

CLINICAL & RADIOGRAPHIC ASSESSMENT OF THE RELATIVE EFFICACY OF 1:5 CONCENTRATION OF BUCKLEY'S FORMOCRESOL, 5% SODIUM HYPOCHLORITE (NaOCl) AND BIODENTINE™ IN PULPOTOMIES FOR PRIMARY MOLARS: A RANDOMIZED CONTROLLED CLINICAL TRIAL

Mohamed Saber Elsherbini* and Hossam Mohamed Mossa**

ABSTRACT

Background: A pulpotomy therapy, aims to maintain radicular vitality of the pulp, stopping pain and inflammation, and preserving the tooth in the mouth until the eruption of its successor tooth.

Aim: To evaluate clinically and radiographically the efficacy of formocresol, 5% Sodium hypochlorite and Biodentine™ in pulpotomies of primary teeth and following up for 3-,6, and 12-months periods.

Materials and Methods: 75 primary teeth were selected and were randomly classified into three groups, 25 teeth each. In group I, all teeth received pulpotomy treatment by using formocresol. In group II, 5% Sodium hypochlorite was used, and for group III, Biodentine™ (tricalcium silicate) was used as pulpotomy medication. After 3, 6, and 12 months, the three groups were assessed clinically and radiographically.

Results Clinical & radiographic success rates were 100% at 3-months follow-up period for all groups. At 6-months, success rates clinically were 100% for all groups, while radiographically, it reduced in group I and II to be 96% and 91% respectively. After one year, the clinical and radiographic success rates for group I were 96% and 87.5%, and for group II were 91% and 87%, while for group III were 100%, and 96%. Biodentine group recorded the highest clinical and radiograph success rates after one-year follow-up. There was no statistically significant difference among the three groups.

Conclusion Biodentine and 5% NaOCl indicated comparable outcomes to formocresol. hence, they could be promising alternatives medications in Iry teeth pulpotomies. There was no significant difference between groups.

KEYWORDS Pulpotomy, formocresol, tricalcium silicate, Biodentine, Sodium hypochlorite.

Abbreviations: FC, NaOCl. PCO

* Assistant Professor in Pediatric Dentistry, College of Dentistry, Buraidah Private Colleges, Qassim, KSA.
Lecturer of Pediatric & Community Dentistry, College of Dentistry, Assiut University, Assiut, Egypt

** Assistant Professor in Department of Restorative Sciences, College of dentistry ,Buraidah private collages , Qassim, KSA.

INTRODUCTION

The preservation of primary dentition is critical for the integrity of arch length, aesthetics, mastication, speech, and the prevention of abnormal oral habits ^[1]. Pulpotomy, in which the coronal pulp is removed and the radicular pulp tissues are left with the application of a medication at the root canal entrance to fix, preserve, or stimulate the repair of the vital remaining pulp, is the treatment of choice for retaining deep carious primary molars with affected pulp ^[2].

Several pulpal medications have previously been used in the vital pulp therapy of human primary teeth. The formocresol, at a 1:5 dilution, introduced by Buckley in the form of 19% formaldehyde and 35% tricresol in an aqueous solution of glycerin and water, was the gold standard medication used and allowed to devitalize and mummify the entire radicular pulp. It has bactericidal and fixative properties. Its clinical success rates range from 70% to 97%, while radiographic success rates are typically lower; both clinical and radiographic success rates decline over time ^[3-5].

One of the most serious concerns concerning the long-term safety of FC on human health. Toxicity ^[6, 7], postoperative systemic transport [8, 9], possible carcinogenicity ^[10], adverse radiographic modifications in treated teeth, and negative effects in succedaneous tooth enamel have all been observed.

A report has been issued on Carcinogens, in 2011 stating that 'Formaldehyde is a known human carcinogen based on significant evidence of carcinogenicity from human research and supporting data on carcinogenesis pathways ^[11]. new alternatives to high formaldehyde-content medications that interact with vascularized connective tissue within children's dental pulps must be identified and implemented ^[12]. As a result, several alternative materials have been proposed as replacements for FC, including: electrosurgery ^[13], lasers ^[14], glutaraldehyde ^[15], calcium hydroxide ^[16], freeze-dried

bone ^[17], bone morphogenetic protein ^[18], osteogenic proteins ^[19], ferric sulfate (FS) ^[20], mineral trioxide aggregate (MTA) ^[21], sodium hypochlorite (NaOCl) ^[22] and Biodentine ^[23].

In several clinical trials of vital pulp therapy in primary molars, 5 percent NaOCl compared to 15.5 percent (Fe₃)₂(SO₄)₃ as a preservative drug in pulpotomy of primary teeth achieved equivalent treatment effects ^[22].

A retrospective study using 5% NaOCl as a pulpotomy medicament revealed significant clinical radiographic success rates over a mean follow-up time of 10.5 months ^[24]. NaOCl is also biocompatible with pulp tissue and has been used as an endodontic irrigant in permanent teeth for decades ^[25].

Biodentine TM is a tricalcium silicate (Ca₃SiO₅)-based nonmetallic inorganic restorative cement marketed as a "bioactive dentine substitute" ^[26]. When compared to its competitors, the material is said to have significantly better physical and biological properties, including material handling, shorter setting time, higher compressive strength, increased density, decreased porosity, and induction of reparative dentine synthesis ^[27]. Despite the lack of clinical evidence, Biodentine TM appears to be a suitable substitute for other tricalcium silicate-based cements.

The purpose of this study was to evaluate the clinical and radiographic efficacy of three different medications (FC as a devitalizing agent, NaOCl as a preservative agent, and BiodentineTM as a regenerative agent) in vital pulpotomies of human primary molars over a 12-month period.

MATERIALS AND METHODS

Study design

A parallel design, randomized controlled clinical trial, double-blind with equal allocation ratio was performed.

The PICOT question was: Did patients receiving pulpotomy treatment for deep decay in primary molars (Population; P) using Biodentine™ or 5% Sodium hypochlorite (Intervention; I) show comparable or increased clinical and radiographic success when compared to pulpotomy using one-fifth Buckley's formocresol (Control; C) when following a set of specified criteria (Outcome; O) when following a set of specified (Time; T).

Sample size and power calculation

For binary primary outcome measures, the sample size was determined using Sealed envelope TM (Sealed Envelope Ltd, London, UK), and 20 teeth per group were required to detect a significant difference with a two-sided type I error of 5% and 80 percent power. To account for dropout during follow-up or other causes of attrition, the sample size was raised by 25%. As a result, each group was given a sample size of 25 people.

Ethical regulation

The treatment processes, as well as any potential discomforts or risks against advantages, as well as the duration of follow-up, were thoroughly discussed to the patients and their parents or guardians. Prior to the start of the study, an informed consent was also obtained.

The ethical committee of Qassim University's College of Dentistry has given their permission to the proposal with the registration number ST/6087/2020. The research was carried out throughout the months of January and February of 2020. By withholding information regarding the therapy group to which the patients and their parents were assigned, the patients and their parents were rendered blind.

Participants

This study included 75 mandibular primary teeth (1st and 2nd molars) from 60 seemingly healthy cooperative children who were classified as ASA I by the American Society of Anesthesiologists and

had at least one carious primary molar indicated for pulpotomy. Their ages ranged between (4-8) years old, who were being treated at Orthodontics and Pediatric Dentistry Department, Faculty of Dentistry, Qassim University.

