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Dentinal pH changes following electrophoretically activated calcium hydroxide ions in the root canal space of bovine teeth

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Abstract – The aim of the study was to evaluate pH changes of external root dentin surface at different depths following electrophoretic activation of calcium hydroxide (CH) in the root canals. For the study, 60 cavities were drilled on three external root surfaces of 20 bovine teeth specimens to obtain remaining dentin thickness (RDT) of 0.3, 0.7 and 1.0 mm. CH paste was inserted in the lumens. In the experimental group (10 specimens) CH paste was electrophoretically activated. Microelectrode was used to measure pH changes in the cavities immediately after placement of CH, following electrophoretical activation, and after 30 days storage. A significant ($P < 0.05$) increase in pH following electrophoresis was found in all specimens in the experimental group. Cavities with 0.4 mm RDT showed a maximal pH increase to the value of 11.3 ± 0.4. In the control group no change in pH was observed after 3 min. A similar increase in pH was observed in both groups after 30 days. The pH changes were significantly depended on the RDT ($P < 0.05$) in all groups. Electrophoretically activated CH could significantly increase dentinal pH of external root surface within minutes up to 30 days.

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Root resorption is a frequent sequence of injuries to the periodontal apparatus (1). The etiology of root resorption involves two phases: injury and stimulation (1–3). Injury is related to dental trauma, bleaching procedures, orthodontic treatment, or periodontal procedures. Stimulation is related to bacteria in the root canal or periodontium, prolonged pressure during orthodontic treatment, impacted teeth or tumors. Bacteria and bacterial products in the root canal act as stimulating factors of inflammatory root resorption and calcium hydroxide (CH) is a medicament of choice to arrest this process (4).

Calcium hydroxide has a strong antibacterial effect in the root canal because of release of hydroxyl ions in an aqueous environment and increases the pH of the neighboring tissues (5). However, due to the low solubility of CH and selective permeability of dentinal tubules (6), long-term application is required to disinfect the dentinal tubules and to arrest the inflammatory root resorption (4). CH over long-term could reduce the fracture strength of dentin, thus increasing the risk of root fracture (7).

New methods to rapidly disinfect dentinal tubules in inflammatory root resorption are required to minimize the risk of root fractures. Electrophoretically activated copper with CH has a significantly faster antibacterial effect in dentinal tubules than pure CH without electrical activation (8). However, copper may discolor treated teeth and could cause a certain degree of toxicity to surrounding tissues.

The aim of this study was to evaluate the rate of dentinal permeability to electrically activated CH by measuring pH changes of external root dentin surfaces at different depths.

Materials and methods

Crowns of 20 freshly extracted bovine incisors were removed and the middle third of the roots were cut into 10 mm sections. The lumen diameter was standardized to 2.3 mm by drilling with standardized burs. Outer root surfaces were ground to obtain approximate rectangular blocks. Sixty cavities of 1.3 mm diameter were prepared to the controlled depths on three external surfaces of the dentin to obtain remaining dentin thickness (RDT) of 0.3, 0.7 and 1.0 mm. Thus 20 cavities were prepared with each RDT accordingly (Fig. 1). This was performed to simulate the clinical condition of root resorption.

The specimens were prepared in the laboratory using high precision computer controlled electronic equipment. All specimens were immersed in EDTA for 5 min to remove the smear layer. Canal openings were sealed with blue wax on one side and CH with distilled water paste was inserted into the lumen with the aid of a lentulo spiral.

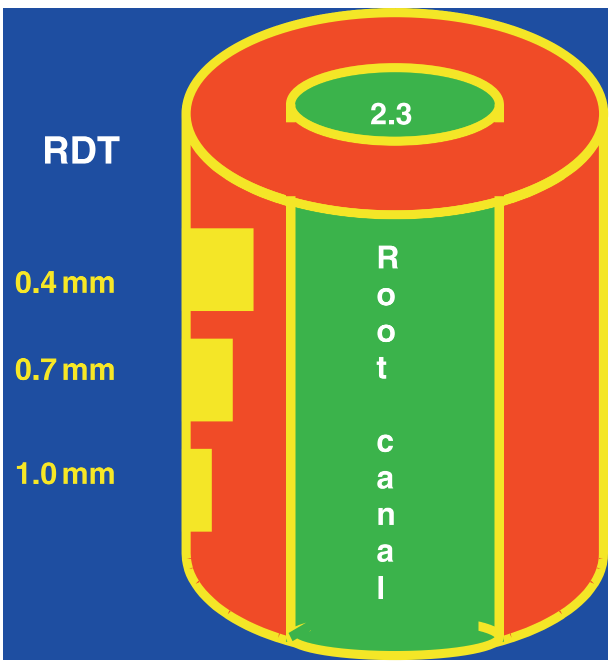

Fig. 1. Diagram of bovine incisor specimen with prepared cavities.

Experimental group (10 specimens with 30 cavities with RDT of 0.3, 0.7 and 1.0 mm)

The electrode of a Depotphoresis device (Depotphorese® equipment, Humanchemie GmbH, Alfeld, Germany) was inserted into the canals to the depth of approximately 2–3 mm. Gauze soaked with saline came into contact with the specimen and with the metallic clip of the Depotphoresis device to close the electrical circuit. The device was activated in the canals at maximum output producing pulses of direct electric current. The electric current was ceased when a 10 mA transfer was registered on the device scale (approximately after 3 min).

