Influence of ultrasonic activation and mixing vehicle on dentinal pH in simulated external root resorptions repaired with MTA

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ABSTRACT

The aim of this study was to evaluate the effect of ultrasonic activation and MTA vehicle on dentinal pH in simulated external root resorptions. So, a cavity was prepared in the root of forty-six bovine teeth. They were filled with MTA mixed with 100% distilled water (DW) or MTA mixed with 80% DW and 20% propylene glycol (PG). Teeth were divided into four groups (n = 10), according to the vehicle (DW or PG) and ultrasonic protocol used for material insertion (activated or not). Control group (n = 6) was unfilled. The pH was assessed after 15, 30 and 60 days of immersion. As results of all that, activation with ultrasound did not significantly alter the pH ($p > 0.05$). The cements were mixed with either DW or DW + PG, with the later association presenting higher pH at 15 days of assessment than the former ($p < 0.05$). Thereby, it can be concluded that mixing MTA with 80% DW and 20% PG increased the dentinal pH, which is positive for root resorption repair.

Keywords: Dentin. Endodontics. Biocompatible Materials.

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Introduction

External root resorptions are pathological conditions resulting from injury to mineralized tissues (precementum or pre-dentin).[1] The damage allows the cell attachment in these areas, initializing the resorption process.[1,2] Continuous infection or trauma results in an uninterrupted activity of osteoclastic cells[1], which can lead to pathological areas of communication between root canal system and support tissues. Root resorption, if/when not treated, frequently leads to tooth loss. Mineral trioxide aggregate (MTA) has been successfully used to treat root resorptions[3], as it induces the formation of a mineralized barrier at the communication areas.[4,5] This induction is related to its alkaline pH, and release of calcium ions.[4] During the hydration process, MTA forms calcium hydroxide, and calcium silicate hydrate, in which the former is released as calcium (Ca^{+2}) and hydroxyl (OH^{-}) ions, resulting in an alkaline pH.[6,7] Alkaline pH provides an unfavorable environment for bacterial growth, and Ca^{+2} release stimulates the formation of a mineralized barrier in the adjacent tissues.[8]

The adequate characteristics of MTA for treatment of root resorptions have encouraged its use for this procedure.[9,10] The application of MTA, in these cases, requires accuracy to achieve a satisfactory seal and prevent continuous communication between the root canal system, and periodontal tissues. However, the sandy and dry consistency of the MTA makes it difficult to use in perforations. The addition of propylene glycol (PG) to MTA liquid has been evaluated, presenting similar tissue responses in comparison with distilled water (DW).[11] Furthermore, the addition of PG increases the push-out bond strength, setting time, flowability, pH, and release of calcium ions.[12,13] The antibacterial property of PG also has a positive effect on preventing bacterial infection.[14] Duarte et al.[12] found that the ideal ratio in a MTA mixture was 20% PG and 80% DW. Higher ratios of PG (50% and 80%), however, resulted in undesirable increase of setting time. Moreover, the use of 100% PG did not allow MTA setting.

Ultrasonic activation has been used to improve penetration of irrigating solutions, calcium hydroxide pastes,[15] and root canal sealers[16] into the dentinal tubules in anatomically complex areas.[17] Duarte et al.[15] found an increase of pH in simulated external root resorptions with the use of ultrasonic activation. Thus, it is possible that this protocol increases the pH, consequently improving the mineralization characteristics of MTA. The aim of the present study was to test the effect of ultrasonic activation on the dentinal pH in simulated external root resorptions after filling the canals with MTA mixed with distilled water, or in association with distilled water and propylene glycol.

Materials and methods

Sample Preparation

A total of forty-six bovine teeth were obtained. They were cleaned and stored in 0.1% thymol solution at 4°C. The crowns were removed with a 0.3-mm diamond disc (Buehler IsoMet, Lake Bluff, Illinois, USA).

The root canals were cleaned, and shaped, by using the crown-down pressureless technique. A sequence of #120, #130 and #140 K-files (Dentsply Maillefer, Ballaigues, Switzerland) were used in the middle, and coronal thirds, until the apical diameter of a #110 size was reached. After the use of each instrument, 2 mL of 2.5% sodium hypochlorite was used to irrigate the canal. Passive ultrasonic irrigation was performed at the end of the shaping procedure as previously reported.[18] A final flush of 2mL of 17% EDTA (Biodinâmica, Ibiporã, Paraná, Brazil) was ultrasonically agitated for 1 minute before being washed with 2 mL of distilled water and dried with paper points (Dentsply Maillefer).

