



Effects of intracanal medicaments and the remaining cavity wall on fracture strength of endodontically treated molars

Efeitos dos medicamentos intracanaís e do muro de cavidade remanescente na força de fratura dos molares endodonticamente tratados

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ABSTRACT

Objective: The aim of this study was to investigate the effects of the short-term intracanal application of two medicaments on the fracture strength of root-filled molar teeth with different levels of tooth structure loss. **Material and Methods:** Standard access cavities of totally 84 intact maxillary molar teeth were prepared in 72 teeth and were divided into 3 main groups. Standard access cavities were kept in the first group, while mesio-occlusal-distal cavities (MOD) were prepared in the second and third groups. One-half of the palatal walls were removed in the third group. Twelve sound teeth were used in the fourth group as control. Each group was then assigned into two subgroups according to the medicament used ($n=12$): 2% chlorhexidine gel and calcium hydroxide. Samples were stored at 37°C and 100% humidity for 1 week. Then the teeth were inserted into a universal testing machine and vertically loaded (5 mm/min) from the occlusal surface. The data was recorded in Newtons and statistically evaluated using a Univariate ANOVA and a Tukey as post hoc test. **Results:** A significant difference was found among the test groups ($p<0.01$). No significant difference was found according to the medicament used ($p>0.05$), however the number of remaining walls significantly affected the fracture strength ($p<0.01$). The first group with access cavity showed mostly repairable fractures (60%–80%) whereas the others showed mostly non-repairable fracture patterns (60%–90%). **Conclusion:** In conclusion, the fracture strength of endodontically treated teeth is related to the structure loss rather than the intracanal medicament used.

KEYWORDS

Endodontically treated teeth; Fracture strength; Intracanal medicament; Remaining cavity wall; Root fracture.

RESUMO

Objetivo: O objetivo deste estudo foi investigar os efeitos da aplicação intracanal de curto prazo de dois medicamentos sobre a resistência à fratura de dentes molares preenchidos com raízes com diferentes níveis de perda de estrutura dentária. **Material e Métodos:** cavidades de acesso padrão de totalmente 84 dentes molar maxilares intactos foram preparadas em 72, dentes e foram divididas em 3 grupos principais. As cavidades de acesso padrão foram mantidas no primeiro grupo, enquanto as cavidades mesio-occlusais-distal (MOD) foram preparadas no segundo e terceiro grupos. A metade das paredes palatinas foi removida no terceiro grupo. Doze dentes de som foram utilizados no quarto grupo como controle. Cada grupo foi então atribuído em dois subgrupos de acordo com o medicamento utilizado ($n = 12$): 2% de gel de clorhexidina e hidróxido de cálcio. As amostras foram armazenadas a 37 ° C e 100% de umidade por 1 semana. Em seguida, os dentes foram inseridos em uma máquina de teste universal e carregados verticalmente (5 mm / min) da superfície oclusal. Os dados foram registrados em Newtons e avaliados estatisticamente usando uma ANOVA Univariada e um Tukey como teste post hoc. **Resultados:** uma diferença significativa foi encontrada entre os grupos de teste ($p < 0,01$). Nenhuma diferença significativa foi encontrada de acordo com o medicamento utilizado ($p > 0,05$), no entanto, o número de paredes restantes afetou significativamente a resistência à fratura ($p < 0,01$). O primeiro grupo com cavidade de acesso apresentou fraturas principalmente reparáveis (60% -80%), enquanto as demais apresentaram padrões de fratura não reparáveis (60% -90%). **Conclusão:** Em conclusão, a resistência à fratura dos dentes tratados endodonticamente está relacionada à perda da estrutura em vez do medicamento intracanal utilizado.

PALAVRAS-CHAVE

Dentes endodonticamente tratados; Força de fratura; Medicamento intracanal; Parede de cavidade restante; Fato de raiz.

INTRODUCTION

The major aims of root canal treatment are complete debridement of infected tissue and a reduction in the bacterial infection. Calcium hydroxide (CH) has been used for this purpose for decades between the appointments during root canal treatment [1]. CH has many advantages, such as a high pH [2], antibacterial effects [3], hard tissue stimulation [4], and reduced periapical tissue cytotoxicity [5]. CH is still a commonly used root canal dressing material for multiple-visit root canal treatments because of its antibacterial activity due to its high pH level [6].

