Histological evaluation of the effect of three medicaments; trichloracetic acid, formocresol and mineral trioxide aggregate on pulpotomised teeth of dogs

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Keywords
Formocresol, inflammation, mineral trioxide aggregate, pulpotomy, trichloracetic acid.

Abstract
The aim of this study was to use clinical, radiographic and histological examinations to compare the dental pulp response in 162 premolar roots of eight dogs when trichloracetic acid (TCA), formocresol, mineral trioxide aggregate (MTA) and zinc oxide eugenol were used as pulpotomy agents. The teeth were divided into four groups. Following pulpotomy, the teeth were restored with amalgam. The animals were sacrificed at 48 h, 2, 4 and 8 weeks (two dogs at each interval). Histological evaluation indicated no cases with necrosis. After 8 weeks follow up, dentine bridge formation was evident in 20%, 50% and 91.7% of formocresol, TCA and MTA cases respectively. The first signs of bridge formation were seen for MTA at 2 weeks and for TCA at 4 weeks. MTA was superior to formocresol and TCA in treating pulps in dogs. However, bridge formation was seen in 50% of TCA cases after 8 weeks which is a desirable finding in pulpotomy procedures.

Introduction
Pulpotomy is a therapeutic procedure, which consists of the surgical amputation of coronally inflamed pulp. The wounded surface of the radicular pulp is treated with a medicament or dressing agent to promote healing or to cause fixation of the underlying tissue. The objective is to maintain vitality of the radicular pulp. Pulpotomy is a common procedure in the treatment of acutely inflamed primary teeth. It is also used in the management of young permanent teeth with open apices (1).

The success of vital pulp therapy techniques in variously exposed primary molar teeth is thought to be dependent upon the technique employed, the inflammatory status of the coronal and radicular pulp tissue, the type of pulp therapy agent used, the period of observation and the criteria used to diagnose success.

The features of a successful pulpotomy treatment can be described as:
1. Dentine bridging;
2. Maintenance of pulp vitality;
3. Lack of undue sensitivity or pain;
4. Minimum pulpal inflammatory response;
5. The ability of the pulp to maintain itself without progressive degeneration;
6. Lack of internal resorption and/or intraradicular pathosis (2).

One of the outcomes felt to indicate a successful pulpotomy is the presence of a dentine bridge at the site of pulp amputation. This phenomenon was thought to indicate healing of the pulp tissue and to be promoted by the application of a material such as calcium hydroxide. However, this supposition is now not without controversy as it is known that pulpal obliteration/dentine bridge formation results from deposition of reactionary dentine also termed irritation dentine.

Studies have indicated that an exposed pulp possesses inherent ability to produce dentine in response to operative procedures or trauma, irrespective of the agent applied to the amputation site (3).

Historically, various materials have been used in pulpotomy procedures. These include, but are not limited to:
Ivory, quill, gold, beaters skin, oiled skin, paper, plaster of Paris, Canada balsam, asbestos, etc. Other pulpotomy dressings have also been examined more recently such as formocresol, calcium hydroxide, freeze-dried bone, gluteraldehyde, ferric sulfate, bone morphogenetic protein, mineral trioxide aggregate (MTA), etc. (4).

Formocresol has been a popular pulpotomy medicament in the primary dentition for the past 60 years. According to Avram and Pulver, in their 1989 survey, formocresol continues to be the most widely used pulpotomy medicament for vital primary teeth (5). The search for a medicament to replace formocresol became imperative after several negative reports questioning both its local and systemic side-effects (6).

A newer material that has been advocated for vital pulp therapy is MTA. Many favourable features have been reported on the use of MTA. These are its excellent sealing ability, biocompatibility, ability to form dentine bridge, and cementum and periodontal ligament regeneration (7). Hence, MTA has been recommended as a retrograde filling material in the repair of perforations, pulp capping and apexification. Although MTA is commonly used for a variety of endodontic indications, the material is expensive.