All selected molars were diagnosed with deep carious lesions and / or reversible pulpitis and required vital pulp therapy. The molars were initially assessed clinically and radiographically for important pulpotomies, however the ultimate diagnosis was verified intraoperatively based on clinical evidence.

The inclusion criteria were as follows ^[28]:

- Male and female healthy children without any systemic disease and / or immunocompromised children.
- Asymptomatic with a deep carious lesion.
- Primary molars with mechanical or traumatic exposure.
- There is no history of spontaneous pain or irreversible pulpitis.
- Normal radiographic findings
- Restorability with a stainless steel crown

The exclusion criteria were as follows ^[28]:

- History of spontaneous pain
- Evidence of pulp tissue necrosis.
- Presence of fistula and soft tissue swelling
- Exposures with purulent discharge or exudates.
- Pathological mobility.
- Tooth with excessive bleeding from the pulp chamber which does not stop spontaneously without using hemostatic agents or tooth with no pulpal bleeding.
- Internal or external root resorption (periapical or furcation radiolucency) and a wider periodontal ligament space on radiographs
- Physiologic root resorption of more than one-third of the root length.

Randomization and blinding

They were randomized to one of three parallel groups (two study groups and one control group) by an independent individual after tooth insertion, based on a set of randomized numbers created by a computer using Matlab 8.0 (The Mathworks Inc., Natick, MA, USA) software. Simple randomization was performed per tooth, similar to previously reported studies [4]. The randomization was hidden behind a sealed envelope.

Each tooth was assigned to one of the three arms based on the randomization;

Group I: included 25 primary molars which were treated using one-fifth diluted Buckley's formocresol FC (control group I)

Group II: included 25 primary molars which were treated using 5% sodium hypochlorite NaOCl solution (study group II)

Group III: included 25 primary molars which were treated using Biodentine™ (study group III)

The allocation was done by a trial-unrelated individual, and the allocation ratio was set to be equal.

All treated teeth were documented in all patient files, ensuring blindness at both the patient and investigator levels.

Clinical technique

Except for the medication used for pulpotomies, all treatment groups followed the same protocol.

1. Using 2 percent lidocaine with 1: 100,000 epinephrine as a local anesthetic (Astra, Westborough, MA, USA).
2. The treated teeth were isolated with a rubber dam.
3. A diamond round #440 bur (Brasseler USA, Savannah, GA, USA) was used in a high-speed hand piece with water cooling to eliminate caries and expose pulp chambers.

4. A spoon excavator was used to remove the coronal pulp.
5. Normal hemostasis was achieved by flushing the pulp chamber with 5 cc sterile saline and applying mild pressure with a cotton pellet after the infected pulp was removed. The pulp stumps were moistened with distilled water, and mild pressure was applied for 2 -3 minutes to achieve hemostasis. If hemostasis was not achieved after 5 minutes, it was presumed that the pulp tissue in the canal was infected, and the tooth was removed from the research.

The teeth were treated in the following ways, depending on the type of pulp medicament used:

In group I, a sterile cotton pellet moistened with a 1:5 concentration formocresol (Buckley's Formocresol, Sultan Health Care, Englewood, NJ, USA) was placed on the pulp stumps for 5 minutes before being covered with zinc oxide-eugenol with polymer reinforcement (IRM_, DENTSPLY Caulk, USA) dressing [29].

In group II, 5 percent NaOCl was made by diluting Clorox bleach (The Clorox Co., Oakland, CA, USA) containing 10% NaOCl in sterile ddH₂O 1: 1. Following hemostasis, the chamber was filled with a cotton pellet saturated in 5% NaOCl for 30 seconds. The pellet was removed, and the pulp chamber was filled with zinc oxide eugenol (ZOE), which was dressed with polymer reinforcement (IRM_, DENTSPLY Caulk, USA) [22].

Biodentine™ was used in group III according to the manufacturer's recommendations. The paste was made by mixing premeasured unit dose capsules in a titrator for 30 seconds at 4200 rpm and applying it to the pulp stumps. After a minimum of 2 mm of Biodentine was applied, it was coated with zinc oxide eugenol (ZOE) with polymer reinforcement (IRM, DENTSPLY Caulk, USA) dressing up to the occlusal level for hermetic sealing after 12 minutes of setting time [30].

Finally, all of the teeth were repaired in one appointment with a properly proportioned stainless steel primary molar crown (3M Unitek SP®, USA) with a well-fitting marginal adaptation and glass ionomer cement (Ketac-Cem; 3M ESPE, USA).

Parents and children were given general oral hygiene advice as well as special instructions for the treated tooth. Parents were informed of all potential outcomes and asked to report any post-operative pain, swelling, pus discharge, or discomfort in the treated tooth as soon as possible.

Clinical and radiographic follow-up

Over 3 months, 6 months, and 12 months, clinical and radiographic evaluations were performed using criteria developed by Sommez et al.^[51] and Vargas et al.^[22].

All pulpotomies were performed by a single operator, while all clinical and radiographic evaluations were performed by two blind investigators who were uninformed of their group assignment and had undergone comprehensive training.

For mandibular molars, digital periapical radiographs were taken with a Kodak® intraoral machine (model 2100) set at 70 Kv and 0.2 seconds of exposure duration. Before being exposed to radiation, patients were given a lead apron and a thyroid collar. A Rinn Snap-A-Ray was used to mount a size 0 ultra-speed dental film intraorally (DENTSPLY Rinn, Elgin, IL, USA).

The radiographs were collected at the following times:

- Preoperatively during the initial examination consultation.
- After pulpotomy and the application of a stainless steel crown (SSC).
- After 3 months, during the first radiographic follow-up.
- After 6 months, at the second radiographic follow-up.

- After a year, at the third radiographic follow-up.

Each chart contained the following information: (1) the identity of the tooth/teeth treated; (2) the clinical and radiographic condition of the tooth prior to treatment; (3) the date of treatment; (4) the date of follow-up(s); (5) the clinical condition of the pulpotomized tooth at follow-up; and (6) the postoperative radiographic findings.

Cohen's unweighted kappa statistic was used to calculate inter and intra-examiner reproducibility ($k = 0.87$ and 0.90 for inter and intra-examiner reproducibility, respectively).

The following indications and symptoms were recorded on standardized forms, and any of them were considered failures:

- (1) a history of spontaneous pain, (2) a consistent complaint of tenderness to percussion/palpation, (3) mobility, (4) swelling, and (5) Fistula or sinus tract

If any of these failure parameters were not satisfied, the treatment was considered a clinical success.

Radiographic success was defined as the absence of (1) periapical/interradicular radiolucency, (2) periapical/interradicular radiolucency, and (3) periapical/interradicular radiolucency

The presence of pulp canal obliteration (PCO) on radiographs was detected, but it was not considered a treatment failure^[31].

Statistical analysis

In parallel, three distinct data sets were collected, compiled, and analyzed. The clinical and radiographic results were evaluated at 3, 6, and 12 months using IBM SPSS version 19.0, which categorizes and summarizes data using percentages and frequencies (Apache Software, Forest Hill, MD, USA). Chi-square tests were used at each follow-up evaluation to report differences in the success and failure rates among the three groups, with a significance level of $P < 0.05$.

