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Assessment of Pulpine Mineral effect on root maturation for immature dog teeth with infected pulp.

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Abstract

Aim: The aim of the study was to assess the effect of pulpine mineral on root maturation for immature dog teeth with infected pulp and compare the results with Mineral Trioxide Aggregate (MTA).

Materials and methods: Sixty (60) permanent dog teeth from six mongrel dogs were selected. Dogs were randomly divided into 2 equal study groups (3 dogs/ group), according to the post-treatment evaluation period. Group one (1 month, n= 30 teeth), Group two (3 months, n= 30 teeth). Each main group was then subdivided according to the materials used into 4 experimental subgroups: Pulpine mineral, n=9, MTA group, n=9, Positive control group, n=6 and negative control group, n=6. Radiographic evaluation was performed to assess the increase in the root length.

Results: The results showed that after 1 month; the radiographic evaluation regarding root length revealed that the difference in root length between one month after treatment and the preoperative condition was recorded 9.94±5.19 mm in the pulpine mineral group while it was recorded 5.38±3.78 mm in the MTA group, the positive control group showed the least one in the change in the root length 1.00±1.87 mm, while the negative control group was 7.00±4.06 mm. After 3 months; results showed The difference in root length between three months after treatment and the preoperative condition was recorded 8.36±2.45 mm in the pulpine mineral group while it was recorded 8.63±5.83 mm in the MTA group, the least change in the root length was detected 1.60±3.13 mm, while the highest change was 12.00±4.90 mm which was the negative control group.

Conclusion: PMIN is a promising alternative to MTA when used for pulpotomy.

Clinical relevance: Vital pulp therapy in immature teeth can be done using PMIN as an alternative to MTA.

Keywords: Dentin bridge · Mineral trioxide aggregate · Pulpine mineral · Pulpine NE · Pulpotomy

Background

he dental pulp is a unique tissue. It is a soft tissue of mesenchymal origin with specialized cells, the odontoblasts arranged peripherally in direct contact with the dentin matrix. The close relationship between odontoblasts and dentine is referred to dentin - pulp complex. Odontoblasts produce dentin, and the dental pulp is dependent upon the protection provided by the dentin and enamel [(1)]. Endodontic therapies today aim to replace essential pulp with synthetic materials rather than biological tissue. A foreign body reaction can occur when an endodontic filling is extruded [(2)]. Teeth filled with a synthetic material lose their ability to sense environmental changes, causing patients to underestimate the advancement of dental caries [(3)]. The capacity of dentin regeneration is another benefit of maintaining the pulp vitality. Moreover, if endodontically treated teeth are not treated adequately, their structural integrity may be compromised, increasing their susceptibility to be extracted [(4)]. The minimally invasive dentistry era has been approaching all the fields of dentistry, thus vital pulp therapy has now been recommended whenever the pulp shows any signs of reversible pulpitis [(5)]. Vital pulp therapy (VPT) is considered the treatment of choice in young individuals with recently exposed pulp and incomplete apical root development due to the high healing capacity of the dental pulp compared to older patients. VPT is recommended in traumatized teeth where the fracture line exposes the vital pulp, as well as in cases of deep caries without signs of irreversible inflammation of the pulp [(6)]. Several techniques have been advocated for this; a pulpotomy procedure is one in which the inflamed coronal pulp is removed and then capped with a pulpotomy material [(7)]. The main target of this procedure is to aid in the formation of a dentine bridge, in order to guard against microbial infection and to preserve healthy pulpal tissue [(7)]. The process of root maturation and completion of immature permanent teeth is very sensitive. It relies on the superior biological ability of dental pulp to heal; which is known as reparative dentinogenesis [(8)]. This whole process depends mainly upon the selection of an ideal pulpotomy material [(9)]. Ideal pulpotomy materials should be characterized by having an efficient antibacterial action, induction of tissue healing, biocompatibility, and sealing ability [(10)]. In 1920, Hermann introduced a new capping material which was calcium hydroxide. Despite the numerous advantages of Calcium Hydroxide as a pulp capping agent, many authors still question the long-term efficacy of using commercially available Calcium Hydroxide products for vital pulp therapy procedures [(11)]. Nowadays a wide variety of materials are available under which the formation of DB occurs, but MTA has proved to owe lesser inflammatory reaction and obvious development of the desired DB gaining the best results [(12)]. Unfortunately, MTA showed discoloration, long setting time, and poor handling characteristics [(13, 14)]. Thus, substitutes to MTA are presented in the market and grab attention [(15)]. There are many other materials that can be used in direct pulp capping rather than MTA. Haffmann's manufacture in Germany developed a new pulp capping material which is pulpine mineral that can alternate the MTA[(16)].