Trichloracetic acid (TCA) is the main pulpotomy dressing being investigated in this study. The use of TCA as a chemical cauterising agent has been popular in medicine and dentistry since the 19th century. The main therapeutic application of TCA in dentistry has been removal of excess gingival tissue before restorative procedures (8). Historically, other dental applications have included the management of sepsis following extraction: reduction of dentine sensitivity; removal of calculus; treatment of necrotising gingivitis; treatment of pericoronal infection; and as a sclerosing agent for jaw cysts to avoid apicectomy (9). Heithersay introduced the use of TCA, as an adjunct for the treatment of aggressive external cervical root resorption (10). It is an inexpensive chemical substance and no carcinogenicity has been reported regarding this material.

It is the first time this chemical substance is being suggested as a pulpotomy dressing for pulpotomy of primary and young permanent teeth. The purpose of this study was to compare the dental pulp response in dog premolars when TCA, formocresol, MTA and zinc oxide eugenol (ZOE) were used as pulpotomy agents. All four materials are investigated clinically, radiographically and histologically.

**Materials and methods**

Ninety-six teeth from eight mixed breed dogs aging 12–18 months and weighing 20–25 kg were used in this experiment. The dogs were first anaesthetised with an intravenous injection of Thiopental Na (15 mg/kg). Each dog was transferred to an operating room and after intubating the dog, it was anaesthetised by standard techniques using halothane. Preoperative periapical radiographs were taken from each quadrant. The teeth were disinfected using betadine and isolated using a rubber dam and cotton rolls. A high-speed handpiece with a continuous water spray, using sterile round and fissure burs, was used to perform the access cavity. The coronal portion of the pulp was removed with a bur and spoon-shaped excavator.

Bleeding was controlled by thoroughly washing the pulp chamber with sterile saline solution and by applying light pressure to the pulp stump on the root orifice using a sterile cotton pellet. The teeth in each dog were divided into four groups so that each group would contain both upper and lower premolars. In each group, the teeth were pulpotomised separately and dressed with TCA (Merck, Darmstadt, Germany), formocresol (B.D., Tehran, Iran), MTA (Angelus, Londrina, Brazil) as experimental groups and ZOE (Dentsply, Surrey, UK) as control group.

**Group A**

This group includes four premolars in each dog, two mandibular third premolars and two maxillary second premolars. Therefore, group A involves 32 teeth and a total of 64 roots in eight dogs.

Following the access cavity procedures and control of haemorrhage, a sterile cotton pellet was dipped in to a 90% aqueous solution of TCA. After excess solution on the cotton pellet was removed by dampening on a sterile gauze, the cotton pellet was carefully applied with light pressure on to the pulp stump for 30 s. If some bleeding was seen after 30 s, this procedure was repeated for another 30 s. After the completion of this procedure, the cavities were sealed permanently with ZOE and restored with amalgam.

**Group B**

This group includes three premolars in each dog, two mandibular second premolars and one right maxillary third premolar. Therefore, group B involves 24 teeth and a total of 48 roots in eight dogs.

After access cavity and hemorrhage control, a sterile cotton pellet was dipped into a formocresol solution. The excess formocresol solution was removed by dampening the cotton pellet on a gauze. Then, the cotton pellet was applied with light pressure on the pulp stump for 5 min. If the pulp stump had not turned brown after 5 min, this procedure was repeated for another 5 min. After the
completion of this procedure, the cavities were sealed permanently with ZOE and restored with amalgam.

**Group C**

This group includes three premolars in each dog, two mandibular fourth premolars and one left maxillary third premolar. Therefore, group C involves 24 teeth and a total of 48 roots in eight dogs.

After access cavity and hemorrhage control, the pulp stumps were covered with MTA mixed in a 3:1 powder–distilled water ratio; light pressure was applied with a wet cotton for 15 min so the primary setting was accomplished and then the cavities were restored permanently with amalgam.

**Group D**

Groups A and B were sealed with ZOE after applying TCA and formocresol respectively. In order to prove that the results obtained from group A (TCA) and group B (formocresol) are independent from the effect that ZOE might have when the dental pulp is covered only by ZOE, a fourth group (group D) was also examined.