RESULTS

Demographic characteristics

A total of 75 teeth of primary 1st and 2nd molars in 60 children (26 boys and 34 girls) were treated in this trial. Of the total number of teeth, 25 teeth were treated with formocresol (Figure 1), 25 teeth with 5% sodium hypochlorite (Figure 2), and 25 teeth with Biodentine™ (Figure 3). Overall, 72/75 (96%) teeth were available for the 3,6, and 12- months assessments (Figure 4). The subjects' ages ranged from 4 to 8 years at the time of treatment, with a mean of 6.000.7 years. Overall, mandibular molars made up (65 percent) of the treated teeth, whereas maxillary molars made up (35 percent) (35 percent), Table 1.

Clinical findings

(57/60) of the patients with 72 primary mandibular molars treated with vital pulpotomies returned for clinical and radiographic evaluations at the 3-month follow-up. (Formocresol=24 in group I, 5% NaOCl=23 in group II, and Bio dentine=25 in group III.) Ten primary mandibular first molars and 14 primary mandibular second molars were evaluated in group I during the first follow-up. There were nine primary mandibular first molars and 14 primary mandibular second molars in group II. Group III, on the other hand, included 11 primary mandibular first molars and 14 primary mandibular second molars.

Formocresol, sodium hypochlorite, and bio dentine demonstrated 100 percent clinical success for all treated teeth at both the 3- and 6-month follow-

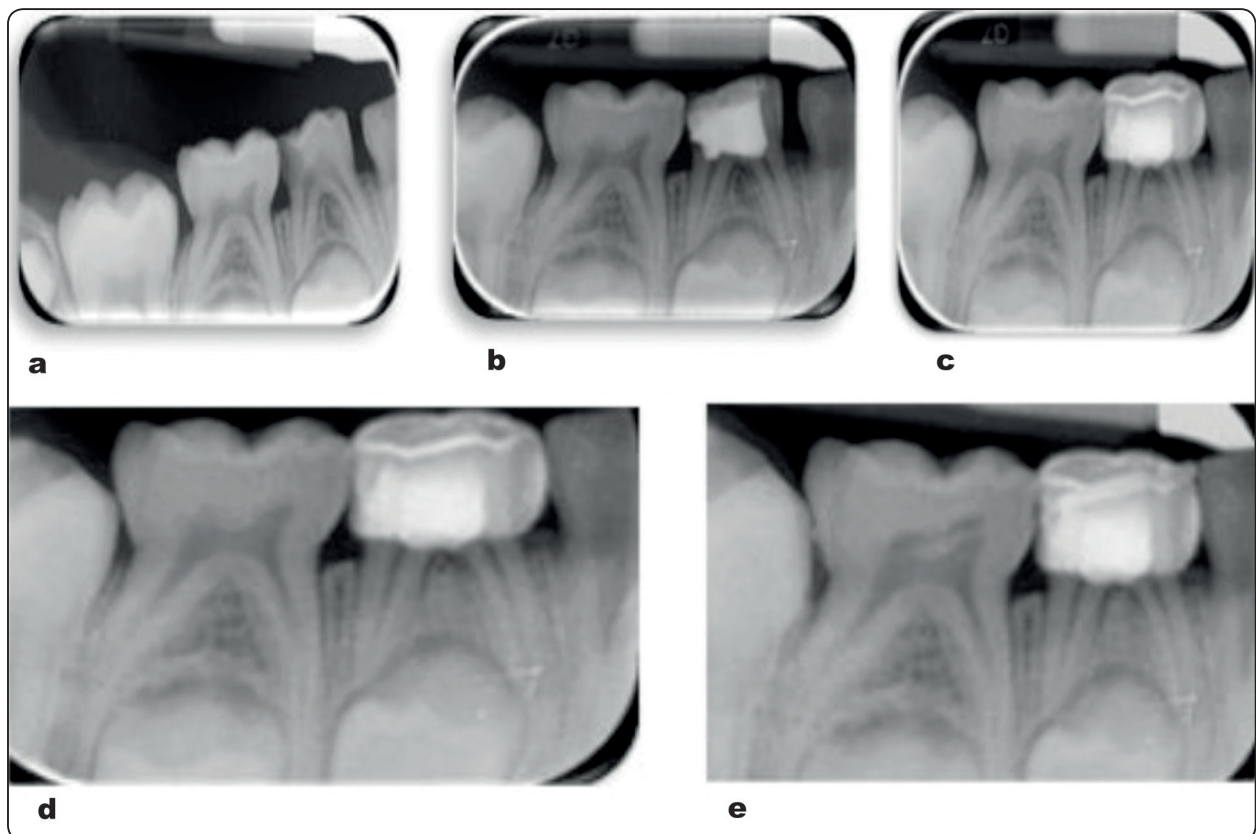


Fig. (1) Sample radiographs representative of radiographic changes in tooth #84 treated with FC (group I) during the follow-up. (a) preoperative radiograph, (b) immediate postoperative, (c) after 3-months, (d) after 6-months, and (e) after 12-months.

ups (Table 2). As a result, there was no statistically significant difference in total clinical success rate between the three groups at 3 and 6 months. All of the teeth were clinically asymptomatic at both time points, with no pain, sensitivity, swelling, tenderness to percussion, abscess, fistulation, or tooth mobility.

At the 12-month clinical follow-up, 4 percent (1/24) of the treated teeth in the formocresol group showed clinical signs of failure, whereas 9 percent (2/23) of the treated teeth in the 5 percent NaOCl group showed clinical signs of failure. However, none of the Biodentine-treated teeth in Group III showed clinical signs of failure (Table 2). One of the failure indicators was pain on percussion (1 case in group I and 2 cases in group II) (Table 3).

Radiographic findings

During the three-month follow-up period, all treated teeth in all groups were radiographically

successful. There was no statistically significant difference in total radiography success between the three groups after three months. On any of the radiographs, there was no evidence of PDL widening, internal resorption, exterior resorption, furcation radiolucency, or periapical radiolucency (Table3).

The only radiographic finding in the Biodentine and formocresol groups was PCO, which was observed in 10/56 (17.9%) and 7/56 (12.5%) cases, respectively.

At the 6-month follow-up, all of the Biodentine group's treated teeth were radiographic success. Radiographic changes were observed in 4% (1/24) of formocresol cases and 9% (2/23) of 5% NaOCl pulpotomies treatment groups (Table 3). All of the unsuccessfully treated teeth were attributed to internal resorption (Table 3).

