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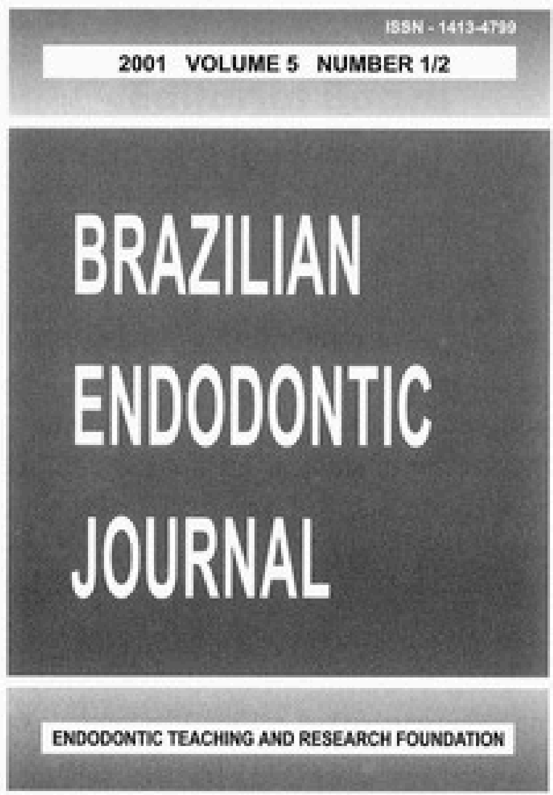

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Editorial

GOOD BRAZILIAN ENDODONTIC RESEARCH!

The past two years were remarkable for the Brazilian endodontic research. If we analyze what has been published in endodontic journals with great international impact, we can observe an important improvement in the number, quality and variety of studies. As an example, from 1999 to 2000, Brazilian studies accounted for about 15% of all publications in the *International Endodontic Journal*. This journal is the leading publication in the world in terms of impact factor. So, this means that our research is being considered as serious and innovative by the rest of the world. Lectures held in different countries using Brazilian studies as reference are no longer rare. Accurate studies are being carried out in Brazilian laboratories, and we should be proud of showing the rest of the world a lot more than Carnival and soccer.

If improvements are made in our research institutes in terms of grant offers, and if they help to establish and maintain laboratories and journals in Brazil, we will be able to show the world how creative, inventive and serious we are with our studies. Also, our Dental Schools should provide everything that is necessary for the development of consistent research in the field of endodontics.

We are happy with the good news, but we understand there is a long way to go. Is anyone tired?

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BIOCOMPATIBILITY OF ENDODONTIC MATERIALS: CYTOTOXICITY OF A POLYURETHANE RESIN DERIVED FROM CASTOR BEAN OIL

Elizeu Alvaro **PASCON**, PhD, Department of Endodontics, University of Toronto, Canada.

Cássio José Alves de **SOUSA**, PhD, Department of Conservative Dentistry, Universidade Federal de Uberlândia, MG, Brazil.

Kaare **LANGELAND**, PhD, University of Connecticut, Farmington, CT, USA.

Abstract

The polyurethane resin derived from castor bean oil (*Ricinus comunis)* presents a molecular composition that has shown compatibility with vital tissues. The purpose of this work was to compare the toxicity of this resin (Poliol) with commercially available root canal filling materials (AH26, Dentinol, Kerr Sealer, and Sealapex) according to the recommendations of FDI and ANSI/ADA. All materials were manipulated according to manufacturer instructions; components were tested individually. The chromium release *in vitro* cytotoxicity test was used. Ten samples of each material were tested right after preparation and after 24 and 60 hours of setting time for 4-hour and 24-hour cell/material contact. Controls consisted of ten samples of cells without material contact for chromium spontaneous release by natural cell death. Statistical analysis of the results showed significant differences between the materials, which were ranked according to decreasing toxicity, as follows: 1) 4-hour contact: *Fresh*: Kerr, AH26, Dentinol, Sealapex, Poliol; *24/60-hour setting*: Kerr, Sealapex, Poliol, AH26, Dentinol; 2) 24-hour contact: *Fresh*: AH26, Dentinol, Sealapex, Kerr, Poliol; *24-hour setting*: Kerr, Dentinol, Sealapex, Poliol, AH26; *60-hour setting*: Kerr, Sealapex, Poliol, AH26, Dentinol. The results allowed to conclude that polyurethane resin presented a better toxicity profile than Kerr Sealer and Sealapex in all testing conditions and equaled AH26 and Dentinol in most of them. The polyurethane resin presented acceptable compatibility and should be considered as a root canal sealer.

