ORIGINAL RESEARCH
Endodontics

Influence of chlorhexidine and zinc oxide in calcium hydroxide pastes on pH changes in external root surface

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Abstract: The objective of this study was to assess the influence of chlorhexidine (liquid and gel) and zinc oxide in calcium hydroxide (CH) pastes on root pH in simulated external resorption. One hundred human anterior teeth with a single root canal were selected. After decoronation and root canal instrumentation, the specimens were divided into 4 experimental groups and 1 control group (without intracanal paste): CH + saline (CH+S), CH + 2% chlorhexidine liquid (CH+ CHX), CH + 2% chlorhexidine gel (CH+ CHXg), and CH + 2% chlorhexidine gel + zinc oxide (CH+ CHXg+ZnO). pH was measured using a microelectrode at 3 and 24 h, and 1, 2, 3, and 4 weeks after inserting intracanal pastes. Data were analyzed statistically using an ANOVA and Tukey's test ($p < 0.05$). The CH+CHXg+ZnO group had the highest pH values throughout ($p<0.05$). The CH+S and CH+ CHX groups had the highest pH values after 1 week and the CH+ CHXg group after 2 weeks. CH+ CHXg maintained the highest pH until the fourth week compared with CH+ CHX ($p < 0.05$). The control group remained at a neutral pH at all evaluated times. It can be concluded that chlorhexidine solution or gel maintained the alkaline pH of CH, and chlorhexidine gel allowed a slower decrease in pH over time. CH+ CHXg+ZnO showed the highest pH values and was an effective intracanal medication for maintaining alkaline root pH in the area of resorption.

Keywords: Chlorhexidine; Zinc Oxide; Calcium Hydroxide, Endodontics

Introduction

External inflammatory root resorption represents a challenge for dentists because it can lead to tooth loss when diagnosis is delayed.[1,2] For resorption to occur, the protective barriers of the dental root, which are represented by the cementoblasts and the pre-cementum, must be destroyed and an inflammatory process must be initiated. This process can be potentiated in teeth with pulp necrosis because bacteria and their metabolic products can diffuse through the dentinal tubules, acting as a stimulant to inflammation on the external root surface.[3] Usually, such lesions appear as sequelae after severe dental trauma, such as luxations and avulsions.[4]

Calcium hydroxide (CH) pastes have traditionally been used as an intracanal medicament to treat external inflammatory root resorption.[3,5]

CH has a high pH, antimicrobial activity, and inhibits the clastic cells responsible for the progression of resorption.[6,7,8,9] An appropriate vehicle must be used for CH to have the desired effect. Saline, distilled water, anesthetic solutions, and propylene glycol are commonly recommended vehicles.[10]

Chlorhexidine (CHX) digluconate is a bisguanide known for its antimicrobial action against bacteria.[11] For endodontic purposes, CHX can be used in a liquid or in a gel presentation and it has been suggested as an alternative vehicle for CH.[11] This combination is associated with excellent antimicrobial activity and high pH, without alteration of the biological characteristics or action as a physical barrier preventing the reinfection of the canal.[11,12]

Depending on the stage of root resorption, CH pastes must be renewed within the canal for several weeks.[3] Abbott[3] states that the intracanal medicament can remain in the canal for 6-12 months, being replaced every 3 months. Chamberlain[13] suggests changing CH pastes at shorter intervals because, after 4 weeks, the pH decreases substantially. Although this type of treatment is well accepted, the constant changes of CH paste are a clinical disadvantage. In addition, renewal and prolonged exposure to CH may alter the mechanical properties of dentin, reducing fracture resistance.[14,15,16,17]

Another proposed intracanal medicament for the treatment of external inflammatory resorptions is the combination of 2% CHX gel, zinc oxide, and CH.[18] This medicament presents greater radiopacity when compared with medicaments without zinc oxide, and remains in the root canal for longer periods without the need for periodic changes. However, no studies in the literature have evaluated how long this medicament remains at a high pH, a critical factor for the control of external inflammatory root resorption.