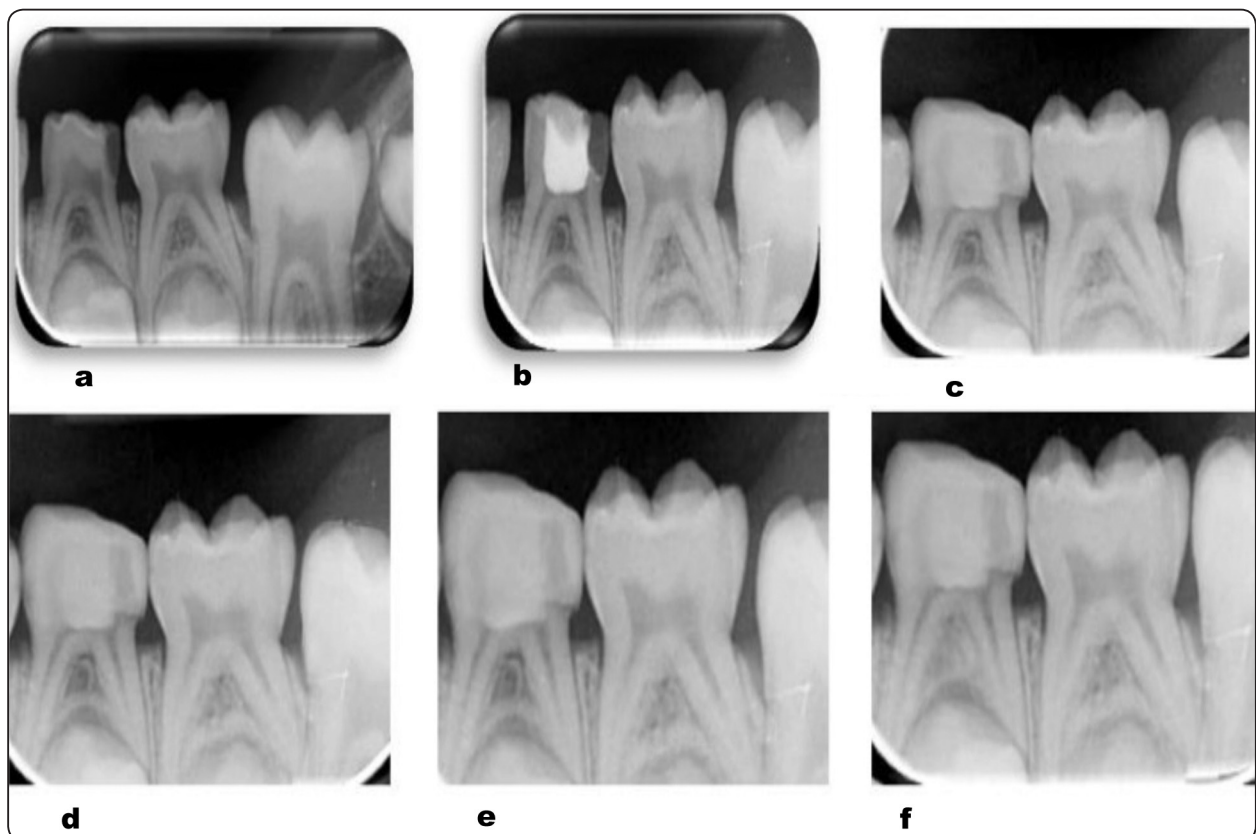


Figure 2 Sample radiographs representative of radiographic changes in tooth #74 treated with 5% NaOCl (group I) during the follow-up. (a) preoperative radiograph, (b) immediate postoperative, (c) after full coverage with SSE, (d) after 3-months, (e) after 6-months, and (f) after 12-months.

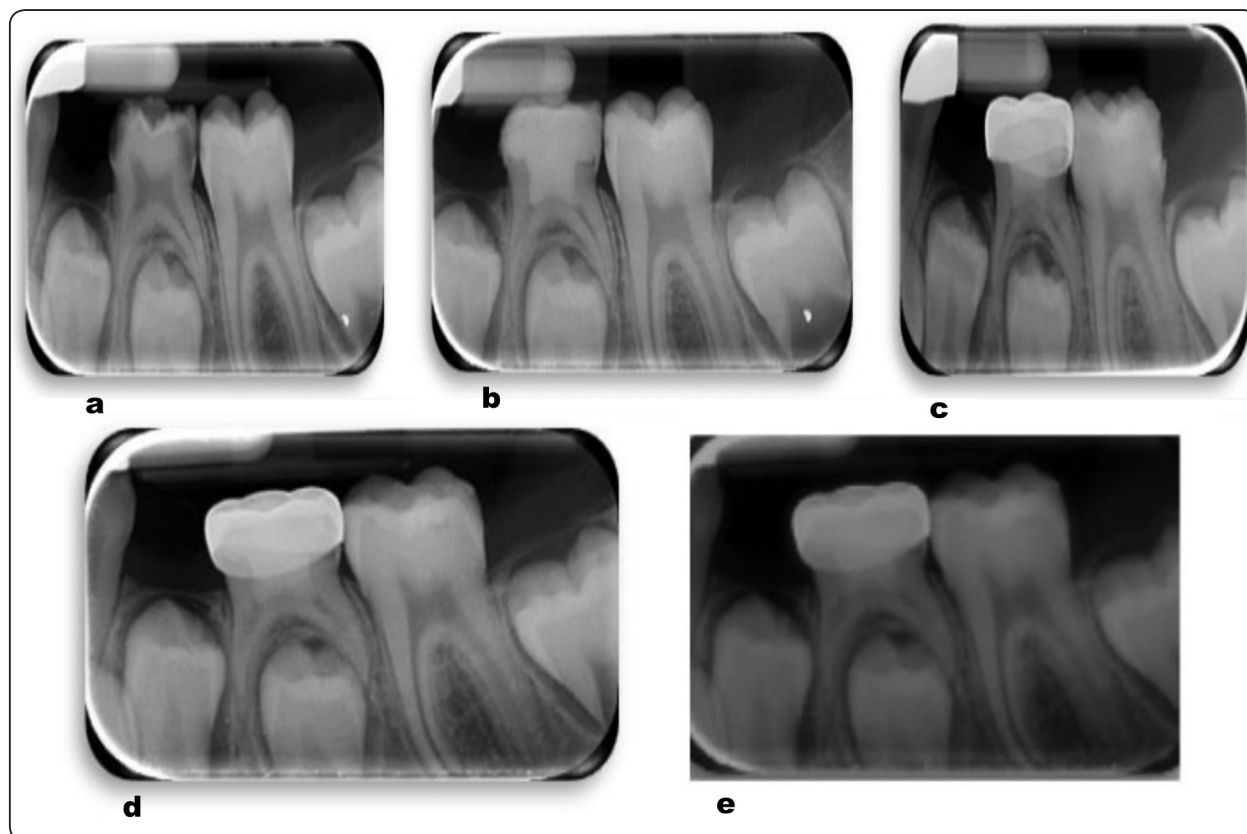


Fig. (3) Sample radiographs representative of radiographic changes in tooth #75 treated with Biodentine™ (group III) during the follow-up. (a) preoperative radiograph. (b) immediate postoperative. (c) after 3-months, and (d) after 6-months, and (e) after 12-months.

At the 12-month follow-up, 12.5 percent (3/24) of the formocresol-treated teeth had pathological alterations in the periapical radiograph, compared to 13 percent (3/23) in the 5% NaOCl group and 4 percent (1/25) in the Biodentine pulpotomies group (Table 2). Internal resorption was associated with three of these failures (one with formocresol groups and two with 5% NaOCl), and furcation involvement was associated with two treated teeth in the FC group, one tooth in the NaOCl group, and one instance in the Biodentine group (Table 3).

Calcific obliterations of the pulp were observed in 4/25 (16%) and 3/24 (12.5%) cases in the Biodentine and formocresol groups, respectively. Clinical and radiographic outcomes did not differ significantly ($P>0.05$) between the three groups (formocresol, 5% NaOCl, and bio dentine). To the nearest whole number, all percentages are rounded. The data is provided in the form of n. (percent).

TABLE (1) Showing demographic data

	Patients n	Teeth n
Total	60	75
Males	26	30
Females	34	45
4 years	8	8
5 years	17	18
6 years	21	28
7 years	7	10
8 years	7	11
1 st molars		26
2 nd molars		49

TABLE (2) Showing frequencies and percentages of clinical successes and failure rate after one-year follow-up .