Key words: root canal obturation materials, cytotoxicity, polyurethane resin.

INTRODUCTION AND LITERATURE REVIEW

Root canal sealers are meant to be used in combination with solid core materials during root canal obturation. The aim is to hermetically fill all spaces left empty after instrumentation within the root canal system and to obtain a complete closure of the apical third.

GROSSMAN[11] has established requirements for an ideal material, which are accepted until the present days. Among them, one of the most important is the compatibility with living tissues from the periradicular area, since the material will be in permanent contact with those tissues. All root filling materials have been found to be irritants when freshly prepared, causing a high level of irritation in periradicular tissues at longer observation periods.[19,20] This irritation results in inflammation, foreign body reaction, and consequently material and bone resorption in that area.[21]

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All root canal sealers tested until today have been demonstrated to be irritant and resorbable.[15] There are published studies reporting that the best root canal filling material is gutta-percha, despite the irritation caused by the presence of zinc oxide in its composition.[19] However, some physical properties of gutta-percha do not allow the canal to be hermetically filled. Thus, a sealer is necessary to block all irregularities between the solid core and dentin walls.[17]

Finding a material that presents biocompatibility with living tissues in the periradicular area has constituted a challenge to investigators. Studies on material compatibility have been conducted with methods that include both human[22,23] and animal[21] experimentation. However, the difficulties of conducting a histological study, as well as the evaluation of tissue response in animals and humans, have made the initial *in vitro* studies become considerably important. Searching for the best compatible material should be a constant task of investigators, but this kind of work must follow universally established criteria.

In the past few years, some studies have introduced a polyurethane resin derived from castor bean oil (*Ricinus Communis*) in the medical field. The material has been tested for bone replacement in surgical wounds,[12] to work as pins implanted in rabbit bones,[14] and in surgical wounds in the rabbit calvaria.[8] These studies have shown that polyurethane resin (Poliol) is tissue-compatible. In the field of dentistry, only one study dealing with this material was found in the literature. Costa et al.[6] implanted polyethylene tubes containing the resin in the subcutaneous tissue of rats, comparing the results with those obtained with zinc/oxide eugenol cement. At 30 and 60 days, the authors observed the presence of fibrous tissue involving the tubes; the surrounding connective tissue showed normal histological characteristics for both materials.

Standardized methods for the evaluation of dental materials – including the recommended and universally accepted initial test using radiochromium release, proposed by Spangberg[27] – are described by the Technical Report #9 (FDI),[7] ISO 7405,[13] and by Document #41 (ANSI/ADA).[1]

The radiochromium release *in vitro* cytotoxicity test offers several advantages, which include a high degree of control when compared to *in vivo* testing. The method is simple, inexpensive and fast, and provides invaluable help during the development and production of materials. However, it does not allow a direct comparison between the material and the living host tissues. Actually, there are no publications indicating a positive correlation among the various *in vitro* tests, which could replace usage tests. Generally speaking, *in vitro* tests provide the toxicity profile of a given material under specific testing conditions. Furthermore, they allow the testing of the material as recommended by its manufacturer and also the evaluation of material components.

Testing materials as recommended and in the way they are used by professionals in their medical routine is of outmost importance. SPANGBERG and PASCON[29] showed that material preparation may significantly alter the toxicity profile. These authors tested several root canal filling materials, including Sultan, Wach's, Tubliseal, and Diaket, which showed higher levels of toxicity when tested as solids – freshly prepared and after setting – than when tested in solutions.