In view of the above information, the aim of this study was to assess the influence of CHX and zinc oxide in CH medications on pH in simulated external root resorption.

Methodology

This study was approved by the Research Ethics Committee of the Health Sciences Center of Federal University of Paraiba (protocol number: 44722715.4.0000.5188).

Sample size was calculated according to a previous study with similar methodology.[9] The minimal sample size to detect a difference with a power of 80% at 95% confidence interval was 12. (G*Power 3.1.7 software for Windows; Heinrich Heine, Universität Düsseldorf). However, additional specimens were used to compensate for possible sample loss.

One hundred anterior permanent human teeth with similar anatomic characteristics were selected. Before the analysis, all teeth were radiographed in the buccolingual and mesiodistal directions to confirm the presence of a single canal with no curvature. Teeth with morphological alterations, cavities, or destruction of the root cementum were excluded from the study sample.

The teeth were decoronated 15 mm from the apex to create roots of equal length. Confirmation of the root length was performed with a digital caliper. The procedure was followed by instrumentation of the canals using a Reciproc 50.05 instrument (VDW GmbH, Munich, Germany) in accordance with the manufacturer's instructions. The working length was 1 mm short of the apical foramen. A K-file 15 (Dentsply, Bailagues, Switzerland) was inserted up to the apical foramen for maintaining apical patency. Canal irrigation was performed with 15 mL of 2.5% sodium hypochlorite. On completion of the instrumentation, the canals were irrigated with 5 mL of 17% EDTA, and 10 mL of distilled water.

To simulate external root resorption, cavities on the buccal surface of the roots were created with a 1.4-mm high-speed diamond round bur (Brasseler, Savannah, USA). Only one defect was created on each tooth. The cavities were positioned 5 mm above the root apex, in the middle third, and were 4 mm in diameter. To remove the smear layer, the simulated root resorptions were irrigated with 3 mL of 17% EDTA and then with 5 mL of distilled water.

Division of experimental groups and analysis of root pH

The specimens were divided into four experimental groups and one control group, as shown in Table 1.

Table 1. Control and experimental groups (n = 20 for each).

Groups	Intracanal paste
Control	Saline
CH+S	Calcium Hydroxide[1] + Saline
CH+CHX	Calcium Hydroxide + 2% Chlorhexidine liquid[2]
CH+CHXg	Calcium Hydroxide + 2% Chlorhexidine gel
CH+CHXg+ZnO	Calcium Hydroxide + 2% Chlorhexidine gel[3] + Zinc Oxide[4]

[1]Konne Ltda., Belo Horizonte, MG, Brazil; [2]Maquira, Maringá, PR, Brazil; [3]Essential Farma, Itapetininga, SP, Brazil; [4]S.S. White Ltda.,Rio de Janeiro,RJ, Brazil.

Before material placement, all canals were dried with paper points. The intracanal pastes for each group were manipulated on a glass plate, adding CH to the vehicle in a ratio of 1:1 until a creamy consistency was obtained. The insertion into the root canals was performed using lentulo spirals, filling the entire root canal. For the CH+CHXg+ZnO group, manipulation was also performed on a glass plate, adding CH, CHX gel, and zinc oxide in a ratio of 2:1 2 as described by Soares et al.[18] The consistency of this intracanal paste is similar to that of Coltosol (Coltene/Whaledent, Mahwah, USA). This medicament was inserted incrementally with an endodontic condenser (Odous de Deus, Belo Horizonte, Brazil) until it filled the root canal. Complete placement of CH pastes was verified radiographically.

Coronal sealing was performed with Coltosol (Coltene/Whaledent, Mahwah, USA) and composite resin (Filtek 3M Espe, Sumaré, Brazil). Apical sealing was performed with cyanoacrylate and sticky wax. Subsequently, the specimens were inserted into individual devices containing non-buffered saline solution. The cap of each device was filled with sticky wax to allow fixation of the specimens and prevent their displacement. The specimens were stored in an incubator at 37 °C until the root pH was assessed.