A cavity was prepared in the middle of the buccal root surface by using a #1014 diamond bur at high speed. The root surfaces were made impermeable with an application of a layer of nail polish and a layer of sticky wax, except in the cavity area and root canal access.

Obturation

MTA cements (Angelus, Londrina, Paraná, Brazil) were mixed with a liquid composed of 80% distilled water (DW) and 20% propylene glycol (PG; Pharmacia Specífica, Bauru, SP, Brazil) and MTA mixed with DW. The cements were mixed at a ratio of 1g powder to 0.3 mL liquid.

The teeth were randomly divided into four experimental groups (n = 10), according to the cement used to fill the root canals and the ultrasound agitation, including a control group (n = 6), as follows:

- Group 1 (DW + NA): MTA mixed with distilled water (DW) and no ultrasound activation (NA);
- Group 2 (PG + NA): MTA mixed with DW and propylene glycol (PG) and no ultrasound activation (NA);
- Group 3 (DW + UA): MTA mixed with DW with ultrasound activation (UA);
- Group 4 (PG + UA): MTA mixed with DW and PG with ultrasound activation (UA);
- Control group: No filling.

The root canals were filled with the cements by using a lentulo spiral (Dentsply Maillefer) at low speed. After filling, in Groups 3 and 4, the cements were ultrasonically activated using an ultrasonic unit (Jet-Sonic Four Plus; Gnatus, Ribeirão Preto, SP, Brazil) set to the Endo mode and in 30% potency for 1 minute (30 seconds in mesio-distal and 30 seconds to buccal-lingual), with a mini irrisonic tip (Helse Ind Ltda, Santa Rosa do Viterbo, Brazil). After each cycle, the canals were filled again with the cements with a lentulo spiral (Dentsply Maillefer).

After the final canal filling, the crowns were sealed with a composite resin and then made impermeable by using a fast-drying glue. The specimens were immersed individually in 20 mL of deionized water and stored at 37 °C.

Dentinal pH Assessment

After 15, 30 and 60 days, the teeth were placed in new flasks containing an equal volume of new deionized water. The pH of the water in which the teeth had been kept was measured with a pH meter (model 371; Micronal, São Paulo, SP, Brazil), previously calibrated using buffer solutions. After the removal of the specimens, the container was placed in a shaker (model 251; Farmem, São Paulo, SP, Brazil) for 5 seconds before measurement. The temperature of the room during the reading was 25 °C.

Statistical Analysis

Statistical analysis was performed by using the nonparametric Kruskal-Wallis and Dunn's tests ($p < 0.05$) due to the absence of normal distribution, which was confirmed in the preliminary analysis performed by D'Agostino and Pearson's tests.

RESULTS

The ultrasonic activation significantly increased the pH for MTA mixed with the association of distilled water, and propylene glycol at 15 days of assessment in relation to the control group ($p < 0.05$). At 30 days, the ultrasonic activation significantly increased the pH only for the MTA mixed with distilled water ($p < 0.05$). Median and range of pH are listed in Table 1.

The use of ultrasound to activate the cements did not significantly alter the pH between the groups in the experimental periods ($p > 0.05$). Independently of the use of ultrasound, the cements mixed with DW and PG presented higher pH at 15 days compared to those mixed with DW only ($p < 0.05$). No statistical differences were verified at 30 and 60 days ($p > 0.05$). Mean and standard deviations of the groups regarding ultrasonic activation are listed in Figure 1 and those regarding the mixing vehicle (DW and DW + PG) are listed in Figure 2.

Table 1. Median and range of pH at 15, 30 and 60 days.