There are many studies on cytotoxicity using cell cultures, with many different techniques: standardized tubes containing sealers in contact with fibroblasts from the periodontal ligament;[2] dentin chips mixed in cell cultures;[18] mammalian cell mutagenicity;[25] density of L929 and BHK 21/C13 cells in culture;[4] and periodontal ligament fibroblast proliferation.[10] The problem with these studies is that the difference in methodology does not allow a direct comparison of results.

SPANGBERG[27] developed a simple and inexpensive test using cell cultures and the incorporation of sodium chromate (Na_2CrO_4), with radioactive chromium, into the cytoplasm. The method was adopted by FDI[7] and ANSI/ADA.[8] Considering that the method allows direct contact between materials and cells, it can be carried out right after preparation and also after hours of setting time. Unfortunately, in the ISO 7405[13] draft, only the agar gel overlay method was maintained as the recommended *in vitro* method. The disadvantage of this method is that it does not allow direct contact and reaction between cells and materials. It only reflects the diffusion of possible irritants through gel.

The purpose of this study was to compare the biocompatibility of polyurethane resin (Poliol) with AH26, Dentinol, Kerr Sealer, and Sealapex, the sealers most commonly used in the method described above.

MATERIALS AND METHODS

Materials

1. Experimental sealer made of polyurethane resin (Poliol). Composition information was not requested

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to the manufacturer. The material (two different vials of liquid resin), should be mixed with 30 g of calcium carbonate. The resin was also mixed with barium sulfate.

2. AH26 (De Tray, Zurich, Switzerland). Composition according to manufacturer information:

Powder: Bismuth trioxide: 50.0 g
Hexamethylene tetramine: 25.0 g
Silver powder: 10.0 g
Titanium dioxide: 5.0 g

Resin: Bisphenol diglycidyl ether: 100.0%

3. Dentinol (The LD Caulk Company, Division of Dentsply International Inc., Milford, Delaware, Switzerland). Composition according to manufacturer information:

Powder: Bismuth trioxide: 80.0%
Hexamethylene tetramine: 20.0%

Resin: Bisphenol diglycidyl ether: 100.0%

4. Pulp Canal Sealer (Kerr Manufacturing Company, Romulus, USA). Composition according to manufacturer information:

Powder: Zinc oxide: 41.2%
Silver powder: 30.0%
White resin: 16.0%
Dithymol: 12.8%

Liquid: Clove oil: 80 ml
Canada balsam: 20 ml

5. Sealapex (Kerr Manufacturing Company, Romulus, USA). Composition according to manufacturer information:

Powder: Calcium hydroxide: 25.0%
Barium sulfate: 18.6%
Zinc oxide: 6.5%
Titanium dioxide: 5.1%
Zinc esterase: 1.0%

Materials were manipulated as recommended by the manufacturers, and were tested right after preparation (freshly prepared), and after setting for 24 and 60 hours at 37 °C and 100% humidity. Powder/base or liquid/accelerator were also tested individually. After preparation, the material was placed in a tuberculin syringe, and 0.05 cc was dispensed in ten wells of a tissue culture cluster and accommodated in order to cover the whole bottom surface.

Experimental procedure

Cells, media and the ^{51}Cr labeling procedure were as described in previous articles.[27] Three to five-day old cultures of L929 mouse fibroblasts were used. The culture medium was changed every other day, and on the day before the experiment, cultures were labeled overnight with ^{51}Cr. Cells were harvested with 0.02% trypsin in phosphate buffer solution (PBS) and suspended in the culture medium at a density of five million cells per milliliter. Two milliliters of cell suspension were dispensed on top of the material in the wells and incubated for 4 and 24 hours. Ten wells were assigned to each observation period and received 2 cc of cell suspension with no material to provide the negative control for spontaneous release of chromium. At the end of the incubation period, 1 ml of culture medium was withdrawn from each culture well and transferred into test tubes. Samples were centrifuged during 10 minutes at 1800 rpm, and 0.5 ml of the supernatant in each tube was withdrawn and counted for 10 minutes in a gamma counter (t samples). While dispensing the cells, 10 0.5-ml samples were withdrawn randomly and also counted in the gamma counter to serve as reference for the total incorporated label (r samples) (Figure 1). The percentage of radiochromium release in the experiment was calculated on the basis of the total amount incorporated into the target cells using the following formula:

$$\textbf{Percent of } ^{51}\textbf{Cr release} = \frac{T - b}{R - b} \times 100,$$

where T = ^{51}Cr released in the samples, b = radiation noise, and R = reference samples.

RESULTS

The results shown in Tables 1 to 5 were submitted to statistical analysis. The first analysis aimed at verifying whether data distribution was "normal" or "non-normal". Therefore, the analysis of variance for normality was applied to data from the control group. Since the results showed that the distribution was "non-normal", data were transformed into logarithms, and the analysis of variance was applied again; the "non-normal" distribution of data was confirmed by this second test. In view of these findings, we decided to use the non-parametric analysis of variance. Friedman's test[26] was applied to the results of each

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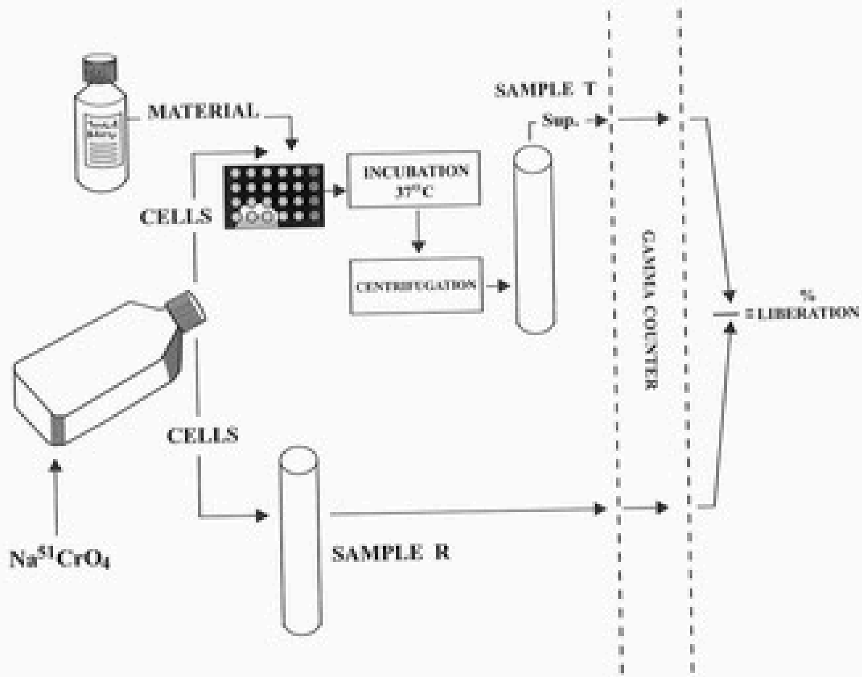

Figure 1. Experimental procedure

experimental material at 4- and 24-hour cell/material contact and controls, in order to verify the occurrence of significant differences between the groups. The level of significance for all tests was established at 0.05, in a bilateral test, and the critical value for the chi-square test was 11.07 (degree of freedom = 5). According to the results, there were significant differences between all material groups and the control group.

Table 1 presents the results obtained with the Poliol group, compared to the control group. The Wilcoxon test[26] was applied to assess differences between Poliol in association with calcium carbonate ($PCaCo_3$) and Poliol in association with barium sulfate ($PBaSo_4$) at 4- and 24-hour cell/material contact. The results indicated that $PBaSo_4$ was less toxic than $PCaCo_3$, and the differences were significant for all values, except for freshly prepared and 24-hour set at 24-hour cell/material contact. Base and accelerator were also considered toxic and the differences were significant.