Pulpine mineral composed of hydroxyapatite, which forms about 70% of natural dentin embedded in the composite of calcium hydroxide and propolis. It forms a very stable setting matrix without gaps and without necrosis formation. The antibacterial properties of propolis lead to a complication-free healing of infected pulp tissue[(17)]. It can be used in cases of indirect and direct pulp capping without irreversible pulpitis. As it has many advantages such as excellent antibacterial effect, no necrosis formation, easy application, very good adhesion, and quick setting. The thin (non-dripping) creamy consistency applied direct on the exposed pulp and the tooth restored with a filling material. As pulpine mineral contains propolis so, the aim of the present study is to evaluate the efficacy of pulpine mineral to keep root maturation after capping the exposed infected pulp and compare these results with Mineral Trioxide Aggregate [(16)].

Method

Animals:

The present study was approved by the Institutional Animal Care and Use Committee at Faculty of Dentistry, Ain Shams University, Egypt (No: FDASU-REC-16- 2021). The authors followed up all institutional and international guidelines for animal care and use during this study. The Animal Research: Reporting in Vivo Experiments guidelines (ARRIVE) were also followed up [18]. Sample size calculation done using statistical power analysis. Sixty (60) permanent dog teeth from six mongrel dogs were selected for this study aged 4-6 months [9, 19] and weighted about 15-20 kg. We selected three incisors and one canine and the first premolar. All the selected teeth were on the same side. These animals were obtained commercially from Al-Fahad Trading Company for Animals (Abu-Rawash, Giza, Egypt).

Samples classification:

Dogs were randomly divided into 2 equal study groups (3 dogs/ group), according to the post treatment evaluation period. Group one (1 month, n= 30 teeth), Group two (3 months, n= 30 teeth) Each main group was subdivided according to the materials used; 4 experimental subgroups Pulpine mineral, n=9, MTA group, n=9, Positive control group, n=6, negative control group, n=6.

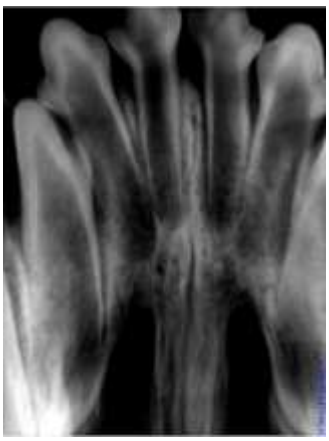
Samples preparation:

Each dog was subjected to a full physical examination by an expert veterinarian to exclude any diseased dog. The animals were kept in the animal house at the dog hospital in Abbasya under proper conditions of nutrition, ventilation, clean environment and 12 h light/ dark cycle. They were kept on separate kennels (1.5 m × 2.5 m × 3 m) and acclimatized to housing and diet for two weeks before the experiment. The dogs were given two meals per day (Soft food and milk) and fresh water and libitum [18].The dogs were injected subcutaneously with Ivermectin at a dose of 200 mg/kg body weight for control of external and internal parasites.

Anesthesia [19]:

General anesthesia was administrated after fasting the dogs for 12 hours. Following subcutaneous injection of Atropine sulphate 0.05 mg/kg weight and Xylazine HCl, 1.1 mg/ kg body weight given intravenously. The anesthesia was induced with Ketamine HCl at a dose of 5 mg/kg body weight via a 20-gauge IV cannula fixed in the cephalic vein. Anesthesia was maintained by 25 mg/kg incremental doses of Thiopental sodium 2.5% solution. After general anesthesia, the teeth were disinfected by 0.5% povidone iodine solution. The anesthetic effect occurred after 15-20 min and last for 30-60 minute.
Radiographic x-ray was performed for all teeth to confirm incomplete root formation [18] and to establish baseline working length for further comparison [16] **(Figure 1)**

Figure (1): showed preoperative periapical radiograph of the lower anterior teeth.



