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Comparative Assessment of Diffusion of Calcium and Hydroxyl Ions from Calcium Hydroxide Formulations used for Obturation in Primary Teeth

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Abstract

Introduction: Calcium hydroxide ($Ca[OH]_2$) has been extensively used in pediatric endodontics and its properties depend on two ions, calcium and hydroxyl. The aim of the study was to assess the diffusion of calcium and hydroxyl ions from three $Ca(OH)_2$ based materials through roots of primary teeth using atomic absorption spectrometer and pH meter, respectively.

Materials and Methods: A total of 40 extracted human deciduous teeth roots were used for the study. The specimens were divided into 4 groups, with 10 roots in three experimental groups and 10 in control group. The root canals in the experimental group were filled with $Ca(OH)_2$ mixed with propylene glycol (CaPE), Ultracal paste and Metapex, respectively, whereas root canals in the control group were left empty. pH analysis and calcium ion diffusion from the specimens were done using digital pH meter and atomic absorption spectrophotometer, respectively at baseline, 24 h, 7, 15, and 30 days. Statistical analysis was performed using analysis of variance.

Results: Calcium and hydroxyl ion diffusion was maximum from CaPE group at all test periods except at 24 h, where ultracal group showed maximum diffusion of both the ions. Metapex group showed intermediate diffusion of ions.

Conclusion: Clinical situations that require a rapid ionic liberation, aqueous $Ca(OH)_2$ pastes (Ultracal) should be used and in situations that require a gradual ionic liberation; a viscous vehicle containing paste should be used such as CaPE paste. Situations where very slow ionic dissociation is required, pastes containing oily vehicles (Metapex) should be used.

Key words: CaPE, Metapex, Primary teeth, Ultracal

INTRODUCTION

The main objective of pulp therapy in primary teeth is to maintain health of the teeth and supporting structures stabilize the affected primary tooth, but also create a favorable environment for normal exfoliation of the primary tooth, without harm to the developing enamel or interference with the normal eruption of its permanent successor.[1]

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Since the introduction of calcium hydroxide ($Ca[OH]_2$) to dentistry, it has been included within several materials and antimicrobial formulations which are used in a number of treatment modalities in endodontics. The use of $Ca(OH)_2$ in endodontic treatment of necrotic; infected teeth is now well documented.[2] $Ca(OH)_2$ is also useful in the treatment of root resorptions, perforations, root fractures, apexification, and pulp capping.[3,4] The material is chemically classified as a strong base. The ionic dissociation of Ca^{2+} and OH ions and their effect on vital tissues is responsible for its antimicrobial activity and the property of hard tissue deposition.[5]

Studies conducted on permanent teeth proved that $Ca(OH)_2$ has the capacity to release calcium and hydroxyl ions which diffuse through exposed dentinal tubules and raise the pH of roots' surface and periapical environment.[6,7] However,

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only a few studies have been conducted on primary teeth to assess the diffusion of calcium and hydroxyl ions from $Ca(OH)_2$ based pastes through root dentin.[8,9] The vehicles mixed with $Ca(OH)_2$ powder play an important role in the overall dissociation process because they determine the velocity of ionic dissociation causing the paste to be solubilized and resorbed at various rates by the periapical tissues and from within the root canal.[10] Vehicles used to mix $Ca(OH)_2$ can be classified into aqueous, viscous, and oily.[11]

The three materials used in the study represented all the three vehicles used to mix $Ca(OH)_2$. Considering these points, the purpose of this research was to evaluate the diffusion of Ca^{2+} and OH^- ions from three $Ca(OH)_2$ based materials, through the intact roots of primary teeth using atomic absorption spectrometer and pH meter, respectively.

MATERIALS AND METHODS

The study was conducted on 40 extracted primary human teeth roots, with single and straight canals. Institutional Ethical Committee clearance was obtained for the study. Initially, the teeth were stored in a 10% formaldehyde solution until ready for use. The soft tissues and dental calculus adhered to the roots were removed with an ultrasonic dental scaler. Transverse sectioning of roots 2 mm coronal to cementoenamel junction using double faced diamond disk was done to obtain the specimens. All the roots were then analyzed macroscopically using stereoscopic magnifying glass (×4). Only intact roots with no perforating resorption were included in the study. However, since the teeth used in the study were deciduous, they were in initial stages of physiologic resorption. Thus, they presented with apices showing different degrees of resorption. Therefore, to standardize root lengths, the apices were cut at 7 mm from cementoenamel junction using double faced diamond disk. Instrumentation was done for all the roots by a single operator. The canals were enlarged till 40 no. K file and 1% sodium hypochlorite was used for irrigation between change of files. The specimens were randomly divided into Four groups, with 10 roots in each experimental group (Groups 1-3) and 10 in the control group (Group 4). Simple randomization using random table was used.

