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Sealing ability of white mineral trioxide aggregate mixed with 2.25% sodium hypochlorite gel used for repairing furcal perforations in primary molars: an in vitro study

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Abstract:

Objectives:

This study aimed to evaluate the sealing ability of mineral trioxide aggregate (MTA) and 2.25% sodium hypochlorite (NaOCl) gel mixture in repairing furcal perforation in primary molars using methylene blue dye penetration.

Materials and methods:

It was an in vitro experimental study. Sixty human primary molars were randomly divided into four groups (n = 15). Group 1 (MTA + distilled water (DW)): Furcal perforations were repaired with MTA and DW mixture. Group 2 (MTA + NaOCl gel): Furcal perforations were repaired with MTA and 2.25% NaOCl gel mixture. Group 3 (Positive control): Furcal perforations left untreated. Group 4 (Negative control): Primary molars with no furcal perforations. The primary molars underwent amputation 3 mm apical to the furcation area, then received a standard access cavity preparation. The flowable composite was used to seal the canal orifices and the apical end of each root. Clear nail varnish was applied to cover the cavity walls and pulpal floor. The molars' pulp chambers were placed in a 2% methylene blue solution for 24 hours. The samples were then cut into mesiodistal sections, and the extent of dye penetration was measured on each wall from the bottom of the perforation to the floor of the pulp chamber.

Results:

The dye penetration score for the MTA + DW group was 0.05 ± 0.05, followed by the MTA + NaOCl gel group (0.07 ± 0.07). The MTA + DW mixture did not outperform the MTA + NaOCl gel's sealing ability ($p = 1.000$). Both materials have good sealing ability since no statistically significant difference was noted with the negative control group ($p > 0.05$).

Conclusions:

The MTA + NaOCl gel mixture may serve as a viable alternative for repairing furcal perforations in primary molars.

Keywords: Sodium hypochlorite gel, White mineral trioxide aggregate, Furcal perforation, Sealing ability

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تقييم القدرة الخاتمة لمزيج هلام هيبوكلوريت الصوديوم 2.25% مع مركب ثلاثي الأكاسيد المعدنية الأبيض في سدّ انثقابات مفترق الجذور في الأرحاء المؤقتة: دراسة مخبرية

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الملخص:

الأهداف:

هدفت هذه الدّراسة المخبرية إلى تقييم القدرة الخاتمة لمزيج هلام هيبوكلوريت الصوديوم 2.25% مع مركب ثلاثي الأكاسيد المعدنية الأبيض في سدّ انثقابات مفترق جذور الأرحاء المؤقتة باستخدام صبغة الميثيلين الأزرق.

المواد والطرق:

قُسمت ستين رحى مؤقتة بشرية بشكلٍ عشوائي إلى أربع مجموعات (ن = 15). المجموعة 1: خُتمت الانثقابات بمزيج مركب ثلاثي الأكاسيد المعدنية الأبيض مع الماء المقطر. المجموعة 2: خُتمت الانثقابات بمزيج هلام هيبوكلوريت الصوديوم 2.25% مع مركب ثلاثي الأكاسيد المعدنية الأبيض. المجموعة 3 (شاهدة إيجابية): تُركت الانثقابات دون ختم. المجموعة 4 (شاهدة سلبية): لا تحوي الأرحاء المؤقتة على انثقابات صنعية. قُطعت جذور الأرحاء المؤقتة بمقدار 3 مم من قمة مفترق الجذور، ثم أُجري تحضير الحجرة اللبية. أُستخدم الراتنج السيال لإغلاق فوهات الأقنية والنهاية الذروية، ووضع طلاء أظافر لتغطية جدران وأرضية الحجرة. غُمست الأرحاء المؤقتة في محلول أزرق الميثيلين 2٪ لمدة 24 ساعة، ثم أُجري مقطع أنسي – وحشي، وتم قياس مدى اختراق الصبغة بالملم على كل جدار من أسفل الانثقاب الصنعي إلى أرضية الحجرة اللبية.

النتائج:

0.07) ملم، لم يتفوق مزيج مركب ثلاثي الأكاسيد المعدنية الأبيض مع الماء المقطر على مزيج هلام هيبوكلوريت الصوديوم 2.25% مع مركب ثلاثي الأكاسيد المعدنية الأبيض في جودة الختم ($p = 1.000$) تتمتع كلتا المادتين بقدرة خاتمة جيدة حيث لم يتم ملاحظة أي فرق ذي دلالة إحصائية مع المجموعة الشاهدة السلبية ($p > 0.05$).