Induction of infection:

Following the general anesthesia, the selected teeth were exposed to the oral cavity and left uncovered to get infected. Using a mouth gag was applied to separate the jaws. Standard class V cavities [20] were prepared in all the experimental teeth and the positive control teeth 2 mm away from the gingival margin. Deepening of the pulpal floor for each cavity was done until the color of pulp tissue was reflected through the remaining dentin layer. Sterile sharp probe was used mechanically to expose the pulp. Bleeding was controlled by rinsing with sterile saline until the physiologic hemostasis occurred [19]. The exposed pulp was left uncovered for 2 weeks [21].

Treatment Modilities

After general anesthesia, partial pulpotomy for the coronal pulp tissues leaving some infected pulp tissues to be covered with experimental materials. The upper anteriors were capped with pulpine mineral material, while the lower anteriors were capped with MTA. The 1st premolars in each dog were used as positive control and canine were used as negative control. The cavities were sealed after a procedure with glass ionomer cement. Periapical radiographs were taken for further comparison.

Radiographic evaluation:

Digital image files were converted to 32-bitt TIFF files using Image-J analysis software. TurboReg plug-in was used to transform the non-standardized pre-operative and post-operative radiographs to standardized images. The increase in root length was evaluated according to Tawfik et al [22]. The sections were examined by 2 observers who did not know the source of the specimens. The obtained data was submitted to the suitable statistical analysis test.

Statistical analysis

Statistical Analysis Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data showed normal (parametric) distribution. Parametric Data were presented as mean, standard deviation (SD) and 95% Confidence Interval for the mean (95% CI) values.

Repeated measures m Analysis of Variance (ANOVA) was used to study the effect of irrigation technique, root level and their interaction on mean percentage of dead bacteria. Bonferroni's post-hoc test was used for pairwise comparisons when ANOVA test is significant.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Clinically all dogs ate and drank well. No signs of pain and no allergic reactions were reported in any dog during this study.

Radiographic evaluation:

I. One-month follow-up group.

Effect of the capping material on the increase in the root length

A) Regarding the mean change in root length

The difference in root length between one month after treatment and the preoperative condition was recorded 9.94±5.19 mm in the pulpine mineral group while it was recorded 5.38±3.78 mm in the MTA group, the positive control group showed the least one in the change in the root length 1.00±1.87 mm, while the negative control group was 7.00±4.06 mm.

As for the percent change the pulpine mineral group had the highest increase in the root length after one month (61.24±32.46%) followed by the negative control group (50.48±36.14%) and then the MTA group

(33.49±25.89 %) while the positive control group showed the least improvement in root length with percentage difference (8.00±15.11 %).

Regarding the pairwise comparison, there was no significant difference between pulpine mineral group and MTA and the negative control group. But pulpine mineral group showed a statistically significant difference from the positive control group (p= 0.023). **Table (2), Figure (2)**

Effect of time on the increase in the root length:

When comparing base-line root length to root length after one month within the same groups the results revealed the following **Table (1)**

- Group 1 showed a statistically significant increase in root length from (16.43±.99) at baseline to (26.38±4.93) at the 1-month follow-up. (P=0.001)
- Group 2 showed a statistically significant increase in root length from (18.38±3.96) at baseline to (23.75±2.49) at the 1-month follow-up. (P=0.005)
- Group 3 showed an increase in root length from (15.00±1.73) at baseline to (16.00±.71) at the 1-month follow-up. (P=0.298) which is statistically non-significant
- Group 4 showed a statistically significant increase in root length from (15.80±3.49) at baseline to (22.80±1.92) at the 1-month follow-up. (P=0.018)

Table (1) showed the mean ±SD of the root length at baseline and after one month for all groups.