To measure the pH, the teeth were removed from the individual devices and washed with distilled water. A digital pH meter with a microelectrode (HI1093B, Hanna instruments, São Paulo, SP, Brazil) was used to verify root pH changes. The microelectrode was calibrated with solutions of known pH (4.7 and 9) before every five measurements. The assessments were performed at 3 h, 24 h, and 1, 2, 3, and 4 weeks after inserting the intracanal pastes. The methodology and the periods of analysis were based on previous studies.[9,13]

Statistical analysis

Kolmogorov-Smirnov analysis of the raw data indicated a bell-shaped distribution. Therefore, the data were analyzed with a one-way analysis of variance (ANOVA) and the groups were compared using Tukey's multiple comparison test (with a 95% confidence interval, $p = 0.05$). Data were analyzed using SPSS 11.5 statistical software (SPSS Inc, Chicago, USA)

Results

Table 2 shows the mean pH values, standard deviation, and statistical differences found in the between-group and within-group analyses. The CH+CHXg+ZnO group presented the highest pH values at all evaluated times, differing statistically from the other groups ($p < 0.05$). The maximum pH values of the CH + S and CH + CHX group were 9.5 and 9.92, respectively, reached in the first week. The CH + CHXg group reached the peak pH value (9.99)

Table 2. Mean (Standard deviation) pH values for the groups at each time point.

Time	Saline	CH+S	CH+ CHX	CH+ CHXg	CH+ CHXg+ZnO
3 h	7.72 (0.38) Aa	8.53 (0.25) Ba	8.81 (0,24) Ca	8.69 (0.27)BCa	9.5(0.31) Da
24 h	7.7 (0.27) Aa	8.47 (0.24) Ba	9.01 (0.34) Ca	8.5 (0.32) Ba	9.69 (0.39)Ca
1 week	7.9 (0,33) Aa	9.5 (0.29)Bc	9.92 (0.49)Cb	9.84 (0.34)BCc	11.14 (0.75)Dc
2 weeks	7.99 (0,24)Aa	9.15 (0,34)Bb	9.04 (0.24) Ba	9.99 (0.44)Cc	10.24 (0.38)Cb
3 weeks	7.78 (0.29) Aa	8.70 (0.25) Ba	8.84 (0.19) Ba	9.91 (0.24)Cc	10.13 (0.38)Cb
4 weeks	7.74 (0.29) Aa	8.68 (0.21) Ba	8.78 (0.19) Ba	9.44 (0.21)Cb	9.69 (0.23) Da

*Different uppercase letter indicates significant difference between different groups within the same time point and different lowercase letter indicates significant difference between the time points within the same group.

in the second week; it decreased more slowly until the fourth week compared with the CH + S and CH + CHX groups ($p < 0.05$).

Discussion

Pulp necrosis is one of the factors responsible for the progression of external inflammatory root resorption, because bacteria and their metabolic products can diffuse through the dentinal tubules, reach the root surface, and increase destruction in this area, thus making endodontic treatment necessary.[3] As CH has an active influence on the reduction of osteoclastic activity and induction of repair, it plays an important role in controlling resorption.[13,19,20] Such effects are possible because of the pH of CH.[10] Pure CH paste has a high pH (12.5 to 12.8) and it is classified as a strong base.[10] pH values found in this study varied from 8.4 to 11.1 because the pH was measured on the root surface. Other studies with a similar methodology found similar pH values.[9,13] The decrease in pH on the root surface can be explained because the diffusion of hydroxyl ions along the dentinal tubules was probably slowed by the buffering capacity of dentin.[21]

Aqueous solutions are recommended as vehicles for CH because they allow rapid release of ions. In the present study, the use of saline confirmed this. The maximum pH peak was reached after 1 week, remaining above pH 9 until the second week. Thereafter, the decrease was significant. Chamberlain et al.[13] verified the pH changes in simulated external root resorption in canals completely or partially filled with CH, and also observed that the pH values began to decrease significantly after the second week. However, the authors used UltraCal XS (UltraDent Products Inc., South Jordan, USA), which also has an aqueous vehicle, and stated that this medication must be renewed within the canal after 4 weeks. The results of this research confirm the need for renewal to maintain the alkaline pH of the root surface when saline is used as a vehicle.