In this group (control group), 16 teeth in eight dogs were used. After access cavity and hemorrhage control, the pulp stumps were covered with ZOE and restored permanently with amalgam.

The dogs were re-anaesthetised after periods of 2 days, 2, 4 and 8 weeks (two dogs in each period). After taking periapical radiographs from each quadrant, vital perfusion with 10% formalin through the common carotid artery was performed.

When the fixative procedure was completed, the soft tissue around the lower and upper jaw was removed using a surgical blade. The lower and upper premolars were resected using a surgical saw. Each tooth with its surrounding bone was placed in a sample container containing 10% formalin and was labelled according to the teeth.

Following decalcification in 5% nitric acid (Merck, Darmstadt, Germany) for 14 days, the specimens were dehydrated using 30%, 70% and 100% alcohol and finally embedded in paraffin. Twenty to thirty serial 6-μm thick sections, in a buccolingual and apicocoronal direction, were obtained for each root and stained with haematoxylin and eosin. The sections were examined with light microscopes under low and high magnifications, by two observers (an endodontist and a pathologist) who were not aware of the source of the specimens.

Every sample was evaluated for severity of tissue reactions. The degree of inflammation was classified in groups from 0 to 4 as none, mild, moderate, severe or necrosis (Table 1), modified after Heyeraas et al. (11). Each group was evaluated for the degree of inflammation at each pulpotomy duration.

The presence and quality of bridge formation and reappearance of odontoblasts were also evaluated for each group at each pulpotomy duration with the help of a light microscope at low and high power.

The data were submitted to statistical analysis using chi-square, Kruskal–Wallis and ANOVA tests ($P ≤ 0.05$) with the help of SPSS software.

**Results**

The number of cases in each pulpotomy duration with regard to the pulpotomy dressing is given in Table 2. Six TCA and eight formocresol cases were excluded from the study due to damage to the amalgam fillings, teeth fracture and other technical problems. The final sample consisted of 162 roots of dogs premolar teeth including 58, 40, 48 and 16 pulpotomised with TCA, formocresol, MTA and ZOE respectively.

**Clinical and radiographic findings**

The experimental dogs tolerated the pulpotomy procedures well. No clinical symptoms such as swelling and fistula tracts were observed after the four pulpotomy durations. Radiographic findings revealed no periapical

### Table 1 Description of criteria for classification of pulp inflammation, modified after Heyeraas et al. (11)

<table>
<thead>
<tr>
<th>Degree</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None: normal pulp structure.</td>
</tr>
<tr>
<td>1</td>
<td>Mild: increased number of cells, predominately fibroblasts. A few inflammatory cells are involved. An increased number of capillaries are noted, and a few extravasated red blood cells may be found.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate: predominately characterised by more cells in the area than in the slight reaction. Increased number of capillaries and vessels are found.</td>
</tr>
<tr>
<td>3</td>
<td>Severe: marked cellular infiltration, numerous blood vessels are found in the tissue surrounding the intense cellular infiltration.</td>
</tr>
<tr>
<td>4</td>
<td>Necrosis of the pulp.</td>
</tr>
</tbody>
</table>

### Table 2 Frequency distribution of samples

<table>
<thead>
<tr>
<th>Pulpotomy agent</th>
<th>Pulpotomy duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>48 h</td>
</tr>
<tr>
<td>TCA</td>
<td>16</td>
</tr>
<tr>
<td>Formocresol</td>
<td>12</td>
</tr>
<tr>
<td>MTA</td>
<td>12</td>
</tr>
<tr>
<td>ZOE</td>
<td>4</td>
</tr>
</tbody>
</table>

TCA, trichloracetic acid; MTA, mineral trioxide aggregate; ZOE, zinc oxide eugenol.
pathosis associated with any of the pulpotomy dressings after the four pulpotomy durations.