Groups	Root length at zero (Mean± SD)	Root length after one month (Mean± SD)	P value *
1 (Pulpine mineral)	16.43±.99	26.38±4.93 ^{A}	0.001
2 (MTA)	18.38±3.96	23.75±2.49 ^{A}	0.005
3 (Positive control)	15.00±1.73	16.00±.71 ^{B}	0.298
4 (Negative control)	15.80±3.49	22.80±1.92 ^{A}	0.018
P value*	0.194	< 0.001	

**P value is considered statistically significant if < 0.05*

**Different letters in the same column indicate significant differences between groups.*

Table (2) showed the difference in millimeters as well as the percentage change between preoperative root length and after one month between the four experimental groups.

	1 (Pulpine mineral)	2 (MTA)	3 (Positive control)	4 (negative control)	P value
Change in mm (percentage)	9.94±5.19 mm (61.24±32.46%) A	5.38±3.78 mm (33.49±25.89%) AB	1.00±1.87 mm (8.00±15.11%) B	7.00±4.06 mm (50.48±36.14%) AB	0.023

**P value is considered statistically significant if < 0.05*

**Different letters in the same column indicate significant differences between groups.*

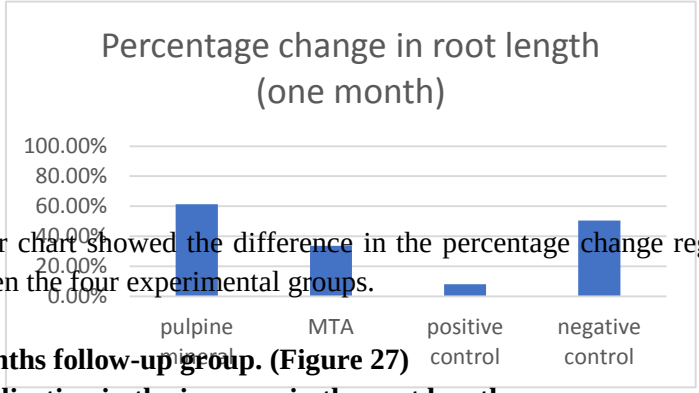


Figure (2): bar chart showed the difference in the percentage change regarding the root length after one month between the four experimental groups.

II. Three months follow-up group. (Figure 27)

Effect of material application in the increase in the root length

A) Regarding the mean change in root length:

The difference in root length between three months after treatment and the preoperative condition was recorded 8.36±2.45 mm in the pulpine mineral group while it was recorded 8.63±5.83 mm in the MTA group, the least change in the root length was detected 1.60±3.13 mm, while the highest change was 12.00±4.90 mm which was the negative control group.

As for the percent change the negative control group had the highest increase in the root length after three months (85.33±55.63 %) followed by the MTA group (52.73±39.58 %) and then the pulpine mineral group (48.69±19.66 %) while the positive control group showed the least improvement in root length with percentage difference (13.00±25.88 %).

Regarding the pairwise comparison, there was no significant difference between pulpine mineral group and MTA and the negative control group. there was no significant difference between pulpine mineral group and the MTA group and the positive control group while the positive control showed a significant difference with the negative

Groups	Root length at zero (Mean± SD)	Root length at three months (Mean± SD)	P value *
1 (Pulpine mineral)	18.50±2.45	27.13±1.25 ^{A}	< 0.001
2 (MTA)	16.63±.92	25.25±5.55 ^{A}	0.004
3 (Positive control)	15.00±1.73	16.60±1.52 ^{B}	0.317
4 (Negative control)	15.80±3.49	27.80±1.92 ^{A}	0.005
P value	0.053	< 0.001	

control group. **Table (3) figure (3).**

Effect of time in the increase in the root length

When comparing base-line root length to root length after three months within the same groups the results revealed the following **Table (4)**

- Group 1 showed a statistically significant increase in root length from (18.50±2.45) at baseline to (27.13±1.25) at the 3-month follow-up. (P <0.001)
- Group 2 showed a statistically significant increase in root length from (16.63±.92) at baseline to (25.25±5.55) at the 3-month follow-up. (P=0.004)
- Group 3 showed an increase in root length from (15.00±1.73) at baseline to (16.60±1.52) at the 3-month follow-up. (P=0.317) which is statistically non-significant
- Group 4 showed a statistically significant increase in root length from (15.80±3.49) at baseline to (27.80±1.92) at the 3-month follow-up. (P= 0.005)

Table (3) showed the mean ± SD of the root length at baseline, after three months between the four experimental groups.