	Clinical Evaluation[n (%)											P- value	
	3 months				6 months				12 months				
	Success		Failure		Success		Failure		Success		Failure		
	N	%	N	%	N	%	N	%	N	%	N		%
Formocresol	24	100	0	0	24	100	0	0	23	96	1	4	0.315
5% NaOCl	23	100	0	0	23	100	0	0	21	91	2	9	0.331
Bio dentine	25	100	0	0	25	100	0	0	25	100	0	0	---

TABLE (3) Showing frequencies and percentages of radiographic successes and failure rate after one-year follow-up

	Radiographic Evaluation [n (%)											P- value	
	3 months				6 months				12 months				
	Success		Failure		Success		Failure		Success		Failure		
	N	%	N	%	N	%	N	%	N	%	N		%
Formocresol	24	100	0	0	23	96	1	4	21	87.5	3	12.5	0.347
5% NaOCl	23	100	0	0	21	91	2	9	20	87	3	13	0.299
Bio dentine	25	100	0	0	25	100	0	0	24	96	1	4	0.315

TABLE (4) Showing frequencies and percentages of clinical & radiographic sign and symptoms of failed cases after one-year follow-up

	Clinical assessment			Radiographic assessment		
	Formocresol	5% NaOCl	Bio dentine	Formocresol	5% NaOCl	Bio dentine
Spontaneous Pain	0	0	0	0	0	0
Swelling	0	0	0			
Pain on percussion	1	2	0			
Pain on palpation	0	0	0			
Mobility	0	0	0			
Sinus tract or fistula	0	0	0			
Internal resorption				1	2	
External resorption				0	0	0
Periodontal ligament widening				0	0	0
Furcation involvement				2	1	1

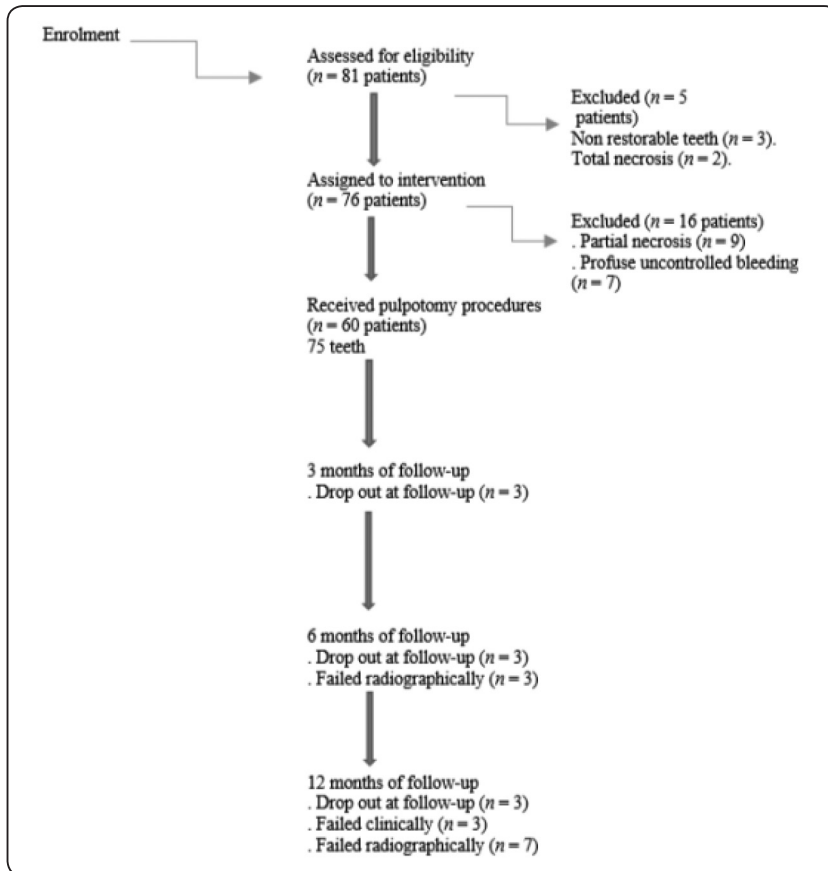


Fig. (4) Flowchart of participating children and teeth up to 12 months. that received FC, 5% NaOCl, and Biodentine pulpotomies.

DISCUSSION

One of the most important characteristics of any drug used in pulpotomies on primary teeth is that it maintains the pulp and surrounding tissues in a physiological state, resulting in high clinical and radiographic success rates. FC is composed of 19% formaldehyde and 35% cresol in a 15% glycerin and water (Buckley's solution) carrier^[32]. Formocresol has excellent fixative properties as well as the ability to mummify a large area of remaining pulp tissue, which results in a high success rate for teeth treated with it^[33].

Formocresol pulpotomy, on the other hand, caused an increase in chromosomal breaks and abnormalities in peripheral lymphocytes, indicating a mutagenic effect in the pediatric patient. Furthermore, when exposed to formaldehyde, primary tooth pulp tissue contains a large number of undifferentiated stem cells, which have a high proclivity for mutagenesis^[34].

As a result, the American Academy of Pediatric Dentistry (AAPD) advocates for more research into novel procedures and drugs that are biologically compatible. These suggestions prompted us to conduct this study, which compared the efficacy of 5 percent NaOCl and Biodentine as pulpotomy dressing materials in primary teeth to that of formocresol^[35].

Histological studies have shown that NaOCl, as a pulpotomy medication, improves the removal of blood clots and stops hemorrhage, which interferes with pulp healing^[36]. After pulp amputation, microorganisms may remain in the pulp canal orifices, causing an inflammatory reaction. The antimicrobial properties of NaOCl improved the pulp's healing potential and the success rates of the treated teeth^[37].

Recent advances in dentistry have been seen with the introduction of new bio inductive and regenerative dental products such as BiodentineTM^[37].

There is plenty of evidence that it has beneficial effects when it comes into contact with essential pulp tissue [38,39]. It can induce tertiary dentin apposition by stimulating odontoblasts and promote the early development of reparative dentin by inducing tertiary dentin. Because of its high pH (pH = 12),

Biodentine™ possesses superior antimicrobial properties, as well as high biocompatibility and bioactivity [40,41]. Collado-Gonzalez et al. demonstrated that Biodentine™ outperformed MTA Angelus in terms of cysto-compatibility and bioactivity on stem cells from human exfoliated primary teeth [42]. This prompted its application in pulpotomy.

The chosen patients in the current clinical trial ranged in age from 4 to 8 years old. In this age range, the operator could achieve good patient cooperation, and physiological root resorption would not interfere with the reported results as one of the confounding factors.

Teeth were selected based on precise clinical and radiological criteria in order to avoid and reduce failure due to faulty diagnosis, ensuring – to a large extent – the absence of irreversible changes in the tooth pulp. Selective teeth were treated in a single visit by a single operator using the same procedure, avoiding intra-operator differences. All treated teeth were also fitted with appropriately sized stainless steel crowns to ensure an adequate seal against both immediate and long-term micro-leakage at the restoration interface [43]. Because failure of a primary molar pulpotomy is most likely revealed in the furcation or periapical area, periapical radiographs were chosen as a baseline comparison for the anticipated follow-ups [44].