**Histological findings**

**Inflammation**

Degree of inflammation with regard to pulpotomy duration for each pulpotomy dressing was investigated and is discussed as below:

TCA showed a higher per cent of moderate degree of inflammation in all four pulpotomy durations (Fig. 1). When the TCA cases were observed, 56.3% after 48 h, 57.1% after 2 weeks, 64.3% after 4 weeks and 57.1% after 8 weeks revealed a moderate degree of inflammation. Only one case of mild inflammation was reported after 1 week. The percentage of severe inflammation in TCA cases was 43.8%, 35.7%, 35.7% and 42.9% for 48 h, 2 weeks, 4 weeks and 8 weeks respectively.

Formocresol showed a higher per cent of moderate degree of inflammation in all four pulpotomy durations except the 48 h duration which had 50% moderate and 50% severe inflammation (Fig. 2). When formocresol cases were observed, 50% after 48 h, 90% after 2 weeks, 100% after 4 weeks and 70% after 8 weeks revealed a moderate degree of inflammation. Only one case of mild inflammation was reported after 8 weeks. The percentage of severe inflammation was also reported as 50%, 10%, 0% and 20% for 48 h, 2 weeks, 4 weeks and 8 weeks respectively.

Findings revealed that MTA has a higher per cent of moderate degree of inflammation in all four pulpotomy durations.
durations except at 2 weeks which revealed 50% moderate and 50% severe inflammation (Fig. 3). In 48 h, 2 weeks, 4 weeks and 8 weeks, the percentage of moderate degree of inflammation for MTA was 100%, 50%, 91.7% and 75% respectively. Only three cases of mild inflammation were reported after 8 weeks. The percentage of severe inflammation was also reported as 0%, 50%, 8.3% and 0% for 48 h, 2 weeks, 4 weeks and 8 weeks respectively.

ZOE revealed a higher percentage of severe degree of inflammation in all four pulpotomy durations except the 48-h pulpotomy duration which showed 50% moderate and 50% severe inflammation. No cases of mild inflammation were reported. The 4-week and 8-week pulpotomy duration revealed 100% severe inflammation (Fig. 4).

None of the four pulpotomy dressings showed a degree of inflammation of 0 (normal pulp structure) or 4 (necrosis of the pulp) according to Heyeraas et al.’s (11) classification for inflammation.

**Comparison of inflammation**

Kruskal–Wallis test was used to investigate the degree of inflammation for different pulpotomy dressings in different pulpotomy durations. The results of the analysis are
presented in Figure 5. The results indicated a significant difference between the four pulpotomy dressings in 48 h (Chi-square = 8.47, Sig. = 0.037). MTA had the lowest mean rank for inflammation after 48 h (mean rank = 15), while the mean ranks for TCA, formocresol and ZOE were 24.63, 26 and 26 respectively.

Findings for 2-week pulpotomy duration showed no significant difference for degree of inflammation among the four pulpotomy dressings (Chi-square = 5.9, Sig. = 0.116). However, formocresol showed the lowest mean rank for inflammation (mean rank = 15.45) followed by TCA (mean rank = 19.52).

The 4-week pulpotomy duration revealed a significant difference for degree of inflammation between the pulpotomy dressings (Chi-square = 16.25, Sig. = 0.001). It is interesting to note that formocresol like the 1-week duration had the lowest degree of inflammation (mean rank = 14.5). The mean ranks of inflammation for TCA, MTA and ZOE were 21.29, 16.08 and 33.5 respectively.

Application of Kruskal–Wallis test for degree of inflammation at 8-week pulpotomy duration showed a significant difference among different pulpotomy dressings (Chi-square = 16.29, Sig. = 0.001). MTA had the lowest (mean rank = 13) and ZOE the highest (mean rank = 34.50) mean rank for degree of inflammation. TCA and formocresol had a mean rank of 24.21 and 18.70 for degree of inflammation.

In general, MTA had the lowest degree of inflammation followed by formocresol and TCA. ZOE showed the highest degree of inflammation.

