetes on the pulp and periapical tissues. Chronic hyperglycemia in diabetic patients is well known to cause microvascular changes, hypoxia, and a prolonged inflammatory response. These factors can retard tissue healing, allowing the nociceptive stimulus to continue. In addition, pro-inflammatory cytokine release, including interleukin-6 and tumor necrosis factor-alpha, is altered with diabetes, and the increased control and delayed resolution of the inflammatory response heighten pain perception. [30] There may be an increase in pain in the early phases of neuropathic shifts due to long-term hyperglycemia, which increases pain sensitivity in the early stages of nerve malfunction. As a result, diabetic individuals are prone to exhibit more intense or long-lasting postoperative pain after VPT, reflecting both their reduced healing capacity and the reorganized pain pathways. The healing prospects of VPT should be assessed in light of these findings with respect to systemic metabolism.

## CONCLUSION:

All three i.e., MTA, Bioceramic, and Nanohydroxyapatite were effective in relieving postoperative pain following adult pulpotomy in diabetic patients suffering from symptomatic irreversible pulpitis under the limits of the present study. However, Nanohydroxyapatite showed the lowest pain ratings at all study periods, which was the most convenient for the patients, and has the potential for clinical value as a pulpotomy bioactive material. More large-scale studies on the long-term effectiveness of NHAP are recommended.

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