Table (4) showed the difference in millimeters as well as the percentage change between preoperative root length and after three months of material application between the four experimental groups.

	1 (Pulpine mineral)	2 (MTA)	3 (Positive control)	4 (negative control)	P value
Change in mm (percentage)	8.36±2.45 mm (48.69±19.66 %) ^{AB}	8.63±5.83 mm (52.73±39.58 %) ^{AB}	1.60±3.13 mm (13.00±25.88 %) ^{A}	12.00±4.90 mm (85.33±55.63 %) ^{B}	0.035

**P value is considered statistically significant if < 0.05*
**Different letters in the same column indicate significant differences between groups.*

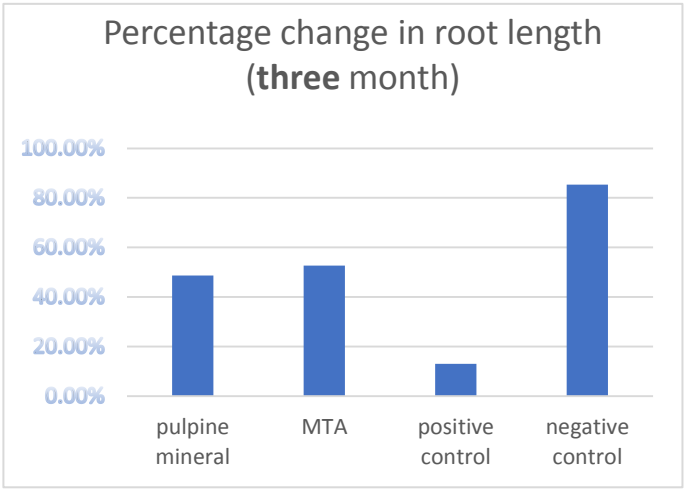


Figure (3): bar chart showed the difference in the percentage change regarding the root length after three months between the four experimental groups.

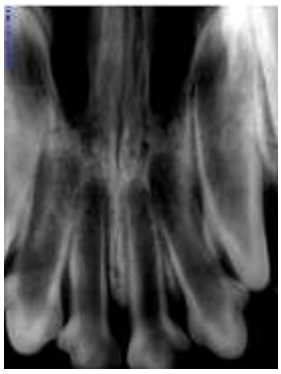


Figure (4): Showing the preoperative condition of the upper anterior teeth (root length, root thickness, apical diameter)

Figure (5): Showing the one month follow up after capping with the experimental materials of the upper anterior teeth (right side capped with pulpine mineral, left capped with MTA)

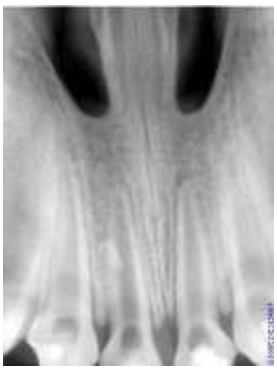


Figure (6): Showing the three months follow up after capping with the experimental materials of the upper anterior teeth (right side capped with pulpine mineral, left capped with MTA)

Discussion

Maintenance of pulp vitality is a concerning issue in contemporary restorative dentistry. Dental pulp is a distinctive soft tissue, consists of blood vessels, nerve fibers, collagen fibers, fibroblasts, odontoblasts, and immune cells, and has the potential for healing like other connective tissues. Direct pulp capping (DPC) is one of the strategies of vital pulp therapy, seeking to preserve the integrity of pulpal tissue [(16)].

When vital pulp therapy and subsequent apexogenesis are successful, the maintained viability of Hertwig's epithelial root sheath allows for continued root growth and root-end closure. Viable odontoblasts produce additional layers of dentine to strengthen the developing root and provide a natural dentin barrier or "bridge" between viable pulp and the pulp dressing material [(23)].

The degree of root development is a critical factor to be considered when dealing with cases of immature root with exposed pulp [(24)]. The duration of pulp exposure is another important factor that may affect the outcome. The degree of bacterial contamination and apical movement of inflammation is directly related to the duration of the pulp being exposed. Therefore, the prognosis for preservation of tooth vitality in cases of injured pulp decreases with prolonged periods of pulp exposure especially in mature teeth which may have relatively greater pulp compromise compared with immature teeth [(25)]. The choice of the material for pulp capping significantly determines the effectiveness of vital pulp therapy. As well as possessing adequate biocompatibility and strong antibacterial activity, an ideal pulp capping agent must be able to induce the formation of reparative dentin [(16)].

