Root fracture resistance of simulated immature teeth treated with different calcium hydroxide medications

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ABSTRACT

Objective: The aim of this study was to evaluate the influence of calcium hydroxide medications on root fracture resistance of simulated immature teeth. **Methods:** Sixty bovine teeth were decoronated, had root canals prepared with #45-80 K-files, and were irrigated with sodium hypochlorite (1%). Tooth apexes were amplified with type-703 drills to simulate incomplete root formation, standardizing the foramen diameter at 2.1 mm. Roots were embedded in blocks of acrylic resin and divided into three groups: GI = control (no intracanal medication); GII = calcium hydroxide (CH) and saline solution; and GIII = CH + chlorhexidine gluconate 2% (CHX) gel + zinc oxide (ZO). Specimens were stored in saline solution for 30 or 45 days at 37 °C, and then subjected to compression test at 90°, using a universal testing machine at speed of 1 mm/min until fracture occurred. Data were evaluated by ANOVA statistical analysis and a post hoc Bonferroni test. **Results:** Both groups (GII and GIII) showed a reduction in fracture resistance compared to the control group, after both 30 and 45 days ($p < 0.05$). In all three groups, there was no statistical difference between the two treatment periods. **Conclusion:** With the procedure used in this study, CH dressings in combination with saline solution, or CHX and ZO, led to significant reductions in root fracture resistance, compared to the control group.

Keywords: Endodontics. Apexification. Calcium hydroxide. Chlorhexidine. Zinc oxide.

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Introduction

The consensus on clinical treatment of immature teeth with vital pulp is apexogenesis. This is due to the importance of preserving remaining vital tissue to allow continued physiological development and complete root formation. Teeth with necrotic pulp must be cleaned and have canals filled with calcium hydroxide (CH; the most commonly used agent) to induce the formation of a calcified barrier at apexification, followed by filling of the root canal system.[1,2]

The inherent properties of CH underpin its clinical success. A high pH provided by the release of hydroxyl ions denatures proteins of the bacterial cytoplasmic membrane, thereby killing the microorganism by disrupting metabolism, nutrient transportation, and cell division. The alkalized environment promotes periapical repair and mineralization of the apical barrier. However, prolonged exposure to high alkalinity of CH may lead to neutralization, dissolution and denaturation of proteins and proteoglycans of the radicular dentin organic matrix. This process can influence dentin mechanical properties and disrupt the interaction of hydroxyapatite and collagen fibrils.[3] Reductions in root fracture resistance can occur after long-term exposure to CH dressings.[4]

The influence of intracanal dressings periodical changes on dentin fracture resistance has been investigated. Periods in between changes of 30 days to 6 months have been proposed as the ideal clinical procedure.[1,2] Nevertheless, histological analysis of canines with different periods between CH dressing replacement has demonstrated that frequent changes may result in a delay in apexification. It has been suggested that CH dressing should not be renewed for 5 months, thus allowing mineralization of the apical barrier to occur without interruptions.[5] Moreover, CH medication should be changed only after its dissolution on root canal apical third, which can be observed by radiographic control.[6]

The use of CH in association with other agents has been suggested. The aim is to improve antibacterial spectrum and its physicochemical properties by improving viscosity, hydrosolubility and release rate of hydroxyl and calcium ions.[5] A novel protocol of interappointment medication, using CH, 2.5% chlorhexidine gel (CHX) and zinc oxide cement (ZO), has been developed by Soares et al.[7] Their intention was to obtain a low-cost intracanal dressing, with easy handling, radiopacity, and a broad antibacterial spectrum, and which would stimulate mineralization and remain inside the root canal for a long period.

Investigations into different protocols of intracanal CH dressings during endodontic treatment are important, especially with regard to biomechanical changes to dentin properties. The purpose of the present study was to determine changes in fracture resistance of bovine teeth, provided by two different intracanal dressing protocols (CH combined with either saline, or CHX + ZO), after 30 or 45 days of intervention.

Methods

Sixty recently-extracted bovine teeth were tested. Inclusion criteria for tooth selection included: lack of root resorptions, extensive caries, cracks or deformations. Periapical radiographs were taken to confirm root canal anatomy. Using a digital pachymeter (Vonder, Curitiba, Paraná, Brazil), tooth thickness was measured for standardization to avoid bias in results. After selection, teeth were stored in saline solution for 72 hours.

Tooth crowns and roots were sectioned at 8 mm and 12 mm from the dentin-enamel junction (DEJ), respectively, using a rotating diamond disc. Specimens were standardized to a total length of 20 mm. Pulp tissue was removed using Hedströem files (Dentsply Maillefer, Ballaigues, Switzerland), and root canals were prepared using K-files #45-80 (Dentsply Maillefer, Ballaigues, Switzerland), with 1% NaOCl irrigation after each file. Canals were amplified with a 703 bur to simulate an open apex tooth. An internal diameter of 2.1 mm was achieved using a digital pachymeter (Vonder, Curitiba, Paraná, Brazil).

Specimens were randomly divided into three groups based on the protocol of intracanal dressing. Group I (control) (n = 20): No intracanal dressing. Teeth were sealed with a temporary filling material (Coltosol; Vigodent-Coltene, Rio de Janeiro, Brazil), and stored in an incubator at 37 °C for either 30 or 45 days. Group II (n = 20): CH (Biodinâmica, Ibiporã, Paraná, Brazil) and saline solution. Medication was inserted using a Lentulo Spiral filler instrument, at low speed, into the root canal extension. Teeth

were sealed with Coltosol (Vigodent-Coltene, Rio de Janeiro, Brazil) and stored in an incubator at 37 °C for either 30 or 45 days. Group III (n = 20): Combination of CH, CHX gel (Biodinâmica, Ibiporã, Paraná, Brazil) and ZO (Dentsply Maillefer, Ballaigues, Switzerland) at a proportion of 2:1:2, respectively. Medication was inserted into the root canal length in incremental volumes with a vertical condenser. Storage conditions were as per Group II.