Group 1: Thickened $Ca(OH)_2$ powder with a viscous vehicle propylene glycol (CaPE) was mixed in a ratio of 2:1 by weight and canals were obturated using reamers and cotton pellet. Group 2: Aqueous vehicle based $Ca(OH)_2$ paste-Ultracal (Ultradent) was used to fill the canals using a disposable plastic tip connected to a syringe. Group 3: Premixed metapex (Meta Biomed) consisting of an oil based vehicle was used to fill the canals using a syringe with disposable plastic tip. Group 4 (control group): BMP was performed and irrigation was done as in experimental group, but the canals were kept empty without any medication. The canals were considered full when the paste flowed from the pulp chamber at the root canal opening for all the samples in the experimental group. Following this, vertical pressure was applied with cotton pellets. Individual radiographs using pedo films were taken in buccolingual direction to check whether the canals were completely filled. After confirming that the canals of all the roots were totally filled, the access cavities were restored with glass ionomer cement. The teeth from the control group were also restored using the same technique. Roots were then cleaned to remove debris of the filling material from the external surface. Araldite (Brascola Ltd.), mixed in equal parts of base paste and catalyst, according to the manufacturer's instructions, was used to make the foramen and apical third impermeable. After a hardening time of 30 min, a layer of nail varnish was applied over the Araldite. This was done to make the teeth more impermeable so that the diffusion of ions occurred only through the roots of teeth.

The teeth were stored in individual plastic flasks, each containing 30 ml of saline solution. They were kept at a constant temperature of 37°C and at 100% relative air humidity during the entire test period of 1-month. The flasks had a modeling wax lid where the tooth's crowns were fixed, allowing only the root to be in contact with the saline solution.

Measurements were taken at regular intervals for each group at baseline, 24 h, 7, 15, and 30 days. The pH was measured using a digital pH meter. The pH readings were taken for the test and control groups after 2 min of electrode immersion in the solutions that contained each specimen. After measurement, each tooth was returned to the same flask. Between readings, the electrode was washed with deionized water and dried with absorbent paper. The values obtained were then recorded. An atomic absorption spectrophotometer was used to determine the concentration of calcium ions. For determination of calcium ions released in the saline solution, 0.5 ml liquid was removed with a pipette from each flask and transferred to a sterile test tube pertaining to each group. Since there were 10 samples in each group, 5 ml liquid was collected which was then transferred to a test tube.

A small quantity from these 5 ml of solution from the test tube of each group (never <0.1 ml) was removed with a pipette for analysis. This was then diluted according to the saturation of the solution. The solutions were kept at room temperature at the time of readings. Calcium ion diffusion was measured at baseline, 24 h, 7, 15, and 30 days.

The collected data were tabulated, and statistical analysis was performed using analysis of variance to compare groups. The decision criterion was to reject the null hypothesis if the *P* value was <0.05. Otherwise, null hypothesis was accepted. If there was a significant difference between the groups, multiple comparisons (*post-hoc* test) using Bonferroni test was carried out.

RESULTS

All the study groups as well as the control group showed diffusion of calcium and hydroxyl ions at various test periods. The diffusion of calcium ions was very less for the first 24 h for all the groups after which it increased significantly. However, for the control group, it remained low over the entire test period. Overall, the mean calcium ion diffusion was maximum from Group 1, i.e., $Ca(OH)_2$ mixed with propylene glycol. In first 24 h, Group 2, i.e., Ultracal showed maximum diffusion. Highest diffusion of calcium ions from all the groups was seen at 7 days after which it declined. At 24 h, maximum diffusion was seen from Ultracal group followed by $Ca(OH)_2$ mixed with propylene glycol, Metapex and control group. At 7, 15, and 30 days; maximum diffusion was seen from $Ca(OH)_2$ mixed with propylene glycol followed by Metapex, Ultracal and control group (Table 1 and Figure 1).

The pH was close to 6 for all the groups at the baseline. It was acidic for all the groups because the media in which the teeth were placed was saline. pH increased for all the study groups after 24 h when the diffusion of hydroxyl ions started. At 24 h pH of Group 1, i.e., Ultracal was seen to be highest. At 7, 15, and 30 days pH of Group 2, i.e., $Ca(OH)_2$ mixed with propylene glycol was highest. For all the groups except Group 2, i.e., Ultracal, highest pH was recorded at 15 days. For Group 2, it was recorded at 24 h. pH decreased significantly for all the groups at 30 days (Table 2 and Figure 2).