Measurements of pH were performed by microelectrode (model MI 4152; Microelectrodes Inc, Londonderry, NH, USA). Microelectrode was calibrated before measurements with standard solutions of pH 4 and pH 7. In all cavities, the pH was measured immediately after CH placement, after activation with the electrophoresis device, and after 30 days.

Control group (10 specimens with 30 cavities with RDT of 0.3, 0.7 and 1.0 mm)

Specimens were prepared identically to the experimental group, except that CH was not subjected to electrophoresis. The pH was measured in the cavities immediately after placement of CH, after 3 min, and after 30 days. The specimens in both experimental and control groups were stored in 100% humidity between measurements throughout the experiment. Results were statistically analyzed using ANOVA test with repeated measures.

Results

No changes in pH occurred immediately after placement of CH in both groups. In the experimental group with electrophoretically activated CH, there was a statistically significant increase in pH after activation with the electrophoresis device in all specimens ($P < 0.05$) (Table 1). In the control group, where CH was placed in the root canals without electrophoresis, no change in pH was observed after 3 min. There were no significant differences in pH between groups after 30 days.

An increase in pH significantly depended on the RDT: smaller RDT values resulted in a greater increase in pH ($P < 0.01$).

Discussion

The suggested antibacterial mechanism of CH is related to the release of hydroxyl ions and a subsequent increase of alkalinity of an adjacent

Table 1. Mean pH measurements at three RDT levels for experimental and control groups

RDT	Immediately after CH		After 3 min		After 1 month	
	Control	Experimental	Control	Experimental*	Control	Experimental
0.4 mm	6.9 ± 0.1	6.9 ± 0.1	6.93 ± 0.5	11.3 ± 0.4	11.3 ± 0.5	11.1 ± 0.2
0.7 mm	6.9 ± 0.1	6.9 ± 0.1	6.92 ± 0.8	8.9 ± 1.5	10.0 ± 1.2	9.9 ± 1.0
1.0 mm	6.9 ± 0.1	6.9 ± 0.1	6.92 ± 0.5	7.3 ± 0.2	9.4 ± 0.4	9.5 ± 0.3

*Significant increase in pH after electrophoresis in experimental group ($P < 0.05$). RDT, remaining dentin thickness; CH, calcium hydroxide.

aqueous environment. Therefore, pH changes of external root surface following placement of CH in the root canal could indicate its antibacterial activity in dentinal tubules. In the present study, a bovine tooth model was used, which allowed standardization in diameters of dentinal tubules and root canal lumen. The use of bovine teeth was based on their availability and basic morphology similar to human teeth (6). Cavities were prepared on external root surfaces at different depths to simulate external inflammatory root resorption. High precision electronic equipment was used, which allowed manufacturing of the internal lumen and external cavities of the specimens with the accuracy of 1 micron. Previous studies (9, 10) that used human teeth could not achieve the same degree of standardization and accuracy as in the present study.

Placement of CH without electrophoretical activation for 30 days significantly increased pH levels in the external root surfaces to 9.4 ± 0.4 in cavities with 1.0 mm RDT and to 11.3 ± 0.5 in cavities with 0.4 mm RDT. This pH increase could suggest the presence of a certain degree of antibacterial effect of CH inside the dentinal tubules. Fuss et al. (9) report no significant pH changes of medium surrounding teeth that contained CH. They concluded that hydroxyl ions do not diffuse through dentinal tubules sufficiently to have a therapeutic effect. Their contradictory findings to the present study can be attributed to a shorter time of CH application in the root canal (only 1 week) and to RDT values >1 mm. In addition, a large volume of buffer solution in vials surrounding the roots was measured unlike the present study where small cavities of precise depth with microelectrode were used.

Nerwich et al. (10) used a microelectrode to study the pH changes in small cavities in the root dentin after placement of CH dressing for 30 days. An increase in pH in external root cavities to a maximal pH of 9.3 was found, which is similar to the present results in cavities with 1 mm RDT. It is conceivable that their results are related to cavities of 1 mm RDT, although no they used no accurate control of RDT. They concluded that hydroxyl ions diffuse through root dentin. In the above studies, as well as in the present one, no significant increase in pH was observed within a few minutes to several days following CH application in the root canal.

In the present study, electrophoretical activation of CH demonstrated an immediate significant increase in pH from 6.9 ± 0.1 to 11.3 ± 0.4 in the external root surfaces of cavities with 0.4 mm RDT. This significant rapid increase in pH could not be detected in any previous study without electrophoretic activation of CH. One explanation of this phenomenon could be that electrical stimulation improves the dissociation rate of CH, thus the concentration of hydroxyl ions increases in the solution and facilitates rapid ingress of ions into the tubules (8). Another explanation could be that electrical stimulation of CH may change the net electrical charge of dentin, which contributes to the buffering effect, and therefore allows rapid penetration of hydroxyl ions through the patent dentinal tubules.

Clinically, application of electrophoretically activated CH in young traumatized teeth may shorten the intracanal medication period. This decreases the exposure time of dentin to CH ions, which could reduce possible adverse effect of CH on the physical properties of dentin (7). Moreover, this will allow faster restoration of a traumatized tooth with possible reinforcement of the dental structure. Subsequent studies on human teeth with modification of electrical current and adjustment of the electrode are in progress.

Conclusion

In this *in vitro* model, electrophoretically activated CH significantly increases the dentinal pH of external root surfaces within minutes. Further *in vivo* researches are necessary to determine if this significant pH increase in a short period of time after electrophoresis could be beneficial in preventing or halting root resorption after traumatic injuries of young teeth.

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