Two experienced pediatric dentists (aside from the operator) who were full-time faculty members and blinded to the type of materials being evaluated performed clinical and radiographic follow-up on all pulpotomized teeth at 3, 6, and 12 months. The score assessment's goal was to label all treated teeth as "success" or "failure" based on isolated signs and

symptoms. Similar scoring based on the presence or absence of clinical and radiographic signs was used in a study by Salem et al. [45]

Based on clinical score evaluation, the overall success rates for FC, 5% NaOCl, and Biodentine groups were all 100 percent in the current study. The results were 96 percent, 91 percent, and 100 percent after 3 months, 6 months, and 12 months of period follow-up, respectively. Furthermore, at the three-month follow-up, all three groups had a radiographic success rate of 100 percent. On radiographic examination, there was no PLS widening, bone lesion, or pathological root resorption. Radiographic success rates in groups I, II, and III were 96 percent, 91 percent, and 100 percent, respectively, after a 6-month follow-up period. However, at the last follow-up period after 12- months, the success rates were with percentages 87.5%, 87%, and 96% in the three groups respectively.

Clinical and radiographic outcomes did not differ significantly ($P > 0.05$) between the three groups (formocresol, 5% NaOCl, and bio dentine). To the nearest whole number, all percentages are rounded. The data is provided in the form of n. (percent). The study found that the three medicines had comparable clinical and radiological success rates.

Al-Mutairi and Bawazir [46] discovered that after 12 months, the clinical and radiographic success rates of 5% NaOCl pulpotomy were 94.6 and 86.5 percent, respectively, which was equivalent to FC pulpotomy. Furthermore, J. D. Ruby et al., 2013 [47] discovered that when FC diluted 1: 5 to 3 percent NaOCl was used as a pulpal medicament in primary molar pulpotomy, the radiographic outcomes were identical after 6 and 12 months. NaOCl has an 86 percent success rate and FC has an 84 percent success rate after 6 months, while FC has a 90 percent success rate after 12 months.

In another study, Vargas et al [22]. compared 5% NaOCl versus 15.5% $(Fe_3)_2(SO_4)_3$ for pulpotomies in primary molars. Their study reported 100% clinical success at 6 and 12 months, 91% radiographic

success at 6 months, and 79% radiographic success at 12 months with 5% NaOCl. The primary cause of radiographic failure in their study was internal root resorption, whereas our clinical trial demonstrated three failures as a result of internal resorption and four failures owing to furcation involvement after 12-months follow-up periods. Shabzendedar et al.^[48], compared Sodium hypochlorite vs formocresol as pulpotomy medicaments in primary molars: and demonstrated comparable success rates to the previous studies.

Biodentine™ has a similar success rate, according to several studies^[30,38,40]. After a 12-month follow-up with the same sample size (25 cases), Rajasekharan et al. achieved 96 percent clinical success with Biodentine™^[30]. Furthermore, the results of this study are consistent with those of Kusum et al., who discovered that Biodentine™ had a 100% overall clinical success rate after nine months of follow-up^[38].

Furthermore, Cuadros-Fernandez et al. discovered that the Biodentine™ group had a 97 percent clinical success rate after 12 months of treatment^[49]. Using Biodentine™ as a pulp-dressing substance, El Meligy also achieved 100 percent clinical success in all pulpotomized teeth^[41].

The Biodentine™ 96 percent radiographic success rate is consistent with Rajasekharan et al.^[30]'s 96 percent⁽¹⁷⁾ success rate at 12 months, but El Meligy et al. reported a slightly higher number (100 percent)^[41]. Furthermore, Cuadros et al. reported a similar outcome, with 94.9 percent radiographic success, one molar exhibiting internal root resorption and the other exhibiting periradicular radiolucency^[49].

Kusum et al. discovered 4% non-perforated internal resorption in pulpotomized primary tooth cases in the Biodentine™ group after 9 months of radiographic monitoring in Biodentine™ on pulpotomized primary molars. In addition, 8% of the Biodentine™ group experienced external root resorption^[38].

Biodentine™ releases a large amount of calcium ions during the initial setup time and lowers long-term ion release, resulting in favorable pulp repair circumstances [50]. A PCO with significant odontoblast-like cell activation and dentin apposition is seen as a favorable response to stimulation and an indication of healing. It's a sign that the tooth's pulp is still alive and well after a long period of time^[39].

At the radiographic evaluation at 12 months, four teeth (16%) showed Pulp calcific obliterations (PCO) and 3/24 (12.5%) cases in formocresol groups out of 25 treated primary molars with Biodentine™. This Biodentine percentage was comparable to that reported by Kusum et al (16%)^[38]. This percentage of PCO, however, is lower than that reported by Rajasekharan et al. (2017), who obtained a percentage of 48%³⁰. This difference could be attributed to different ages, teeth, or clinical techniques used.

The proper inclusion and exclusion criteria for case selection, patient availability at scheduled follow-up visits, high aseptic standards, correct clinical technique, and a properly sized final restoration that prevents micro leakage were all factors in the current study's clinical and radiographic success. It may also be due to Biodentine™'s biocompatibility, bioactivity, and sealing ability. The formation of hydroxyapatite crystals at the surface improves this material's sealing capacity, allowing it to maintain effective marginal integrity^[51].

Trial limitations

The subjects in this study came from various countries and had varying levels of fluoride exposure. In addition, because each medicine had its own fabrication instructions, blinding the operator was not possible in this trial.

A split-mouth design was not used because it is uncommon to find contralateral primary molars in the same arch that are suitable for pulpotomy and meet the same clinical and radiographic criteria.

Furthermore, while the 12-month follow-up of the treated teeth ensured the majority of patients' commitment to follow-up visits, it was too short for analyzing the long-term outcome of pulpotomy and success rate.

Generalizability

In order to reduce failure due to incorrect diagnosis, all patients in this study were treated in ideal clinical settings in terms of clinical inclusion and exclusion criteria, which confirmed definite diagnosis of each case and the lack of irreversible changes in the tooth pulp.

The radiography process was standardized by using a uniform paralleling technique to eliminate any distortion in the vertical dimension and to generate consistent images.

In a single visit, only one operator performs all pulpotomy procedures on all study subjects using the same technique, removing any deviations due to clinical performance differences between physicians. All of the treated teeth received stainless steel crowns, removing the possibility of restorative failure.

All clinical and radiographic evaluations were performed by two investigators who had previously been trained and calibrated, removing the learning curve associated with the use of new equipment.

CONCLUSION

The study's findings lead to the following conclusions:

1. Biodentine™ and 5% Sodium hypochlorite are promising alternatives to one-fifth diluted Buckley's formocresol for pulpotomies in human primary teeth, with comparable clinical and radiographic success rates and no statistically significant differences.

2. Biodentine™ outperforms one-fifth Buckley's Formocresol and 5% Sodium hypochlorite as a pulpotomy medication over a one-year period.

CONFLICT OF INTEREST

In accordance with my ethical obligations as a researcher, I am reporting that I received no funding from any company or organization that may be impacted by the research described in the enclosed paper. The study was entirely self-funded.