CHX is a substance used as an endodontic irrigant and its pH ranges from 5.5 to 7.[11] CHX in combination with CH is an intracanal medicament advocated by several authors who claim that the antimicrobial activity of CH is potentiated by the addition of CHX.[12,22-31] Other advantages of this association are: high pH,[22-25] substantivity as a result of the presence of CHX,[12,28] as a physical barrier against the reinfection of the canal,[12] radiopacity,[29] and diffusion through the dentinal tubules,[29] which is an important factor for the treatment of external inflammatory root resorption.

The maximum mean pH values reached in the root surface by the pastes containing CHX liquid and gel were 9.92 and 9.99, respectively. Such results concur with those of other studies that found pH values between 9 and 12.[32,33,34,35] However, Carvalho et al.[36] observed that when CHX was used as the vehicle, the peak pH was achieved immediately after preparation of the medication (pH = 9); after 7 days, the pH was neutral. These authors have questioned the efficacy of the combination of CHX and CH. In the present study, the use of CHX did not decrease the alkalinity of CH, because when this vehicle was used, the pH values in the first week were higher than with saline. Basrani et al.[37] affirmed that addition of CHX to CH lowers its contact angle and improves the wettability of the medication on the root canal, favoring the penetration of ions into the dentinal tubules.

The paste containing CHX liquid reached the highest pH values after 1 week. The pH decreased significantly in the third and fourth weeks compared with the first one. By contrast, the paste containing CHX gel had higher pH values than did CHX liquid at all evaluated times, reaching the peak in the second week. Duarte et al.[33] found that 2% CHX gel associated with CH had higher pH values when compared with 1% CHX in propylene glycol; they attributed this result to natrosol gel, which is water-soluble and may favor the release of hydroxyl ions. In the present study, the decrease in pH over time was slower for CHX gel than for CHX liquid. In the third and fourth weeks, the pH of 2% CHX gel was also significantly higher. A reason for this is that natrosol may also allow the release of hydroxyl ions for a longer period, allowing the pH to remain alkaline in the fourth week.

One of the disadvantages of CH for the treatment of external inflammatory root resorption is the need for periodic renewals so that it can continue to exert its effects within the canal. Pastes containing zinc oxide can have a longer residence time in the root canal without the need for constant changes. The use of this paste was recommended for the treatment of traumatized teeth with external inflammatory root resorption and achieved good clinical results.[38]

The CH+ CHXg+ZnO group had the highest pH values at all evaluated times. Souza-Filho et al.[22] verified the antimicrobial effect and pH of this paste and observed that, compared with the combination of 2% CHX gel and CH, the pH was higher, which is in agreement with the present research. Guerreiro-Tanomaru et al.[39] verified the effect of the addition of microparticulate and nanoparticulate zinc oxide in CH pastes and observed that the pH peak occurred after 14 days, remaining higher than 10 after 28 days. In the present study, the maximum pH was also observed in the second week, remaining alkaline until the fourth week. The results of this research suggest that, despite having higher viscosity than other pastes, the combination of 2% CHX gel, CH, and zinc oxide allowed the diffusion of ions inside the dentinal tubules, maintaining an alkaline pH in the area of resorption. Zinc oxide has a neutral pH when combined with inert vehicles,[39] but the oxide behaves as an amphoteric oxide;[40] that is, it acts as an acid or a base depending on the medium. It is suggested that zinc oxide combined with CHX gel and CH may raise the pH of these medications, which are already alkaline. Further studies are recommended to verify the chemical association between these medicaments and to evaluate their efficacy in the treatment of external inflammatory root resorption.

According to the results of the present *in vitro* study, we can conclude that CHX solution or gel maintains the alkaline pH of CH, and that CHX gel allowed a slower decrease in pH over time. The combination of 2% CHX gel, CH, and zinc oxide had the highest pH values and was an efficient medication for maintenance of alkaline root pH in the area of resorption in this study.

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