DISCUSSION

In primary dentition, infection of the root canal system quickly extends to involve the periradicular tissues. Early loss of primary teeth causes a number of adverse effects, including space loss for successor permanent teeth.[12] Thus, it is best that primary teeth are saved, provided they can remain free of disease and can be restored. A tooth successfully disinfected and restored is a superior space maintainer than any appliance.[13]

Primary teeth show various anatomical and histological complexities in their root canal systems. Their proximity to the developing permanent tooth germs, coupled with

Table 1: Calcium ion diffusion

Time	Mean±SD				
	Baseline	24 h	7 days	15 days	30 days
Group 1	0.38±0.49	8.24±0.46	15.45±0.50	12.72±0.33	11.22±0.59
Group 2	0.43±0.41	10.63±0.62	8.59±0.53	7.73±0.41	6.25±0.33
Group 3	0.37±0.49	7.52±0.51	13.40±0.88	10.41±0.51	6.91±0.28
Group 4	0.30±0.35	1.79±0.59	3.21±0.38	2.42±0.73	2.05±0.31

SD: Standard deviation

Table 2: Hydroxyl ions diffusion (pH)

Time	Mean±SD				
	Baseline	24 h	7 days	15 days	30 days
Group 1	5.85±0.24	7.20±0.12	7.40±0.12	8.05±0.20	7.40±0.12
Group 2	5.95±0.37	7.57±0.18	7.50±0.18	7.20±0.16	7.10±0.18
Group 3	5.95±0.28	7.50±0.24	7.30±0.18	7.73±0.24	7.42±0.23
Group 4	5.90±0.46	6.08±0.08	7.08±0.15	7.14±0.13	7.12±0.08

SD: Standard deviation

the difficulty in behavior management in children, make the endodontic treatment in deciduous teeth more difficult.

$Ca(OH)_2$, in various combinations, has been used as successful root canal filling material in primary teeth. It is also well documented that all biological actions are due to the ionic dissociation of $Ca(OH)_2$ into calcium and hydroxyl ions.[14] Vehicle plays the most important role in the overall process. It determines the velocity of ionic dissociation, which in turn determines the rate of resorption of these pastes from the periapical tissues and from within the root canal.[11]

Studies conducted on permanent teeth proved that $Ca(OH)_2$ has the capacity to release calcium and hydroxyl ions which diffuse through exposed dentinal tubules and raise the pH of roots' surface and periapical environment.

In general, three types of vehicles are used to mix $Ca(OH)_2$: Aqueous, viscous or oily.[11] None of the previous studies conducted to assess the diffusion of calcium and hydroxyl ions tested all these three media. However, in this study, all the three vehicles were tested. Ultracal paste represented the aqueous vehicle, $Ca(OH)_2$ mixed with propylene glycol was the viscous vehicle, and Metapex represented the oily vehicle.

This study demonstrated the diffusion of calcium and hydroxyl ions through root dentin and cementum of primary teeth. It can be confirmed that the release of the ions had occurred only thorough the roots of the specimen since the crown and apical portion of the roots were sealed, with the only possible passage of ions through root dentin and cementum of the teeth. Diffusion of calcium and hydroxyl ions from deciduous teeth roots have been demonstrated previously.[8,9]

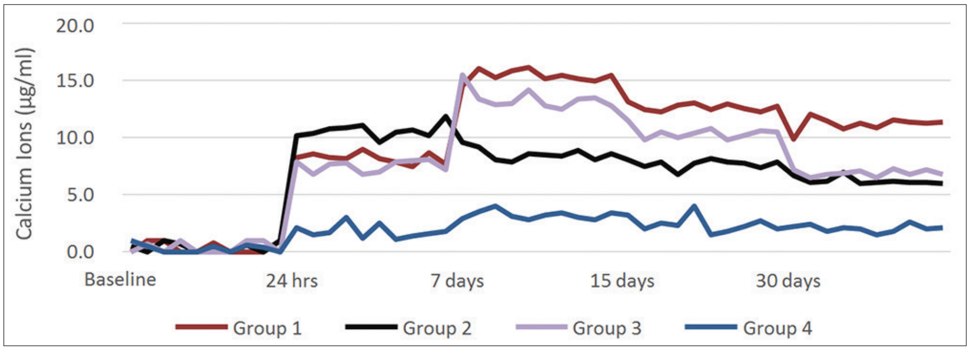

Figure 1: Calcium Ions released at different time intervals in each group (in each sample)