Specimens were embedded into manually manufactured acrylic resin (Jet, São Paulo, Brazil) blocks 2 mm from the DEJ, simulating the tooth-bone interface. Thirty days after insertion of medication, ten samples of each group were subjected to fracture resistance test in a universal testing machine (KRATOS, Cotia, São Paulo, Brasil). Specimens were positioned at a 90° inclination, and compression force was applied at a speed of 1 mm/s. The remaining ten samples of each group were submitted to the same test 45 days after insertion of medication.

Data were analyzed with BioEstat 5.0 software. Normal distribution was verified by means of Shapiro-Wilk test. Intra- and inter-group comparisons of fracture resistance for different medication protocols were determined using two parametric tests: ANOVA, and Bonferroni. A 5% level of statistical significance was applied to analyses.

Results

Both medication groups (II and III) showed lower fracture resistance than the control group after both 30 and 45 days ($p < 0.05$). No differences were observed between Groups II and III, or between the two durations of exposure ($p > 0.05$) (Table 1).

Discussion

Treatment of immature teeth represents a real challenge mainly due to thin walls and open apex. In this study, he samples were prepared to simulate the conditions found in practice by amplifying root canal and apex.

Apexification is the most common treatment for necrotic immature teeth, and consists of successive changes of CH medications until the apical barrier forms, thereby allowing for adequate root canal filling.[8,9] Although apexification is a well-established and successful treatment, the need for periodic changes of intracanal dressing is a major disadvantage, which can be magnified by lack of patient cooperation and lead to treatment failure.

The mechanism of CH-induced root weakening is denaturation of proteins and proteoglycans, which act as the link between hydroxyapatite crystals and collagen fibrils of the dentin organic matrix.[10] A systematic review of in vitro studies on the effects of CH on root fractures concluded that exposure to CH for over five weeks leads to a reduction in dentin mechanical properties.[11] However, data collected on the use of CH for 30 days or less was inconclusive. In the present study, significant reduction in dentin fracture resistance was found after both 30 and 45 days of exposure.

To improve the effectiveness of CH treatment, its combination with several substances has been suggested as alternative intracanal dressings.[9,12,13] Our study evaluated fracture resistance of teeth treated with different medication protocols based on the following combinations: CH and saline solution, and an experimental mixture of CH, CHX and ZO. The latter intracanal dressing may simplify apexification treatment, as it results in a paste of

Table 1. Mean and standard deviation of maximum fracture resistance (in KgF) of different groups and times of exposure.

Time	GI (no intracanal dressing)	GII (CH + saline solution)	GIII (CH, CHX gel and ZO)
30 days	$261.12 \pm 78.13^{A,a}$	$192.12 \pm 35.73^{B,a}$	$188.57 \pm 53.82^{B,a}$
45 days	$268.35 \pm 52.63^{A,a}$	$213.33 \pm 26.14^{B,a}$	$216.50 \pm 40.57^{B,a}$

ANOVA + Bonferroni p-value < 0.05. Different capital letters in a line indicate statistically significant differences between groups; different lowercase letters in a column indicate statistically significant differences between exposure times within groups.

firm consistency, easy manipulation and insertion, good radiopacity, and increased antimicrobial activity. This stable mixture allows the medication to act for a longer period inside the root canal without need for replacement.[4,14]

ZO addition provides better radiopacity to the solution, which is useful for repeated radiographic evaluations. Since reduction in fracture resistance is attributed to CH pH, the use of viscous vehicles (e.g., CHX gel) for CH intracanal dressings provides slow ion-release, which is thought to create minor reduction in fracture resistance. Results of the present study show that a reduction in fracture resistance occurred in teeth treated with CH and saline solution, and a combination of CH, CHX and ZO after 30 and 45 days of exposure. Moreover, a significant difference between these two protocols was not observed. These findings are in agreement with other studies which demonstrated significant reductions in teeth resistance after long-term CH intracanal dressing.[15-17] However, this is the first study on fracture resistance using a new medication protocol based on a combination of CH, CHX and ZO.

Success of endodontic therapy of immature teeth using intracanal dressings of CH solutions is backed by clinical evidence. A relatively high success rate of 86.27% for apexification treatment has been reported.[9] However, no improvements in fracture resistance of teeth treated with CH have been demonstrated, regardless of the dressing analyzed. In a recent study, teeth fracture resistance was tested after treatment with different commercial presentations of CH.[12] No significant statistical difference was observed in the following groups: Ultracal XS, Pulpdent, and Vitapex.

The use of mineral trioxide aggregate (MTA) has been recommended as an alternative therapy for apical barrier formation in apexification cases. A systematic review to compare CH and MTA in apexification procedures concluded that both treatments are efficient at achieving favorable clinical results and apical barrier formation. However, MTA appears to promote superior results within a shorter treatment period.[18] Another treatment for immature teeth is pulp revascularization which increases thickness of root canal walls and teeth length, resulting in complete apical closure and reduced risk of root fracture.[19]

Despite the promising results of alternative protocols, apexification with CH remains the treatment of choice for immature teeth endodontic therapy. This is due to the limited resources of many public health systems around the world, and lack of awareness amongst healthcare professionals regarding alternative therapies that may provide better clinical results.[20]

Conclusion

The application of either CH with saline solution or a mixture of CH, CHX and ZO led to reductions in fracture resistance of bovine teeth after exposure to medications for 30 or 45 days.

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