Bridge formation

Bridge formation was analysed according to presence or absence of bridge beneath the pulpotomy dressing. If a bridge was present, it was also observed as being a regular bridge or irregular bridge with many porosities. Bridge formation for each pulpotomy dressing with regard to pulpotomy duration is given in Figure 6.

Bridge formation was not seen after 48 h in any of the pulpotomy dressing samples. After 2 weeks, bridge formation was seen in 58.3% of MTA cases, of which 41.7% of the bridges were irregular and 16.7% were regular. No bridge was observed in the other pulpotomy dressings after 2 weeks.

At the 4-week pulpotomy duration, bridge formation was seen for both MTA and TCA samples. Bridge formation was observed in 42.9% of TCA cases including 7.1% and 35.8%, regular and irregular bridge formation respectively. MTA revealed 75% bridge formation after 4 weeks and all were irregular bridges.

After 8 weeks, bridge formation was observed in TCA, MTA and formocresol pulpotomy dressings. Irregular bridge formation was observed after 8 weeks in 20%, 50% and 91.7% of formocresol, TCA and MTA pulpotomy dressings respectively. Bridge formation was not observed in any of the pulpotomy durations when ZOE was used as a pulpotomy dressing.

Comparison of bridge formation

For further analysis of data, bridge formation was recoded as 0 (absence of bridge) and 1 (presence of bridge). This dicotomous level of measurement provides the opportunity to apply parametric statistics to compare bridge formation, the results of which will be explained as below:

Comparison of bridge formation for TCA in different pulpotomy durations

The results of ANOVA analysis indicated that there is a significant difference between TCA bridge formation in
four different pulpotomy durations \((F = 8.2, \text{ Sig.} = 0.0001)\). Least Significant Difference (LSD) test was used to search for significant differences among the four pulpotomy durations. The result presented in Table 3 indicated that there is no significant difference in mean bridge formation for TCA between 48 h and 2 weeks and also between 4 and 8 weeks. However, mean bridge formation was significantly higher in 4- and 8-week pulpotomy durations when compared with 2 weeks.

Comparison of bridge formation for MTA in different pulpotomy durations

The results of ANOVA analysis indicated that there is a significant difference between MTA bridge formation in four different pulpotomy durations \((F = 13.8, \text{ Sig.} = 0.0001)\). LSD test was used to search for significant difference among the four pulpotomy durations (Table 3).

The results indicated that no significant difference in mean bridge formation for MTA was observed between 2 weeks and 4 weeks and also 4 weeks and 8 weeks. However, mean bridge formation was significantly higher in 8 weeks when compared with 2 weeks pulpotomy duration.

Comparison of bridge formation between four pulpotomy dressings at 4 weeks and 8 weeks

In 4-week pulpotomy duration, the mean bridge formation for formocresol and ZOE was zero. Therefore, these two treatments were excluded from the analysis and an independent \(t\)-test was performed to test the difference between TCA and MTA in bridge formation at 4-week pulpotomy duration (Fig. 7). The results indicated that MTA had a higher \((x = 0.75)\) mean bridge formation than TCA \((x = 0.43)\), but the difference was not statistically significant \((t = -1.68, \text{ d.f.} = 14, \text{ Sig.} = 0.106)\). TCA, trichloracetic acid; MTA, mineral trioxide aggregate; ZOE, zinc oxide eugenol.

![Figure 6](image_url) Type and percentage of bridge formation with regard to pulpotomy dressing and duration. TCA, trichloracetic acid; MTA, mineral trioxide aggregate; ZOE, zinc oxide eugenol.

![Figure 7](image_url) Comparison of mean bridge formation in 4-week pulpotomy duration. There is no significant difference between TCA and MTA using independent \(t\)-test \((t = -1.68, \text{ d.f.} = 24, \text{ Sig.} = 0.106)\). TCA, trichloracetic acid; MTA, mineral trioxide aggregate; ZOE, zinc oxide eugenol.