MTA was selected as in this study because it is considered a gold standard for vital pulp therapy, MTA stimulates reparative dentinogenesis through the adhesion, differentiation and activation of cells forming hard tissue barrier and contribute to matrix formation and mineralization [(8)]. It can solubilize cytokines embedded in the surrounding dentine and separate growth factors in the extracellular matrix to stimulates reparative hard tissue formation [(26)]. MTA induces the migration of progenitor cells

(fibroblasts) from the central pulp to the site of injury, proliferation of progenitor cells without cell apoptosis and differentiation into odontoblast-like cells [27].

Propolis has an anti-inflammatory, antibacterial and biocompatibility properties, so it had been studied for several medical uses. In dentistry propolis has been used for treatment of aphthous ulcers, periodontitis, Candida albicans and root canal disinfection due to its advantages; it does not stain the tooth crown, inhibits the formation of plaque, is preserved in the root canal, and enhances the bone regeneration [28].Hofmann dental manufacture (Hofmann Dental Manufaktur, HDM, Berlin, Germany) used PS as the main ingredient in the liquid a new material substituting MTA. PMIN which is composed of 70% hydroxyapatite (HAP) implanted in the composite of calcium hydroxide and PS . [9] HAP is a calcium phosphate biomaterial previously used as pulp capping material due to its biocompatibility and osteo-conductivity [29]. This study was conducted to assess the effect of Pulpine mineral to treat the infected pulp and this was through assessment the degree of root development of immature teeth and the degree of inflammation and dentin bridge formation after capping the infected pulp with the experimental material and comparing these results with Mineral Trioxide Aggregate (MTA).

The experimental animal study was selected as the animal model is easy to work, enabling long term evaluation with the potential of providing comparative evaluation of the various materials tested. In current research protocol dogs were the chosen animal model because the mechanism of dentin induction and synthesis in these animals are similar to that in human beings [5], [17]. Dogs have similar apical repair compared with that of humans but in a shorter time (average one sixth of human) due to high growth rate [30]. The dog has a suitable pulp size for the histopathological evaluation and a good number of teeth allowing the comparison of several pulp capping cement in the same dog [20].Moreover, the experimental dogs aged in range of six to nine months which are suitable for assessment of the immature teeth and withstanding of general anesthesia [22]. Anterior teeth were selected for this study because they are easily accessible [18]. Single root teeth were included only for standardization of the results. Class V cavities were prepared in the labial surface as they showed easy handling of the materials and protection from occlusal forces [20]. In addition, the auto-induction of reparative dentinogenesis may be observed on the surfaces of these fragments. [20]

In the absence of bacterial infection, a healthy pulp has a tremendous capacity to repair, a process clearly shown by the formation of a dentin bridge [19]. In this study, cavities were performed in the selected teeth and left open for two weeks in order to induce pulpal infection, for simulation of clinical cases.

The pulp response assessment was carried out over two separate periods, one short period of four weeks to track the initial inflammatory reaction to the two tested materials, as mentioned by El-zekrid et al, who suggested initial dentin bridge formation and pulpal regeneration started from first week after partial pulpotomy using autologous bone marrow–derived stem cells (BMSCS) [31], one longer observation period of 3 months was selected to evaluate the progressive changes in the pulp tissue regarding inflammatory reaction and reparative dentin formation, And to judge the thickness and continuity of the formed dentin bridge, as mentioned by several studies [32-34]

Radiographic evaluation was standardized using Image j software including TurboReg plug-in. This computer software is used to standardize pre-operative and post-operative radiographs. The radiographic findings after one month follow up found that the increase in the root length was not statistically significant between pulpine mineral, MTA, and the negative control groups. Regarding the positive control group, there was a slight increase in root length. This negative outcome in our study was likely related to the prolonged interval between tooth injury and treatment. Human and veterinary studies have

reported a much higher success rate (88 - 94 %) for maintenance of tooth vitality following complicated crown fracture if vital pulp therapy is performed within 48-hours.