الاستنتاجات:

يعتبر مزيج هلام هيبوكلوريت الصوديوم 2.25% مع مركب ثلاثي الأكاسيد المعدنية الأبيض بديلاً قابلاً للتطبيق لإغلاق انثقابات مفترق الجذور في الأرحاء المؤقتة.

الكلمات المفتاحية: هلام هيبوكلوريت الصوديوم، مركب ثلاثي الأكاسيد المعدنية الأبيض، انثقابات مفترق الجذور ، القدرة الخاتمة

Introduction:

Preserving primary dentition is the cornerstone for proper masticatory function, speech sound development, esthetics, and space maintenance [1]. However, dental caries is a widespread infectious disease that affects children and infant teeth and results in chronic pain, premature tooth loss, and malocclusion [2]. Caries experience and untreated tooth decay impact oral health-related quality of life (OHRQoL) [3]. Pulpotomy is a widespread treatment modality for teeth with reversible pulpitis that aims to surgically remove the inflamed coronal pulp tissue and dress the radicular pulp with a biocompatible agent [4]. Performing pulpotomies may seem relatively easy, but undergraduate students with limited experience, especially when dealing with young children, can encounter iatrogenic issues [5]. Iatrogenic furcal perforation is a significant complication that may occur while preparing endodontic access cavities or locating canal orifices in multirooted teeth [6]. Sealing perforations promptly with an appropriate repair material can improve the likelihood of preserving the tooth [7]. Mineral trioxide aggregate (MTA) exhibited numerous advantageous properties when applied as a repair material for furcal perforations, such as good sealing ability, biocompatibility, bactericidal properties, radiopacity, and the capacity to set even in the presence of blood [8]. MTA's extended setting time presents a difficulty in clinical applications, which is its primary drawback. The typical setting time in clinical practice was 3–4 hours, which may not be practical for pediatric dentistry [9]. Furthermore, the material is hard to handle because of its inconsistent texture, lack of significant antibacterial properties, and short working time when combined with distilled water. These drawbacks are substantial limitations in the field of pediatric dentistry [10].

The MTA mixture was enhanced with several accelerators to address these issues. Previous studies have shown that disodium hydrogen orthophosphate (Na_2HPO_4), calcium chloride ($CaCl_2$), sodium hypochlorite (NaOCl) gel, and KY jelly can effectively decrease the setting time [11]. NaOCl gel consists of a solution of NaOCl with a viscous amino acid solution of carboxymethylcellulose to provide viscosity [12]. The pH range goes from 10.4 to 11.0, making it alkaline, and it exhibits antibacterial behavior similar to that of 5.25% NaOCl solution [13]. The combination of MTA and NaOCl gel showed favorable working characteristics and enhanced the setting time [11, 13, 14, 15]. In addition, several studies in the literature provide evidence of the safety and biocompatibility of this mixture [14, 16]. The solubility of the metal trioxide complex remained zero when NaOCl gel was added to the mixture, making it a viable option for sealing furcal perforations [13]. This study aimed to evaluate the sealing ability of MTA and 2.25% NaOCl gel mixture in repairing furcal perforation in primary molars using methylene blue dye penetration. The null hypothesis is that mixing MTA with 2.25% NaOCl gel will not improve the sealing ability of the MTA in comparison with distilled water (DW).

Materials And Methods:

Study design and ethical considerations

This in vitro experimental study took place at the Department of Pediatric Dentistry, Faculty of Dentistry, Damascus University, during October 2024. Approval from the Local Ethics Committee of Damascus University was secured under N3501/2024, and the study followed Checklist for Reporting In-Vitro Studies (CRIS) guidelines [17]. Patients' legal guardians provided written informed consent for tooth donation, and extraction of human primary molars was performed due to pathological or orthodontic reasons.