In addition to the advantages of CH mentioned above, some studies reported weakening effect of CH on mechanical properties of tooth structure when used as an intracanal medicament [5,7]. White et al. [8] indicated that root dentin was weakened after 5 weeks of exposure to CH. In a study by Kawamoto et al. [9], CH exposure caused teeth to be more prone to fracture. Those teeth subjected to a 30-day application of CH were found to require less compressive strength to break in a micro tensile fracture test [1]. In another study [5], it was stated that CH weakens the dentin at a rate of 23–43.9%. Andreasen et al. [10] also indicated that the fracture strength of CH-filled immature teeth increased the risk of fracture over the long term. Recently, a few studies supporting the previous results have also been published [6,11,12]. Therefore, chlorhexidine (CHX) gel has been suggested as an alternative because of its antimicrobial properties and substantivity [13,14].

To our knowledge, no previous study has compared the effects of using CH and CHX gel as intracanal medicaments on the fracture strength of dentin. In addition, no previous study has investigated the effects of the remaining cavity wall on the fracture strength of dentin with intracanal medicaments. Therefore, the goal of

this in vitro study was to investigate the effects of the short-term intracanal application of CH and CHX gel as intracanal medicaments on the fracture strength of molar teeth with different remaining cavity wall levels. The tested null hypotheses were: (i) there will be no difference in the fracture resistance of the dentin when intracanal medicaments CH and CHX are used for 1 week, and (ii) root canal treatment with different remaining cavity levels walls will not affect the fracture resistance of maxillary molar dentin.

MATERIALS AND METHODS

Eighty-four intact, non-carious, extracted human maxillary first and second molars with fully formed roots were selected for this study. The teeth were stored in saline solution for less than three months from the time of extraction and kept moist at room temperature ($23 \pm 1^\circ\text{C}$) until they were used for the test. All of the teeth were cleaned with water, and the soft tissue and calculus were debrided mechanically. The teeth were divided into 3 main groups and one control group according to the statistical analysis. The widths of the roots at the cemento-enamel junction (CEJ) were measured using a digital caliper (Model CD-6BS; Mitutoyo, Tokyo, Japan) and recorded as 10 ± 1 mm buccolingually and 8.6 ± 1 mm mesiodistally. A one-way ANOVA was used to analyze the samples. No significant differences in terms of the sample dimensions were found among the groups ($p=1.000$).

Twelve teeth were kept as control and standard endodontic access cavities were prepared in 72 teeth with a #4 round bur (Diatech; Coltène/Whaledent GmbH + Co. KG, Langenau, Germany) under sufficient water cooling, and the root canal patency was achieved using a #10 K file (Dentsply Maillefer, Ballaigues, Switzerland). To determine the working length, the #10 K file was placed into the root canal until the end of the file was seen from the apical foramen. The working length was calculated to

be 0.5 mm shorter than the apical foramen. All of the root canals were prepared up to AS40 using the Revo-S Classic Rotary System (Micro-Mega, Besançon, France) in accordance with the manufacturer's instructions. RC-Plus (Medicept, Middlesex, UK) was used for lubrication in the root canal during instrumentation. Irrigation was applied between each file size with 1 ml of 2.5% sodium hypochlorite (NaOCl) for each root canal. After the preparation was complete, each root canal was finally irrigated with 1 ml of 17% ethylenediaminetetraacetic acid (EDTA). Then, all of the canals were dried using paper points, and the cavities were prepared as follows:

- *Group 1:* The standard endodontic access cavities were cleaved as described above by using a diamond fissure burr (Dentsply Maillefer).
- *Group 2:* In addition to the standard endodontic access cavities, standard MOD cavities were prepared by using a special (extra) shaped diamond bur (#237/032 EX-26, Dia-Burs; MANI, Inc., Tochigi, Japan). MOD cavities were prepared in the teeth down to the canal orifices so that the thickness of the buccal wall of the teeth measured 2 mm at the buccal occlusal surface, 2.5 mm at the CEJ, 1.5 mm at the lingual occlusal surface and 1.5 mm at the lingual CEJ.
- *Group 3:* In addition to the treatment described for group 2, one-half of palatal walls were additionally removed by using a special (extra) shaped bur (#237/032, EX-26; MANI, Inc.).
- *Control group:* Twelve sound, unprepared maxillary molar teeth were used for the controls.