	DW + NA	PG + NA	DW + UA	PG + UA	Control
15 days	$7{,}08^{ac}$ (6,80-7,45)	$8{,}28^{ab}$ (7,00-9,73)	$7{,}27^{abc}$ (6,90-7,55)	$8{,}61^{b}$ (7,30-9,95)	$6{,}28^{c}$
30 days	$6{,}87^{ab}$ (6,23-7,35)	$6{,}96^{ab}$ (6,58-8,06)	$7{,}29^{a}$ (6,55-9,89)	$6{,}86^{ab}$ (6,47-10,52)	$6{,}32^{b}$
60 days	$7{,}63^{a}$ (6,81-7,84)	$7{,}31^{a}$ (6,16-8,07)	$7{,}57^{a}$ (6,94-8,28)	$7{,}12^{a}$ (6,29-9,64)	$7{,}17^{a}$

Letters in each column indicate statistical differences in the experimental periods for each group ($p < 0.05$).

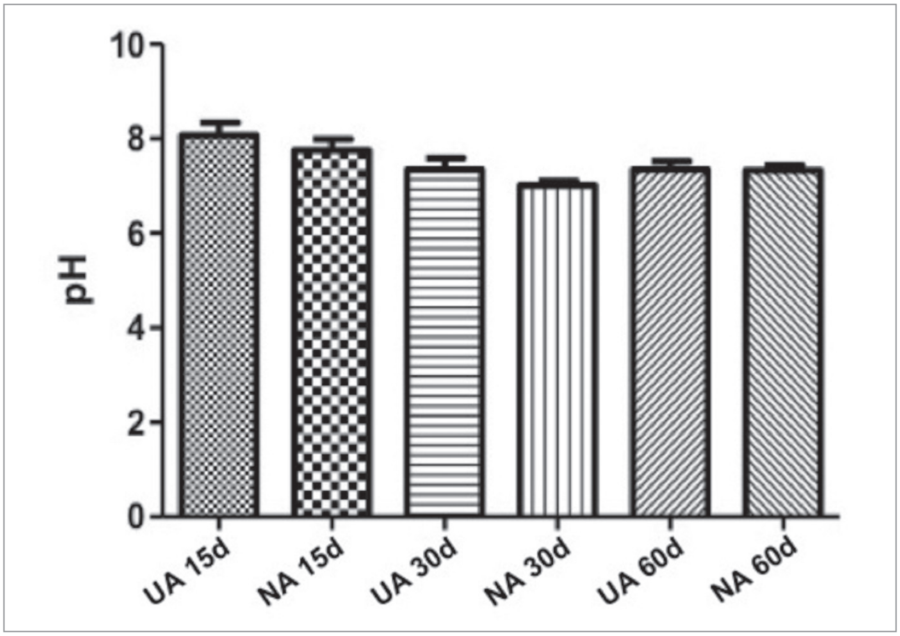

Figure 1. Mean and standard deviation of pH for cements ultrasonically agitated (UA), or not (NA), at 15, 30 and 60 days.

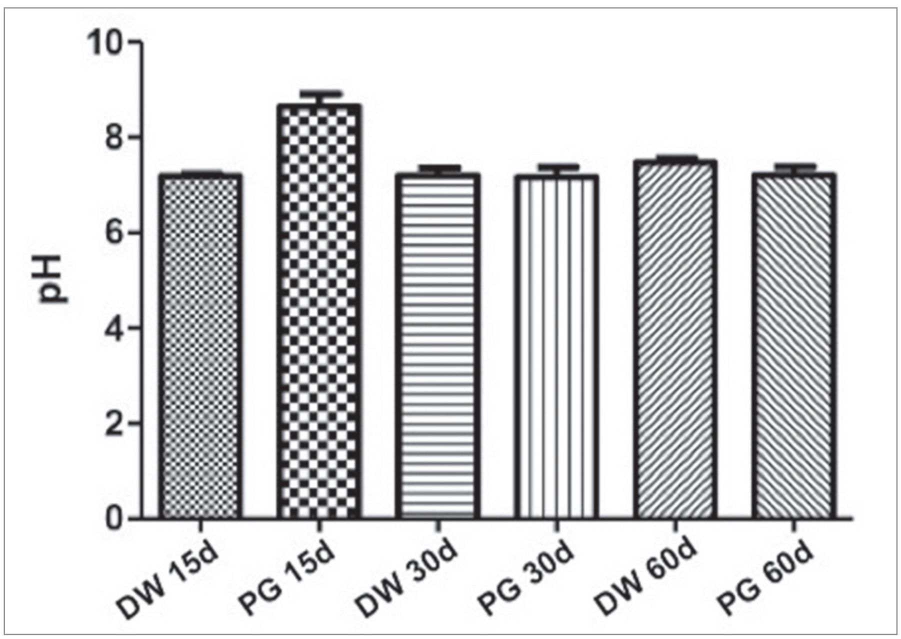

Figure 2. Mean and standard deviation of pH for cements mixed with distilled water (DW), or in association with distilled water and propylene glycol (PG), at 15, 30 and 60 days.