Tooth selection and grouping

The determination of the sample size was based on the following criteria: an effect size of 0.44 (effect size $f = 0.44$), a two-tailed 5% significance level ($\alpha = 0.05$), a 95% confidence interval, 80% statistical power ($1\text{-}\beta$ err prob $= 0.80$), and four experimental groups. Sixty specimens were collected for the sample size, and the effect size was computed based on a preliminary study [18]. The study included first and second maxillary and mandibular primary molars with intact furcation and without internal or external pathologic root resorption, as well as physiologic root resorption not exceeding two-thirds of the root length. Teeth with cracked or extensively decayed crowns were not considered for the study. All teeth underwent disinfection by being kept in 5% NaOCl (Carmel®; AkkaBrothers Co., Carmel Detergent, Damascus, Syria) for seven days. After disinfection, the teeth were rinsed with tap water and stored in normal saline (SODIUM CHLORIDE 0.9%MIAMED, Miamed Pharmaceutical Industry, Damascus, Syria)) until they were used for the study [19]. The sixty human primary molars were randomly divided into four groups (n = 15):

* Group 1 (MTA + DW): Furcal perforations were repaired with MTA and DW (Rootdent, TehnoDent Co., Belgorod, Russia) mixture.

*Group 2 (MTA + NaOCl gel): Furcal perforations were repaired with MTA and 2.25% NaOCl gel (LET'S CLEAN Concentrated Chlorine, DTIC®, Damascus, Syria) mixture.

*Group 3 (Positive control): Furcal perforations left untreated.

*Group 4 (Negative control): Primary molars with no furcal perforations [19].

Randomization and blinding:

The randomization online software https://www.randomizer.org/ was used to apply a simple randomization method. Groups' allocation was concealed from the outcome assessor.

Preparation of specimens:

The primary molars underwent amputation 3 mm apical to the furcation area using a diamond disc. Each tooth received a standard access cavity preparation, utilizing a 2 mm round bur (Dentsply Maillefer, Ballaigues, Switzerland). Acid etching with 37% phosphoric acid gel (Condac 37, FGM, São Paulo, Brazil) was performed for 30 seconds at the canal orifices and the apical end of each root. A bond agent (Ambar, FGM, São Paulo, Brazi) was applied in two consecutive coats and then photopolymerized for 20 seconds using an LED dental curing light (Power Led, Foshan Jerry Medical Apparatus Co., Ltd,Guangdong, China). The flowable composite (Opallis, FGM, São Paulo, Brazil) was used to seal the canal orifices and the apical end of each root, followed by curing for 40 seconds. Clear nail varnish was then applied in two successive layers to each molar, covering the cavity walls and pulpal floor to enhance the marginal seal. The low-speed handpiece was used to create a perforation in the center of the pulp chamber floor using a RA2 bur. Although the width of all the perforations was the same, the length of each perforation varied based on the thickness of the dentine-cementum from the pulp chamber to the furcation area. The materials were applied according to the manufacturer mixing instructions within the perforation utilizing a root canal plugger (Root Canal Plugger 5/7 38171, Elite Inc., Illinois, United States). A moist cotton pad was placed for one hour. WMTA powder was combined with distilled water using a 3:1 powder-to-liquid ratio, and then blended with 2.25% NaOCl gel at a 3:1 powder-to-gel ratio [16]. The pulp chamber was restored in all groups with composite resin (Opallis, FGM, São Paulo, Brazil) [19]. The NaOCl gel concentration is 4%, according to the manufacturer, which was diluted to 2.25% according to the following equation [16]:

$$C1 \times V1 = C2 \times V2$$

C1: starting concentration.

V1: starting volume.

C2: final concentration

V2: final volume

Measurement of microleakage:

The molars' pulp chambers were placed in a 2% methylene blue solution (Terry's Polychrome Methylene Blue 2% Aqueous, Polysciences, Inc., Warrington, United States) for 24 hours. After this time, all specimens were rinsed under running water to remove the methylene blue dye. The samples were then cut into mesiodistal sections parallel to the long axis of the teeth, and the extent of dye penetration was measured on each wall from the bottom of the perforation to the floor of the pulp chamber using a microscope (Portable LCD digital microscope 1-600X, ELECROW, Shenzhen, China) [20].

Statistical analysis:

IBM SPSS software version 26 (IBM Corp., Armonk, NY, USA) was utilized for statistical data analysis. The Kolmogorov-Smirnov test was used to check the normality of data, and the Kruskal-Wallis test was used to compare between study groups. Multiple pairwise comparisons were performed because the overall test showed significant differences across the groups. The significance level was adjusted at 0.05 ($p < 0.05$).