Each of the three experimental groups was randomly divided into two subgroups according to the medicament used (n=12): CHX gel and

CH subgroups. For the CHX gel subgroup, after the root canal preparation, CHX gel was applied to the root canals using a lentulo spiral. For the CH subgroup, after the root canal preparation, the canals were filled with a CH paste that was prepared by mixing CH powder (Vision Calcium Hydroxide; Anadolu Dis Deposu, Istanbul, Turkey) with normal saline. The access cavities were then sealed with a minimum of 3mm thick temporary restorative filling material (Coltosol F; Coltene/Whaledent Inc.) using a spatula. The teeth were stored at 37 °C and 100% humidity for one week.

At the end of the storage period, to simulate the periodontal ligament and alveolar bone support, the root surfaces were dipped into melted wax up to 1mm below the CEJ by using a setup for the wax dipping technique (Ceradip; Bego, Germany) to create a 0.2–0.3 mm thick wax layer. The roots were then vertically embedded in self-curing polymethyl methacrylate resin (Vertex, Dentimex Dental, Zeist, Netherlands) using polyvinyl chloride molds to a level of 1.0 mm apical to the CEJ. The resin was mixed according to the manufacturers' instructions and inserted into the molds immediately after mixing. After resin polymerization, the teeth were removed from the resin blocks, and the wax was eliminated using warm water [15]. The space formed between the root surface and the polymethyl methacrylate resin was then filled with silicone paste (Dow Corning 3140 RTV coating; Dow Corning Corp., Midland, MI, USA). The teeth were reinserted into their sockets and any excess impression material was removed with hand instruments. Thus, a standardized simulated periodontal ligament with a thickness of 0.2–0.3 mm was provided.

After finishing these procedures, the specimens were positioned in a universal testing machine (Instron, Canton, MA, USA) so that the occlusal surfaces of the cores simultaneously came into contact with a 4-mm in diameter steel sphere. All of the specimens were subjected to

a compressive load at a cross-head speed of 5 mm/min until fracture. The force was applied so that it would be parallel to the vertical axis. Each tooth was placed vertically, so that it was placed at the same point each time. The probing was performed to cover the entire occlusal surface at the same time and the teeth were adapted to be equally contacted over all the cusps. The load that was necessary to fracture each sample was recorded in Newtons (N), and the fracture pattern of each sample was classified as follows:

- *Restorable*: Core fracture 1/2 above the CEJ and core fracture more than 1/2 above the CEJ or a vertical fracture at the composite core that did not extend into the root.
- *Non-restorable*: Core fracture (total) above the CEJ and a vertical fracture below the CEJ extending into the root. Vertical longitudinal fractures involving the crown that extended into the root were also considered to be non-restorable.

Statistical analysis

The statistical analyses of the collected data were performed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk's test was used to confirm the assumption of the normality of the data. A Univariate analysis of variance (ANOVA) test was used to determine the differences between the groups, and a post hoc Tukey's test was used to determine the differences between two groups. For all of the tests performed, the level for the significance of the differences was $p \leq 0.05$.

RESULTS

The results of the mean fracture strength values and standard deviations of the force required to fracture for the groups are shown in Table 1.

Table 1 - Distribution of fracture strength values according to the test groups

	Group 1	Group 2	Group 3
CHX Subgroup	1960.3±653.1	630.7±237.1	205.4±70.5
CH Subgroup	1388.9±331.5	673.4±228.1	398.6±153.6
Control Group	1634.6±487.5		

Mean fracture strength values (in Newton) and standard deviations of the test groups (mean±SD).

As a result of the statistical evaluation, no significant difference was found according to the medicament used ($p > 0.05$), but the remaining cavity wall significantly affected the fracture strength ($p < 0.01$).

There was a significant difference between Groups 1 and 2 ($p < 0.05$) and Groups 1 and 3 ($p < 0.05$), but no significant difference was found between Group 1 and the control group ($p > 0.05$). In addition, there was no significant difference between Groups 2 and 3 ($p > 0.05$); however, significant differences were found between Group 2 and the control group ($p < 0.05$) and Group 3 and the control group ($p < 0.05$).

The content of medicaments used in the study is summarized in Table 2.

Table 2 - Chemical composition and application methods of intracanal medicaments

Material	Chemical Composition	Application
Chlorhexidine Gel (Gluco-CHeX; PPH CerKamed, Stalowa Wola, Poland)	Chlorhexidine digluconate 2%, base gel.	Before the treatment immerse the attached applicator into the spirit (ethyl alcohol) and then place it onto the syringe. Introduce the product into the root canal directly on the canal instrument or by means of the attached applicator, at the same time prepare the canal mechanically. While preparing the canal rinse it with hysiological saline or distilled water. Product intended for multiple use except the applicator which is for single use only. Multiple use of applicator may cause the risk of reinfection.
Calcium Hydroxide (Vision Calcium Hydroxide; Anadolu Dis Deposu, Istanbul, Turkey)	Calcium Hydroxide powder.	Mixed with sterile water, saline or glycerin and applied to the root canal. It is recommended to stay in the root canal for 7 to 14 days for adequate disinfection.