![Table 3](image_url) Mean bridge formation for trichloracetic acid (TCA) and mineral trioxide aggregate (MTA) with regard to pulpotomy duration

<table>
<thead>
<tr>
<th>Pulpotomy duration</th>
<th>TCA</th>
<th>Formocresol</th>
<th>MTA</th>
<th>ZOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 h</td>
<td>0.0a</td>
<td>0.0a</td>
<td>0.43b</td>
<td>0.5b</td>
</tr>
<tr>
<td>2 weeks</td>
<td>0.0a</td>
<td>0.58b</td>
<td>0.75bc</td>
<td>0.92c</td>
</tr>
<tr>
<td>4 weeks</td>
<td>35.714</td>
<td>16.667</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>8 weeks</td>
<td>7.1429</td>
<td>8.3333</td>
<td>8.3333</td>
<td>91.667</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different by LSD0.05 tests.
mean bridge formation ($x = 0.92$) than the other three pulpotomy dressings. TCA was the second best treatment for bridge formation after 8 weeks ($x = 0.5$).

Reappearance of odontoblasts

In 48-h pulpotomy duration, bridge formation was not observed in any of the cases; therefore, the reappearance of odontoblasts was not seen either. In the 2-week pulpotomy duration, bridge formation and reappearance of odontoblasts were not observed in any of the pulpotomy dressings except for MTA. Bridge formation was observed in seven cases of MTA pulpotomy dressing, of which reappearance of odontoblasts was observed in only 57.1% (four of seven) of the bridge-formed cases.

At 4 weeks, bridge formation was observed in TCA and MTA pulpotomy dressings. Reappearance of odontoblasts was seen in 33.3% (two of six) and 77.8% (seven of nine) of TCA and MTA cases respectively.

At 8 weeks, bridge formation was observed in TCA, formocresol and MTA pulpotomy dressings. However, reappearance of odontoblasts was not observed in any of the formocresol cases. Reappearance of odontoblasts was seen in 14.3% (one of seven) and 63.6% (seven of 11) of TCA and MTA cases respectively. In general, 23% of TCA cases and 66.6% of MTA cases that had bridge formation also showed reappearance of odontoblasts.

Discussion

In this study, dogs’ premolar teeth were pulpotomised in order to histologically evaluate the response of the dental pulp to four different pulpotomy dressings (TCA, formocresol, MTA and ZOE) over four different pulpotomy durations.

The pulpotomy procedure for primary and young permanent teeth is indicated when the infected coronal tissue can be amputated and the remaining radicular tissue is judged to be vital or affected but still vital, by clinical and radiographic criteria. The main objective of this treatment modality today is to maintain the vitality of the majority of the radicular pulp (12).

The first approach to pulpotomy in primary teeth was the multiple visit formocresol pulpotomy technique introduced by Sweet and was designed to produce devitalisation and complete mummification of the tissue. When completely fixed, the radicular pulp was theoretically sterilised and devitalised, obviating infection and internal resorption (13).

Today, other materials such as MTA have presented excellent results when used on pulp tissue. MTA represents bio-compatible substrates to which formative cells can attach and produce new soft or hard tissue, preserving pulp vitality (14).

Several commonly used dental materials such as ZOE have been shown to inhibit oxygen consumption by pulp tissue, indicating that these agents may be capable of depressing the metabolic activity of pulpal cells. Eugenol can have a number of effects on mammalian cells, depending on the concentration and length of exposure. These effects include cell respiration depression, macrophage and fibroblast cytotoxicity, depressed vasoconstrictor response, inhibition of prostaglandin and suppressing or enhancing effects on immune response (15).

In this study, the samples with ZOE as a pulpotomy dressing showed the highest degree of inflammation when compared with the other three pulpotomy dressings. After 4 weeks, all the samples showed severe inflammation, but none of the ZOE samples revealed necrosis after 8 weeks.

The high degree of inflammation seen after 4 weeks may be due to the cytotoxic effect of eugenol on the pulp tissue. Fadavi and Anderson studied the pulpal response of ZOE on primary teeth of cynomolgus monkeys. The monkeys were followed for a period of 6 weeks and 6 months. After 6 weeks, a severe inflammation was observed in all cases, and after 6 months one-third of the cases showed partial necrosis and two-thirds showed total necrosis of the pulp (16).