Regarding four weeks interval, the percentage change between root length after one month in comparison to preoperative condition showed slight increase in positive control group, and too much increase in the root length in the other three groups. This increase was due to deposition of cementum-like tissue. No apical closure was recorded at this time interval. These results in accordance to Tawfik, H et.al. 2013 [(22)].

After 3 months, no significant difference was found between pulpine mineral and MTA groups regarding the increase in length. This can be attributed to hard tissue deposition which indicates a healing process and the reparative potential of pulpine mineral and MTA and the excellent biocompatibility of these materials. This finding agreed with Mona R. Abo EL Wafa et al. (2021) who found the same results regarding pulpine mineral. Contradictory results were not found due to lack of studies in this field. Most of samples of the positive control group failed to achieve any increase in length in all follow up periods. This could be explained by the absence of any hard tissue deposition in most samples.

Pulpine mineral contains two important ingredients in Pulpine NE, calcium hydroxide, that is present in a very low concentration, that is well known for its ability for reparative dentin formation and its antibacterial properties beside its low concentration that aid in elimination of the possible side effect as pulp tissue necrosis. The second is propolis, which inhibits apoptosis by inhibiting the translation of NFkβ (Nuclear factor NF-Kappa B) into the nucleus. Apoptosis inhibition leads to the prevention of a dramatically decrease in the amount of fibroblast in the pulp. Propolis extract enhances the differentiation of odontoblast like cells, stimulates the chemotaxis of fibroblasts to increase the production of collagen, fibronectin, and proteoglycans [(35)]. These results are in accordance with a study which found that dentin bridge was formed following pulp capping with propolis in most of the samples after 2 months [(36)].

Mineral trioxide aggregate is formed of a refined Portland cement with fine particles distribution that allows cells attachment and proliferation and promotes healing (Camilleri, 2008).

The histopathological results obtained with MTA groups for one week showed limited pulp tissue necrosis and mild pulp inflammation followed by subjacent initial mineralization. This tissue response is believed to be a result of good sealing ability, bio-mineralizing ability and alkaline pH**Error! Reference source not found.**. Calcium and phosphate ions had the capacity to attract blastic cells and promote a favorable environment for dentin deposition. MTA has reparative effect via induction of release of mediators as osteocalcin, some interleukins and alkaline phosphatase. The thickness and homogenesity of the dentin bridge formed by MTA might be due to its fine and homogenous particles allowing tertiary dentin formation [(19)]. Our findings were in agreement with Shabahang et al [(21)].

The mechanism of action of MTA in bridging could be similar to that of $Ca(OH)_2$. Calcium hydroxide has a direct effect on the precapillary sphincters resulting in less plasma outflow, which in turn favors a calcific response in the involved tissue [(37)]. Calcium hydroxide also increases the action of pyrophosphatase enzyme which is Ca2+ dependent. This enzyme transforms pyrophosphatase into orthophosphatase which increases energy utilization and therefore favors a defense mechanism. Holland et al has suggested that hard tissue deposition could be due to the CaO present in MTA which may have a similar mechanism of action to calcium hydroxide [(38)].MTA also has lower values of $Mg2^+$ which is speculated to slow down the mineralization process[(39)].However, it should be remembered that the concept of bridging is a controversial issue, because the presence of a bridge does not necessarily imply that the pulp tissue is healthy. It can be viewed as both a healing response of a reaction to irritation[(40)]. Furthermore the formation of a bridge does not imply that the pulp will be sealed completely from the

environment. The bridge formed is initially permeable but as time progresses, permeability decreases. Various investigators (Mjor – 197230 and Woehrlen – 197731) have suggested that it is not always possible to section perfectly along the perpendicular axis of the tooth, therefore it is difficult to score all the sections and this is a major limitation of a study such as this. Also histologic demonstration of only one section through a dentin bridge following capping of an exposed pulp is not by itself a proper criterion for maintenance of long term pulpal healing. A long term study with a larger sample size is necessary to conclusively prove the efficacy of MTA in inducing a favorable pulpal response.

Conclusion

Under the limitation of this study, Hoffmann's pulpine mineral can be substitute MTA in management of infected pulp.

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