Results:

The lowest dye penetration score was for the negative control group (0.00 ± 0.00) mm, followed by MTA + DW group (0.05 ± 0.05) mm (Figure 1), MTA + NaOCl gel group (0.07 ± 0.07) mm (Figure 2), and the highest score was for the positive control group (0.18 ± 0.03) mm with a statistically significant difference ($p < 0.05$) (Table 1) (Figure 3). The MTA + DW mixture did not outperform the MTA + NaOCl gel's sealing ability ($p = 1.000$). No statistically significant difference was noted between the negative control group and both the MTA + DW group ($p = 0.320$) and MTA + NaOCl gel group ($p = 0.092$) (Table 2), indicating their good sealing ability. Consequently, there was a statistically significant difference between the positive control group and both the MTA + DW group ($p < 0.05$) and the MTA + NaOCl gel group ($p < 0.05$) (Table 2).

Figure (1): A mesiodistal section in a primary molar showing dye microleakage of MTA + DW group.

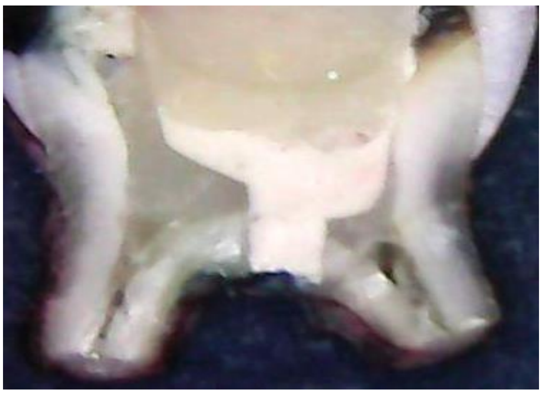

Figure (2): A mesiodistal section in a primary molar showing dye microleakage of MTA + NaOCl gel group.

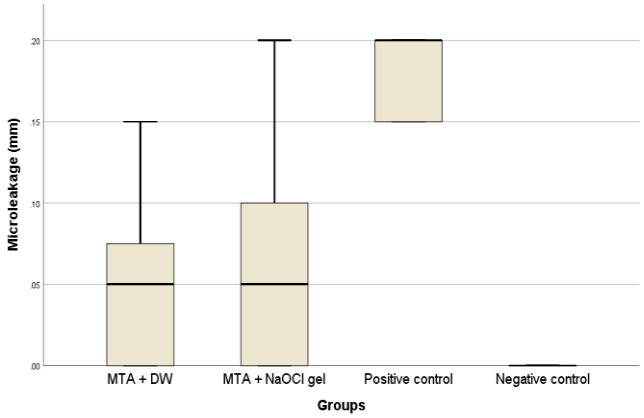

Figure (3): Box plots of the microleakage (mm) showing median, interquartile range, minimum, and maximum in the study groups**.**

Table (1): Descriptive statistics and the results of Kruskal-Wallis test for dye penetration scores (mm) across groups.

Groups	Mean ± SD	Minimum	Maximum	*p*-value
MTA + DW	0.05 ± 0.05	0.00	1.50	< 0.001*
MTA + NaOCl gel	0.07 ± 0.07	0.00	2.00	
Positive control	0.18 ± 0.03	1.15	2.00	
Negative control	0.00 ± 0.00	0.00	0.00	

Table (2): Multiple pairwise comparisons for dye penetration scores across groups.

Pairwise comparison	Test statistic	Std. Error	Std. Test Statistic	*p*-value
MTA + DW vs. MTA + NaOCl gel	-2.933	5.969	-0.491	1.000
MTA + DW vs. Positive control	-24.467	5.969	-4.099	< 0.001*
MTA + DW vs. Negative control	11.533	5.969	1.932	0.320
MTA + NaOCl gel vs. Positive control	-21.533	5.969	-3.607	0.002*
MTA + NaOCl gel vs. Negative control	14.467	5.969	2.424	0.092
Positive control vs. Negative control	36.000	5.969	6.031	< 0.001*

Discussion:

The iatrogenic perforation of the furcal area can result in inflammation of the surrounding periodontal attachment, potentially leading to tooth loss if left untreated [21]. Preventing bacterial infection during treatment is crucial for improving the prognosis. The prognosis of a perforated tooth is influenced by factors such as the duration of contamination, the location and accessibility of the perforation, and the possibility of effectively sealing it [22]. The success of various repair materials used to treat perforations depends on factors like the initial damage to the periodontal tissue, the ability of the material to seal the perforation, its cytotoxicity, bacterial contamination, the timing of repair, and the size and location of the perforation [23].