Glass and Zander found that ZOE in direct contact with the pulp tissue produced chronic inflammation, prevented formation of a calcific bridge and caused pulpal necrosis (17). Weiss and Bjorvatn noted negligible necrosis of the pulp in contact with ZOE and stated that any calcific bridging was probably a layer of dentinal chips (18). In the present study, pulpal necrosis was not seen after 8 weeks in ZOE cases, but if the teeth were followed...
for a longer period, necrosis might have been observed as well. Bridge formation was not evident in any of the ZOE samples even after 8 weeks.

The last reported worldwide survey of dental schools in 1989 showed a majority of paediatric dentistry departments and practising paediatric dentists advocated the formocresol pulpotomy technique, and it may still be widely used in clinical practice (5). Therefore, formocresol was chosen as one of the pulpotomy agents in this study.

In the present study, the pulpotomy samples used with formocresol had a high degree of moderate inflammation. After 8 weeks, 70% of the cases had a moderate degree of inflammation. Only 10% and 20% of the samples had a mild and severe degree of inflammation, respectively, after 8 weeks. After 8 weeks, necrosis was not seen in any of the samples pulpotomised with formocresol. No bridge formation was evident until 8 weeks. In the 8-week pulpotomy duration, 20% (two of 10) of the cases showed an irregular bridge formation. Reappearance of odontoblasts was not seen in any of the cases with bridge formation.

Rolling et al. reported that the pulp, 3–5 years after successful formocresol pulpotomy in primary molars in most instances was vital, and that chronic inflammation was observed in the pulp of half of these teeth (19). Ranly also reported that treatment of the pulp with formocresol leaves the pulp chronically inflamed and susceptible to abscess formation and internal resorption (13). Fuks et al. reported 29% had severe degree of inflammation after an 8-week pulpotomy duration with formocresol (6). This finding is relatively similar to the results of the present study. Bridge formation was not reported by Fuks after 8 weeks. Ibrahim et al. reported in an animal study, the absence of inflammation along with dentine bridging in 15 experimental teeth, when the exposure was medicated with formocresol for 5 min and capped with a mixture of formocresol and ZOE cement (20). Agamy et al. also reported calcific barrier formation after formocresol pulpotomies on primary teeth (21). In the present study, bridge formation was also seen and supports the results of Ibrahim et al. and Agamy et al.

MTA has been proposed as a potential medicament for pulpotomy procedures. MTA was found to maintain pulp integrity after pulpotomy in animal studies and to have a dentinogenic effect on the pulp expressed by dentine bridge formation where it touches the pulp tissue (7,22).

In the present study, MTA was shown to be a suitable material for dentine bridge formation. No necrosis or severe degree of inflammation was observed in the samples after 8 weeks, when MTA was used as the pulpotomy dressing. The MTA samples revealed 75% of moderate degree and 25% of mild degree of inflammation after 8 weeks. The findings showed that 50% of the MTA samples showed a severe degree of inflammation after 2 weeks. Bridge formation was seen after 2 weeks in 58.3% of the cases including 41.7% irregular and 16.7% regular or complete bridge formation. MTA was the only pulpotomy dressing with bridge formation after 2 weeks. Asgary et al. reported a non-dentinal bridge formation after 2-week pulpotomy duration when MTA was used as a pulpotomy dressing for pulpotomised teeth of dogs (23). The present study also supports the formation of a bridge after 2 weeks.

After 4 weeks and 8 weeks, bridge formation was seen in 75% and 91.7% of the MTA samples of The present study, respectively. Bridge formation between the 4-week and 8-week period was not statistically significant, but there was a statistically significant difference between bridge formation in the 2-week period when compared with the 8-week pulpotomy duration (Sig. = 0.0001).

Agamy et al. compared MTA and formocresol in pulpotomised primary teeth. Both MTA and formocresol induced a dentine bridge formation after 6 months. The MTA induced a thick bridge while formocresol induced a thin calcified dentine (21).