According to the medicament used, there was no significant difference between the CH and CHX groups ($p > 0.05$), however a significant difference was found between the control and the CH groups ($p < 0.05$) and the control and the CHX groups ($p < 0.05$).

The use of the intracanal medication decreased the fracture resistance of Groups 2 and 3 when compared to the control group (intact teeth) with a significant difference ($p < 0.05$). Reduced fracture resistance was also found in Group 1 when CH was used as medicament, but the difference was not statistically significant ($p > 0.05$).

The distribution of the groups according to the failure patterns is shown in Table 3. The first group with access cavity showed mostly repairable fracture patterns (60–80%) (Figure 1), whereas the others showed mostly non-repairable fracture patterns (60-90%) (Figure 2).

Table 3 - Chemical composition and application methods of intracanal medicaments

		Repairable (%)	Non-repairable (%)
CHX	Group 1	60	40
	Group 2	10	90
	Group 3	40	60
CH	Group 1	80	20
	Group 2	20	80
	Group 3	20	80
Control		90	10



Figure 1 - A photograph of a tooth that appears to be a repairable fracture.

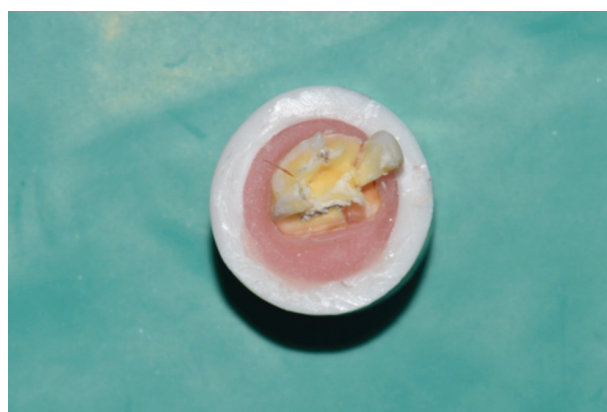


Figure 2 - A photograph of a tooth that appears to be a non-repairable fracture.

DISCUSSION

The purpose of this study was to examine the possible destructive effects of CH and CHX gel on human root dentin, and the remaining cavity wall levels on the fracture strength of endodontically treated teeth. It is evident from previous studies that the conservation of the tooth structure in the cervical area and a higher number of remaining cavity walls increased the tooth strength [16,17]. Higher strength values were expected when the palatal cavity wall remained. It seems, based on this observation, that the palatal wall contributed to the fracture resistance and had an increasing effect on the fracture strength values in this study.

CH has been used in the endodontic treatment of human teeth, often over extended periods of time. In addition, CHX gel is another intracanal medicament that is routinely used in endodontics for reducing microbial growth between sessions. It possesses properties such as substantivity, a broad antibacterial spectrum [18], and a relative absence of cytotoxicity [19]. In order to simulate the clinical conditions, extracted human teeth and a 1 week dressing duration were used in this study.

The fracture strength of the Group 1 with CHX medicament was found to be the highest in this study, while there was no significant difference between the control group and the Group 1 with CH. This finding has not confirmed the well-known fact that tooth structure loss and a long dressing time with CH significantly reduce the strength of a tooth [10, 20]. The results of this study have shown that a short-term root canal dressing with CH reduced the fracture strength of the dentin, but it was not statistically significant according to the medicament used. The findings of the current study are in accordance with the report by Doyon et al. [21], who demonstrated that a 30-day exposure to CH had no significant effect on the fracture resistance of dentin disks. Additionally, Moazami et al. [12] reported that the differences

between the fracture loads were not significant for CH in a 7-day period. However, in the same study, the CH dressings for 30 days and 1 year reduced the flexural strength of the dentin to 72%. One possible explanation for this effect could be the long-term use of CH.