REFERENCES

1. Fuks AB, Eidelman E. Pulp therapy in the primary dentition. *Curr Opin Dent*. 1991 Oct;1(5):556-63. PMID: 1807455.
2. Pilipili CM, Vanden Abbeele A, van den Abbeele K. La pulpotomie de la dent temporaire [Pulpotomy of deciduous teeth]. *Rev Belge Med Dent* (1984). 2004;59(3):156-62. French. PMID: 15526642.
3. Farooq NS, Coll JA, Kuwabara A, Shelton P. Success rates of formocresol pulpotomy and indirect pulp therapy in the treatment of deep dentinal caries in primary teeth. *Pediatr Dent*. 2000 Jul-Aug;22(4):278-86. PMID: 10969431.
4. Huth KC, Paschos E, Hajek-Al-Khatir N, Hollweck R, Crispin A, Hickel R, Folwaczny M. Effectiveness of 4 pulpotomy techniques--randomized controlled trial. *J Dent Res*. 2005 Dec;84(12):1144-8. doi: 10.1177/154405910508401210. PMID: 16304444.
5. Sonmez D, Sari S, Cetinbaş T. A Comparison of four pulpotomy techniques in primary molars: a long-term follow-up. *J Endod*. 2008 Aug;34(8):950-5. doi: 10.1016/j.joen.2008.05.009. PMID: 18634926.
6. Ranly DM, Horn D. Assessment of the systemic distribution and toxicity of formaldehyde following pulpotomy treatment: Part two. *ASDC J Dent Child*. 1987 Jan-Feb;54(1):40-4. PMID: 3468141.
7. Block RM, Lewis RD, Hirsch J, Coffey J, Langeland K. Systemic distribution of 14C-labeled Paraformaldehyde incorporated within Formocresol following pulpotomies in dogs. *J Endod*. 1983 May;9(5):176-89. doi: 10.1016/S0099-2399(83)80090-9. PMID: 6574206.
8. Auerbach C, Moutschen-Dahmen M, Moutschen J. Genetic and cytogenetical effects of formaldehyde and related compounds. *Mutat Res*. 1977;39(3-4):317-61. doi: 10.1016/0165-1110(77)90011-2. PMID: 331091.
9. Garcia-Godoy F. Radiographic evaluation of root canal "calcification" following formocresol pulpotomy. *ASDC J Dent Child*. 1983 Nov-Dec;50(6):430-2. PMID: 6581183.

10. Alacam A. Long term effects of primary teeth pulpotomies with formocresol, glutaraldehyde-calcium hydroxide and glutaraldehyde-zinc oxide eugenol on succedaneous teeth. *J Pedod.* 1989 Summer;13(4):307-13. PMID: 2517844.
11. National Toxicology Program. NTP 12th Report on Carcinogens. Rep Carcinog. 2011;12: iii-499. PMID: 21822324.
12. Patchett CL, Srinivasan V, Waterhouse PJ. Is there life after Buckley's formocresol? Part II - Development of a protocol for the management of extensive caries in the primary molar. *Int J Paediatr Dent.* 2006 May;16(3):199-206. doi: 10.1111/j.1365-263X.2006.00687.x. PMID: 16643542.
13. Sasaki H, Ogawa T, Koreeda M, Ozaki T, Sobue S, Ooshima T. Electrocoagulation extends the indication of calcium hydroxide pulpotomy in the primary dentition. *J Clin Pediatr Dent* 2002; 26:275e7.
14. Saltzman B, Sigal M, Clokie C, Rukavina J, Titley K, Kulkarni GV. Assessment of a novel alternative to conventional formocresol-zinc oxide eugenol pulpotomy for the treatment of pulpally involved human primary teeth: diode laser-mineral trioxide aggregate pulpotomy. *Int J Paediatr Dent.* 2005 Nov;15(6):437-47. doi: 10.1111/j.1365-263X.2005.00670.x. PMID: 16238654.
15. Adlakha VK, Chandna P, Joshi J, Thomas A, Singh N. A comparative evaluation of hydroxyapatite crystals and glutaraldehyde as agents for pulpotomy in deciduous molars. *Int J Clin Pediatr Dent.* 2009 Jan;2(1):13-22. doi: 10.5005/jp-journals-10005-1035. Epub 2009 Apr 26. PMID: 25206093; PMCID: PMC4086550.
16. Gruythuysen RJ, Weerheijm KL. Calcium hydroxide pulpotomy with a light-cured cavity-sealing material after two years. *ASDC J Dent Child.* 1997 Jul-Aug;64(4):251-3. PMID: 9328675.
17. Langeland K. Re: A comparison of pulpal response to freeze-dried bone, calcium-hydroxide, and zinc oxide-eugenol in primary teeth in two cynomolgus monkeys. S Fadavi, AW Anderson. *Pediatr Dent* 18:52-56, 1996. *Pediatr Dent.* 1996 May-Jun;18(3):190-3. PMID: 8784907.
18. Nakashima M. Induction of dentin formation on canine amputated pulp by recombinant human bone morphogenetic proteins (BMP)-2 and -4. *J Dent Res.* 1994 Sep;73(9):1515-22. doi: 10.1177/00220345940730090601. PMID: 7929986.
19. Rutherford RB, Wahle J, Tucker M, Rueger D, Charette M. Induction of reparative dentine formation in monkeys by recombinant human osteogenic protein-1. *Arch Oral Biol.* 1993 Jul;38(7):571-6. doi: 10.1016/0003-9969(93)90121-2. PMID: 8368953.
20. Fei AL, Udin RD, Johnson R. A clinical study of ferric sulfate as a pulpotomy agent in primary teeth. *Pediatr Dent.* 1991 Nov-Dec;13(6):327-32. PMID: 1843987.
21. Agamy HA, Bakry NS, Mounir MM, Avery DR. Comparison of mineral trioxide aggregate and formocresol as pulp-capping agents in pulpotomized primary teeth. *Pediatr Dent.* 2004 Jul-Aug;26(4):302-9. PMID: 15344622.
22. Vargas KG, Packham B, Lowman D. Preliminary evaluation of sodium hypochlorite for pulpotomies in primary molars. *Pediatr Dent.* 2006 Nov-Dec;28(6):511-7. PMID: 17249432.
23. Kaur M, Singh H, Dhillon JS, Batra M, Saini M. MTA versus Biodentine: Review of Literature with a Comparative Analysis. *J Clin Diagn Res.* 2017;11(8):ZG01-ZG05. doi:10.7860/JCDR/2017/25840.10374
24. Vostatek SF, Kanellis MJ, Weber-Gasparoni K, Gregorsok RL. Sodium hypochlorite pulpotomies in primary teeth: a retrospective assessment. *Pediatr Dent.* 2011 Jul-Aug;33(4):327-32. PMID: 21903000.
25. Cox CF, Hafez AA, Akimoto N, Otsuki M, Mills JC. Biological basis for clinical success: pulp protection and the tooth-restoration interface. *Pract Periodontics Aesthet Dent.* 1999 Sep;11(7):819-26; quiz 827. PMID: 10853583.
26. Zanini M, Sautier JM, Berdal A, Simon S. Biodentine induces immortalized murine pulp cell differentiation into odontoblast-like cells and stimulates biomineralization. *J Endod.* 2012 Sep;38(9):1220-6. doi: 10.1016/j.joen.2012.04.018. Epub 2012 Jul 24. PMID: 22892739.
27. Rajasekharan S, Martens LC, Cauwels RG, Verbeeck RM. Biodentine™ material characteristics and clinical applications: a review of the literature. *Eur Arch Paediatr Dent.* 2014 Jun;15(3):147-58. doi: 10.1007/s40368-014-0114-3. Epub 2014 Mar 11. PMID: 24615290.
28. Caruso S, Dinoi T, Marzo G, Campanella V, Giuca MR, Gatto R, Pasini M. Clinical and radiographic evaluation of biodentine versus calcium hydroxide in primary teeth pulpotomies: a retrospective study. *BMC Oral Health.* 2018 Apr 2;18(1):54. doi: 10.1186/s12903-018-0522-6. PMID: 29609572; PMCID: PMC5879808.
29. Fuks AB. Vital pulp therapy with new materials for primary teeth: new directions and Treatment perspectives. *Pediatr Dent.* 2008 May-Jun;30(3):211-9. PMID: 18615986.