In a recent publication, Chacko and Kurikose reported dentine bridge formation after 4 weeks and 8 weeks when MTA was used as a pulpotomy dressing. The dentine bridge formation was more homogenous and continuous with the original dentine when compared with pulps capped with calcium hydroxide (24). Faraco and Holland reported bridge formation after 8 weeks, and Salako et al. reported bridge formation after 2 weeks and 4 weeks when MTA was used as pulpotomy dressing (7,25). Khayat et al. also reported bridge formation after 30 days when dogs’ teeth were pulpotomised with MTA (26). These reports all support the findings from the current study.

In a study by Dominiguez, pulpotomy procedures were performed on 15 male mongrel dogs. When MTA was used as a pulpotomy dressing for a period of 50 days, all cases showed bridge formation after 8 weeks. Dominiguez reported that 40% of the bridges were complete and 60% were irregular (4). In the present study, all bridges were incomplete and irregular.

In the present study, when MTA was used as a pulpotomy dressing, reappearance of odontoblasts was seen in 57.1%, 77.8% and 63.6% of 2-week, 4-week and 8-week pulpotomy durations respectively. In general, 66.6% of cases with dentine bridge formation, revealed reappearance of odontoblasts.

In this study, TCA is introduced as a new pulpotomy agent. The use of TCA, as an adjunct for treatment of aggressive external cervical root resorption, was introduced by Heithersay (10). He recommends applying a 90% aqueous solution of TCA to the resorptive defect in
order to eliminate the resorbing tissue and establish a sound base for tooth restoration. TCA is a chemical escharotic agent that has been used in medicine and dentistry for more than a century. It produces a defined zone of coagulation necrosis when applied to soft tissues (9).

The chemocauterisation effect of TCA is used in this study in order to cauterise the pulp stump on the orifice of the teeth roots after the removal of the pulp from the pulp chamber. When TCA was used in this study as a pulpotomy dressing, no cases of necrosis were reported in any of the pulpotomy durations. No clinical or radiographic signs to show pulp necrosis was seen either.

Bridge formation was evident from the 4th week after pulpotomy in TCA samples. Of the 42.9% cases with bridge formation, 35.8% and 7.1% showed irregular and regular bridges respectively. At 8-week pulpotomy duration, 50% of cases showed bridge formation and all were irregular. There was a statistically significant difference between bridge formation at 2 weeks when compared with 4 weeks and 8 weeks (Sig. = 0.0001), but no significant difference was seen in bridge formation when comparing the 4-week and 8-week pulpotomy duration. Reappearance of odontoblasts was seen in 33.3% and 14.3% of 4-week and 8-week pulpotomy durations respectively. In general, 23% of cases with dentine bridge formation revealed reappearance of odontoblasts.

The results for mean bridge formation revealed that MTA had a significantly (Sig. = 0.0001) higher mean bridge formation than the other pulpotomy dressing. TCA was the second best treatment for bridge formation after 8 weeks.

The presence of inflammatory cells was seen until the end of the experimental duration for all four groups, which indicates that healing and bridge formation can be seen simultaneously with inflammatory response.

No other study has been done on TCA as a pulpotomy agent, so the data cannot be compared with any other similar study.

Based on the findings of this study, it can be concluded that MTA is superior to formocresol and TCA in treating pulps in dogs. It is logical to believe that MTA is a more biologically acceptable material to the pulp tissue than is formocresol and TCA. However, bridge formation was seen in 50% of TCA cases after 8 weeks which is a desirable finding in pulpotomy procedures.

TCA is a material with a chemocauterisation effect used in medicine and dentistry. It is relatively inexpensive and available compared with MTA. No carcinogenic or mutagenic effect regarding this material has been reported. It is the first time TCA has been recommended as a pulpotomy agent.

Although necrosis was not reported in any of the TCA cases, and bridge formation was seen in 50% of the cases after 8 weeks, more clinical studies are encouraged before TCA can be recommended as a pulpotomy medicament in clinical practice.

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