In this study, the MTA + DW mixture was utilized because of its numerous advantageous characteristics, such as biocompatibility, effective sealing capabilities, and the capacity to harden in the presence of moisture and blood [8]. Nevertheless, its drawbacks include challenges in handling and an extended setting time [9]. Therefore, MTA + NaOCl gel was tested in the current study because this combination exhibited advantageous working properties and short setting time [11, 13, 14, 15]. Furthermore, multiple studies in the literature support the safety and biocompatibility of this mixture [14, 16]. Thus, the objective of this study was to assess the sealing ability of the MTA + NaOCl gel mixture in the repair of furcal perforations in primary molars by utilizing methylene blue dye penetration.

For positive control, furcal perforations are left untreated. As noted by Galhorta et al. [24], having a positive control group is essential to confirm that the experiment is yielding valid results. In the case of the negative control group, the surfaces of the specimens were entirely coated with nail varnish. Aqrabawi et al. [25] emphasize that a negative control group must rule out any microleakage resulting from experimental errors. Dye penetration is an effective, safe, economical, and user-friendly technique for assessing microleakage [26]. Various dyes have been utilized, such as Indian ink, methylene blue solution, erythrosine B solution, basic fuchsin dye, and fluorescent dye [27]. The small molecular weight particles in methylene blue solution penetrate the dentinal tubules as effectively as small bacterial products, making it a precise method for evaluating microleakage [26]. Furthermore, its relatively low cost and ease of use contribute to its continued application in numerous recent studies conducted in Syria and other developing nations [20, 28, 29, 30].

In this study, a 2.25% hypochlorite gel was chosen over lower concentrations because it effectively dissolves tissue and possesses alkaline characteristics [31]. Additionally, 2.5% NaOCl gel has been found effective in lowering the counts of E. faecalis [32]. Furthermore, Andrade et al. [33] reported that combining WMTA with a 1% NaOCl gel did not improve its antibacterial efficacy compared to using a mixture of WMTA and DW. Moreover, the research by Al Kurdi et al. [34] demonstrated that mixing 2.2% NaOCl gel with white Portland cement enhanced its antibacterial properties, as white Portland cement has a similar chemical composition to WMTA, which consists of 75% white Portland cement. However, Al Kurdi et al. [34] injected a large amount of the mixture in the bucco-mandibular gingival sulcus of white experimental rabbits. Thus, the mixture was prohibited from clinical use since it was not biocompatible.

The null hypothesis is accepted. The new mix did not improve the sealing ability. However, there were no significant differences between the two mixtures in terms of sealing ability. No statistically significant difference was noted between the negative control group and the MTA + DW group and MTA + NaOCl gel group, indicating their good sealing ability. These results can be explained by the Andrade et al. [33] study, which reported that adding 1% NaOCl gel to WMTA did not affect its solubility as it remained zero, similar to the WMTA + DW mixture. According to Espir et al. [35], the solubility could be closely related to the capability of a material to seal. In addition, Karkoutly et al. [16] stated that the initial SEM analysis revealed that the WMTA + NaOCl gel exhibited a less homogenous surface, but it became more consistent after 28 days. EDX analysis demonstrated that the WMTA + NaOCl gel group had higher percentages of calcium and silicon at first, with both groups showing an increase in these elements after 28 days. Therefore, both materials behave similarly. In addition, Dsouza et al. [36] suggested that mixing MTA with 3% NaOCl improves its sealing ability. Based on the findings of Abdelmotelb et al. [37], MTA is a promising substance for the repair of furcal perforations in primary molars. Thus, both materials can be used to seal furcal perforations. The main limitation of this study was the laboratory environment, which may not accurately reflect the conditions of the oral cavity when measuring microleakage. Therefore, it would be beneficial to perform clinical trials that better replicate the conditions found in the oral cavity [38]. Furthermore, the limited duration of the follow-up period is another drawback.

Conclusions:

The MTA + NaOCl gel mixture may serve as a viable alternative for repairing furcal perforations in primary molars because of its superior sealing properties that are comparable to the MTA + DW mixture.

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