Discussion

Ultrasonic activation was used to enhance the pH level of MTA with different vehicles in simulated external root resorption. Several studies have evaluated the effect of ultrasonic activation on MTA properties, reporting an increase in flowability, sealing ability, and reduction of voids.[19-21] However, the compressive strength was not altered.[22] It is postulated that the effect of ultrasonic activation on MTA results in the re-arrangement of the cement particles.[19] Thus, the movement of the cement could possibly separate the particles and influence the release of calcium (Ca^{+2}) and hydroxyl (OH^{-}) ions, resulting in alkaline pH.

Bovine teeth were selected for the present study due to the similarity of their pH in relation to human teeth.[23] A similar methodology to evaluate pH in simulated external root resorption was previously described.[15] The authors found an increase of pH with the activation of calcium hydroxide pastes with ultrasound. In the present study, in the initial period of 15 days, the samples submitted to ultrasonic activation presented high pH levels with both vehicles tested, but they were not statistically significant in comparison with the non-activated specimens. Ultrasonic activation probably favored the high penetration of cement particles into the dentinal tubules, which also favored an increase of the pH level at the outside of the dentin, as described in the Fick's first law.[15,24]

Some factors such as particle size and water-to-powder ratios could also influence the pH of MTA under ultrasonic activation. A recent study evaluating the pH and calcium ion release of a nano-sized MTA, in comparison with conventional MTA, showed a significant increase of pH for the nano-sized cement in the initial period of analysis.[25] Aminoshariae et al.[26] reported an influence of water-to-powder ratio on the properties of MTA submitted to ultrasonic activation. The authors reported that large amounts of water in the mixture are not favorable for ultrasonic activation.

Distilled water (DW) is normally the vehicle for MTA mixing, since MTA sets in the presence of water.[27] During its hydration process, the hydrolysis of calcium silicate produces calcium hydroxide and hydrate of calcium silicate,[7] with the dissociation of ions resulting in increase of pH levels.[28] To improve the mixing characteristics of MTA, some authors have evaluated different vehicles.[12,29,30] Propylene glycol (PG) has been shown to improve flowability, adhesion, and working time for MTA mixing, without interfering with biological properties when associated with distilled water.[11-13] Duarte et al.[12] reported an increase of pH levels with a ratio of 80% DW to 20% PG at 3 hours of assessment, which was not significant in comparison with 100% distilled water. In the present study, the mixing vehicle interfered in the pH level at 15 days. Statistically significant alkalinization was verified in this period with 20% PG associated with 80% DW. Also, at 30 days, the pH was higher for the association, but not significantly.

High pH levels were verified for cements mixed with PG at 15 days, independently of the activation with ultrasound. The results suggest that the association of PG in the MTA mixing favored the penetration of cement into the dentinal tubules, and that ultrasonic agitation can partially corroborate with permeability. Cruz et al.[31] reported higher dye penetration into the dentin with the use of propylene glycol than with distilled water. This could elucidate the high external pH verified for samples filled with MTA mixed with PG. As previously demonstrated, MTA mixed with 80% DW and 20% PG favored an increase of working time and alkaline pH in the initial periods.[12] The increase of working time favors the release of calcium hydroxide in water during the setting reaction and, consequently, the alkalinity. Other possible explanation for the high pH levels in the group using PG is that such a mixture of PG resulted in lower water/cement ratio and consequent increase in setting time as previously demonstrated.[12] The retardation of setting allows high solubility, ion release, and thus, elevation of pH.[32]

Conclusion

Ultrasound activation did not significantly alter the pH of MTA. As for the mixing vehicle, the association of 80% distilled water and 20% propylene glycol increased the pH.

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