30. Rajasekharan S, Martens LC, Vandembuleke J, Jacquet W, Bottenberg P, Cauwels RG. Efficacy of three different pulpotomy agents in primary molars: a randomized control trial. *Int Endod J*. 2017 Mar;50(3):215-228. doi: 10.1111/iej.12619. Epub 2016 Mar 6. Erratum in: *Int Endod J*. 2020 Feb;53(2):288. PMID: 26863893.
31. Subramaniam P, Konde S, Mathew S, Sugnani S. Mineral trioxide aggregate as pulp capping agent for primary teeth pulpotomy: 2 year follow up study. *J Clin Pediatr Dent*. 2009 Summer;33(4):311-4. doi: 10.17796/jcpd.33.4.r83r38423x58h38w. PMID: 19725237.
32. Haghgoo R, Abbasi F. A histopathological comparison of pulpotomy with sodium hypochlorite and formocresol. *Iran Endod J*. 2012 Spring;7(2):60-2. Epub 2012 Jun 1. PMID: 23056120; PMCID: PMC3467126.
33. Havale R, Anegundi RT, Indushekar K, Sudha P. Clinical and radiographic evaluation of pulpotomies in primary molars with formocresol, glutaraldehyde and ferric sulphate. *Oral Health Dent Manag*. 2013 Mar;12(1):24-31. PMID: 23474578.
34. Zarzar PA, Rosenblatt A, Takahashi CS, Takeuchi PL, Costa Júnior LA. Formocresol mutagenicity following primary tooth pulp therapy: an in vivo study. *J Dent*. 2003 Sep;31(7):479-85. doi: 10.1016/s0300-5712(03)00087-3. PMID: 12927459.
35. American Academy of Pediatric Dentistry. Guideline on pulp therapy for primary and immature permanent teeth. Available at: "http://www.aapd.org/media/Policies_Guidelines/G_Pulp.pdf". Accessed November 10, 2015.
36. Hafez AA, Cox CF, Tarim B, Otsuki M, Akimoto N. An in vivo evaluation of hemorrhage control using sodium hypochlorite and direct capping with a one- or two-component adhesive system in exposed nonhuman primate pulps. *Quintessence Int*. 2002 Apr;33(4):261-72. PMID: 11989375.
37. Poggio C, Arciola CR, Dagna A, Chiesa M, Sforza D, Visai L. Antimicrobial activity of sodium hypochlorite-based irrigating solutions. *Int J Artif Organs*. 2010 Sep;33(9):654-9. doi: 10.1177/039139881003300911. PMID: 20963729.
38. Kusum B, Rakesh K, Richa K. Clinical and radiographical evaluation of mineral trioxide aggregate, biodentine and propolis as pulpotomy medicaments in primary teeth. *Restor Dent Endod*. 2015 Nov;40(4):276-85. doi: 10.5395/rde.2015.40.4.276. Epub 2015 Sep 9. PMID: 26587413; PMCID: PMC4650523.
39. Nowicka A, Lipski M, Parafiniuk M, Sporniak-Tutak K, Lichota D, Kosierkiewicz A, Kaczmarek W, Buczkowska-Radlińska J. Response of human dental pulp capped with biodentine and mineral trioxide aggregate. *J Endod*. 2013 Jun;39(6):743-7. doi: 10.1016/j.joen.2013.01.005. Epub 2013 Apr 10. PMID: 23683272.
40. Cohn C. Pulpotomy for Primary Teeth with Tricalcium Silicate Material. *Inside Dentistry*. 2013 Sept;9(9):7-11.
41. El Meligy OA, Allazzam S, Alamoudi NM. Comparison between biodentine and formocresol for pulpotomy of primary teeth: A randomized clinical trial. *Quintessence Int*. 2016;47(7):571-80. doi: 10.3290/j.qi.a36095. PMID: 27175451.
42. Collado-González M, García-Bernal D, Oñate-Sánchez RE, Ortolani-Seltenerich PS, Álvarez-Muro T, Lozano A, Forner L, Llana C, Moraleta JM, Rodríguez-Lozano FJ. Cytotoxicity and bioactivity of various pulpotomy materials on stem cells from human exfoliated primary teeth. *Int Endod J*. 2017 Dec;50 Suppl 2: e19-e30. doi: 10.1111/iej.12751. Epub 2017 Mar 17. PMID: 28169432.
43. Farsi N, Alamoudi N, Balto K, Mushayt A. Success of mineral trioxide aggregate in pulpotomized primary molars. *J Clin Pediatr Dent*. 2005 Summer;29(4):307-11. doi: 10.17796/jcpd.29.4.n80t77w625118k73. PMID: 16161395.
44. Erdem AP, Guven Y, Balli B, Ilhan B, Sepet E, Ulukapi I, Aktoren O. Success rates of mineral trioxide aggregate, ferric sulfate, and formocresol pulpotomies: a 24-month study. *Pediatr Dent*. 2011 Mar-Apr;33(2):165-70. PMID: 21703067.
45. Salem GA, Farouk YM. Clinical and radiographic evaluations of testing different concentrations of sodium hypochlorite as vital pulpotomy treatment in primary teeth: a randomized controlled trial. *J Arab Med Res* 2017; 12:106- 11
46. Al-Mutairi MA, Bawazir OA. Sodium hypochlorite versus Formocresol in primary molars pulpotomies: a randomized clinical trial. *Eur J Paediatr Dent*. 2013 Mar;14(1):33-6. PMID: 23597217.
47. Ruby JD, Cox CF, Mitchell SC, Makhija S, Chompu-Inwai P, Jackson J. A randomized study of sodium hypochlorite versus formocresol pulpotomy in primary molar teeth. *Int J Paediatr Dent*. 2013 Mar;23(2):145-52. doi: 10.1111/j.1365-263X.2012.01237. x. Epub 2012 Apr 13. PMID: 22502601.
48. Shabzendedar M, Mazhari F, Alami M, Talebi M. Sodium hypochlorite vs formocresol as pulpotomy medicaments in

- primary molars: 1-year follow-up. *Pediatr Dent*. 2013 Jul-Aug;35(4):329-32. PMID: 23930631.
49. Cuadros-Fernández C, Lorente Rodríguez AI, Sáez-Martínez S, García-Binimelis J, About I, Mercadé M. Short-term treatment outcome of pulpotomies in primary molars using mineral trioxide aggregate and Biodentine: a randomized clinical trial. *Clin Oral Investig*. 2016 Sep;20(7):1639-45. doi: 10.1007/s00784-015-1656-4. Epub 2015 Nov 18. PMID: 26578117.
50. De Rossi A, Silva LA, Gatón-Hernández P, Sousa-Neto MD, Nelson-Filho P, Silva RA, de Queiroz AM. Comparison of pulpal responses to pulpotomy and pulp capping with biodentine and mineral trioxide aggregate in dogs. *J Endod*. 2014 Sep;40(9):1362-9. doi: 10.1016/j.joen.2014.02.006. Epub 2014 Mar 18. PMID: 25146016.
51. Malkondu Ö, Karapinar Kazandağ M, Kazazoğlu E. A review on biodentine, a contemporary dentine replacement and repair material. *Biomed Res Int*. 2014; 2014:160951. doi: 10.1155/2014/160951. Epub 2014 Jun 16. PMID: 25025034; PMCID: PMC4082844.