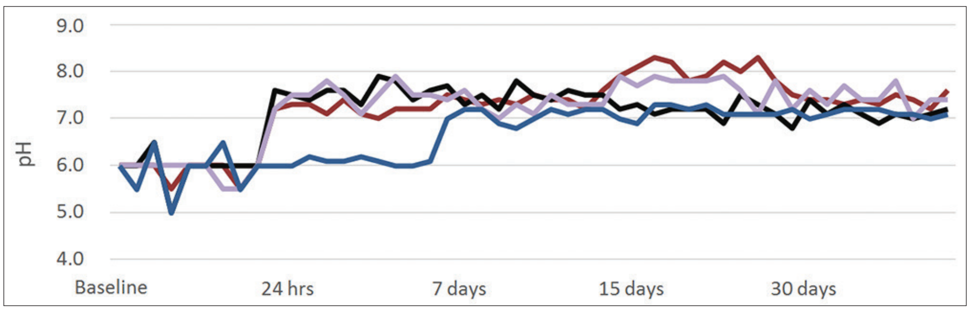

Figure 2: pH recorded at different time intervals

Biomechanical preparation consisted of instrumentation with K files and intermediate irrigation with 1% sodium hypochlorite solution. This was followed by root canal filling. The same methodology was used in a few previous studies.[8] It has been shown that 1% NaOCl solution has good antimicrobial action and promotes pulp tissue dissolution. This capacity of NaOCl is increased when used with root canal dressings containing $Ca(OH)_2$.[15]

Selection of the materials tested in this study was based on the fact that the three materials contained three different vehicles, i.e., aqueous, viscous and oily. Some *in vitro* studies have shown that the type of vehicle has a direct relationship with the diffusion and the velocity of ionic liberation as well as with the antibacterial action of the paste in a contaminated area.[16]

This study showed that ultracal group showed maximum diffusion of calcium ions at 24 h, i.e., 10.63 mg/L. Furthermore, this group showed maximum diffusion of hydroxyl ions at 24 h represented by pH, i.e., 7.57. At 7, 15, and 30 days test periods, the calcium ion and hydroxyl ion diffusion from this group declined. This was because when $Ca(OH)_2$ is mixed with a water-soluble substance or an aqueous media, calcium and hydroxyl ions are rapidly released. Aqueous vehicles promote higher solubility when the paste is in direct contact with the tissue and tissue fluids. This also causes it to be rapidly solubilized and resorbed by macrophages. This implies that the root canal may become empty in a short period, delaying the healing process.[17] However, the root canal may have to be redressed several times until the desired effect is achieved, thus increasing the number of appointments.

In a recent study, it was reported that maximum diffusion of calcium and hydroxyl ions occurred from CaPE group.[9] Even in this study, the maximum diffusion of calcium ions was seen from Group 1, i.e., $Ca(OH)_2$ mixed with propylene glycol (CaPE) which is a viscous vehicle. This was seen at 7, 15, and 30 days.

Viscous vehicles are also water-soluble substances. However, they have higher molecular weights which lower their solubility when compared with aqueous vehicles. This slower diffusion maintains the paste in the desired area for longer intervals, prolonging the action of the paste.[14] As a viscous vehicle containing paste may remain in the root canal for a 2-4 months interval, the number of appointments and redressing of the root canal is reduced.[11] It has been asserted that an infected deciduous tooth should not be obturated in 1 week. It is best to wait at least 1 month to allow a residual action of the $Ca(OH)_2$ dressing, thus allowing better wound healing.[8] For these clinical situations, viscous vehicles are the best choice. Some examples of viscous vehicles are glycerine, polyethyleneglycol, and propylene glycol.

The mean calcium ion and hydroxyl ion diffusion from Metapex was found to be more than Ultracal group but less than CaPE group. This was in accordance with a previous study where the authors had found that Vitapex released lesser calcium and hydroxyl ions than CaPE.[8] Metapex contains silicon oil, i.e., an oily vehicle. Pastes containing this kind of vehicle may remain within the root canal for longer than the pastes containing aqueous vehicles. Some examples of oily vehicles are olive oil, silicone oil, camphor (the essential oil of camphorated parachlorophenol), metacresylacetate and some fatty acids such as oleic, linoleic, and isostearic acid.

The control group, although did not contain any intracanal medication, showed a slight increase in the pH and calcium ion diffusion. Similar findings were also reported in some previous studies.[8,9] This was because the roots of primary teeth had inherent hydroxyapatite crystals. However, this was in contrast to a study where the authors did not find any increase in calcium ion or pH in control group.[18] This may be due to different methodology used by these authors, i.e., the use of glass tubes instead of extracted human primary roots in their studies. The relevance of this study is based on the results that indicate importance of each material for different clinical situations.

CONCLUSION

Based on the results of this study, it is recommended that that $Ca(OH)_2$ mixed with aqueous vehicle can be used in clinical situations that require a fast release of ions at the beginning of treatment, such as in an infected tooth with periapical lesion or in an acute exacerbation of a chronic lesion.

$Ca(OH)_2$ mixed with a viscous vehicle such as propylene glycol can be used in clinical situations that require a gradual and uniform ionic liberation such as in chronic lesions.

$Ca(OH)_2$ mixed with an oily vehicle can be used in those clinical situations that require a very slow ionic dissociation over time. These pastes are recommended to be used for obturation of primary teeth depending on the clinical situation.

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