It is evident from previous studies that the root dentin structure is weakened by CH over time. The Andreasen et al. study [10] showed that the CH dressing in the root canal had a significantly destructive effect on the fracture strength of the root dentin that was inversely proportional with time. In addition, Rosenberg et al. [5] showed that a CH root canal dressing reduced the micro tensile fracture strength of teeth by almost 50% between 7 and 84 days. In another CH treatment study [6], long-term intracanal dressing with CH was shown to cause an increase in the fracture risk with regard to the microtensile fracture strength in endodontically treated teeth. White et al. [8] suggested a possible advantage of using a minimal CH treatment time in the canal to decrease the weakening of the treated teeth. These results are confirmed by the Kawamoto et al. study [9], which showed that exposure to CH paste significantly increased the mean elastic modulus of bovine dentine from 16.3 to 22.1 GPa, with other studies also supporting this [22,23]. As in this study, Grigoratos et al. [14] applied CH in the root canals for one week; however, they found that the CH exposure significantly reduced the flexural strength of the root dentin bars. These results can be explained by the differences in the study designs. Sahebi et al. [1] demonstrated that a 30-day root canal dressing with CH reduced the strength of the dentin of mature human teeth by almost 15%. Moreover, Yassen et al. reported that the 3-month application of CH paste significantly reduced the fracture resistance of teeth when compared to a 1 week application [24].

One possible explanation for the reducing effect of CH on the fracture resistance of dentin

could be its alkaline pH. The protein structure of dentin contributes to the strength of the tooth structure, and a high pH can cause a breakdown of the protein structure of dentin, therefore weakening the dentin [25]. In addition, the relatively long-term exposure of radicular dentin to CH might be the reason for the significant reduction in the root's resistance to fracture.

Another possible result of the reduction in the fracture strength may be changes in the organic matrix of the dentin exposed to CH [10]. A dissolving effect by CH on the pulp tissue by way of denaturation and hydrolysis has been reported [26], and this may negatively affect the interactions of the collagen fibrils and hydroxyapatite crystals [21]. Moreover, the irrigation protocols suggested during endodontic treatment might cause a further reduction in the root fracture resistance. For example, sodium hypochlorite adversely alters the mechanical properties of root dentin, when used as an endodontic irrigant. In addition, EDTA, which is usually recommended for dissolving inorganic tissue at the end of the endodontic treatment, was found to significantly reduce the root's resistance to fracture [27].

It seems, based on these observations, that the long-term application of CH to root canal dentin following endodontic treatment could weaken the fracture strength of the dentin. However, in our study, we found that a 1 week intracanal administration, independently of the medicament type used, weakened the root dentin, but the difference found was not significant.

Despite all of these findings, a systematic review of the literature found inconclusive data regarding the negative effects of CH exposure for 1 month or shorter on the mechanical properties of the radicular dentin [25]. Recently, based on Hawkins et al.'s findings [11], there was insufficient evidence to support CH causing a decrease in the fracture resistance of dentin over a 6-month period. In the present study, our

findings appear not to support the argument that exposure to CH affects the physical properties of dentin. This may be related to the dentin's short-term exposure to CH in our study.

There is limited number of studies in the literature about the effects of CHX on the fracture strength of teeth. In the Valera et al. study [28], irrigation with 2% CHX showed a significantly lower fracture resistance than that of the control group. As an intracanal medicament, 0.5% CHX was added to CH in Prabhakar et al.'s study [29], and the mixture was applied to the root canal for 30 days. They found no statistically significant changes in the fracture strength values among all of the groups. From these studies, it could be concluded that there is not a full consensus about the effects of CHX on the fracture strength of root canal dentin. Within the limitations of this *in vitro* study, the results demonstrated that CH and CHX dressing for only 7 days did not promote a significant reduction in the dentin fracture resistance. Therefore, a shorter intracanal dressing period is required in root canal therapy to prevent non-restorable fractures in the dentin.

One of the limitations of this study was that the clinical environment of the mouth was not fully tested. The chewing forces, occlusion, and parafunctional habits can also affect the fracture resistance endodontically. Therefore, advanced study designs are needed to clarify the correlation between the intracanal medicaments and the other factors that may cause vertical root fractures. The second limitation of this study could be the short time application of the intracanal medicaments. However, further studies comparing the intracanal medications used in root canal therapy should be designed to better define the most effective period of time for the antimicrobial action, without interfering with the mechanical properties of the weakened roots.

CONCLUSION

Within the limitations of this *in vitro* study, it was concluded that the remaining cavity wall level is more important than the intracanal medicament used for endodontically treated teeth in terms of fracture resistance. Further studies should be performed to confirm these results and evaluate the exact mechanism of dentin fracture resistance.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest

The authors declare that they have no conflicts of interest with regard to this research.

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Ethical Approval

All of the procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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