The Mann-Whitney U test[26] was applied to data from all material groups at 4 hours (Table 2) and 24 hours (Table 3) to verify differences between them. The results indicated significant differences between almost all groups. Freshly prepared Kerr Sealer showed the highest level of toxicity, followed by AH26, Dentinol, Sealapex, and Poliol, and all differences were statistically significant, but for Sealapex *versus* Poliol and Dentinol *versus* AH26. After the 24-hour set, the decreasing order of toxicity was changed: Kerr Sealer and Sealapex were still highly toxic, while Poliol was more toxic than AH26 and Dentinol; differences were statistically significant. The same order was found after the 60-hour set: Kerr,

Table 1. Cytotoxicity - Poliol (percent of incorporated chromium liberation, X±SD, n=10)

Contact material/cells	4 hours	24 hours
P-Base	75.4±9.0	86.0±7.7
P-Accelerator	59.0±6.7	77.0±6.3
$PCaCO_3$ Fresh	47.5±7.4	69.4±5.4
$PBaSO_4$ Fresh	38.5±5.1	70.3±8.8
$PCaCO_3$ 24-h set	18.1±1.4	40.8±3.7
$PBaSO_4$ 24-h set	14.6±1.3	38.2±5.3
$PCaCO_3$ 60-h set	19.6±1.7	41.7±3.4
$PBaSO_4$ 60-h set	13.1±0.8	35.4±3.0
Control	12.9±1.3	35.2±2.7

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Table 2. Cytotoxicity (percent of incorporated chromium liberation, X±SD, n=10)

	4-hour contact material/cells					
	Fresh	Control	PD/Base	Control	LIQ/ACC	Control
Poliol	47.5±7.4	12.9±1.3	75.4±9.0	12.9±1.3	59.0±6.7	12.9±1.3
Seal	52.4±5.3	7.2±0.8	25.2±5.4	9.4±0.6	95.5±3.6	6.5±0.6
Dent	70.3±6.3	6.8±2.1	12.4±2.4	6.5±0.6	4.4±0.5	4.4±0.2
AH26	72.4±6.1	9.9±1.8	24.1±5.3	6.8±0.6	6.9±0.6	6.8±0.6
Kerr	84.0±4.1	6.8±0.6	23.2±5.2	9.4±0.6	94.3±3.3	6.5±0.6

PD: Powder; LIQ: liquid; ACC: accelerator

Table 3. Cytotoxicity (percent of incorporated chromium liberation, X±SD, n=10)

	24-hour contact material/cells					
	Fresh	Control	PD/Base	Control	LIQ/ACC	Control
Poliol	69.4±5.4	35.2±2.7	86.0±7.7	35.2±2.7	77.0±6.3	35.2±2.7
Kerr	84.0±4.0	24.8±0.6	45.2±2.7	24.8±0.6	87.5±1.6	24.8±0.6
Seal	90.3±3.8	25.0±1.5	27.6±2.5	25.0±1.5	76.6±3.6	25.0±1.5
Dent	94.8±1.9	24.8±0.6	25.0±4.8	24.8±0.6	25.0±0.9	24.8±0.6
AH26	95.1±2.5	24.8±0.6	36.0±6.6	24.8±0.6	24.0±0.6	24.8±0.6

PD: Powder; LIQ: liquid; ACC: accelerator

Sealapex, Poliol, AH26, and Dentinol. The Poliol base showed the highest level of toxicity, followed by Sealapex, AH26, Kerr, and Dentinol powders, and the differences were significant, with the exception of Kerr *versus* Sealapex. The liquid showed the following decreasing order: Sealapex, Kerr (with significant differences), Poliol, AH26, and Dentinol.

Statistically significant differences were also found for the 24-hour cell/material contact test (Tables 4 and 5). Freshly prepared materials were ranked in a decreasing degree of severity as follows: AH26, Dentinol, Sealapex, Kerr Sealer, and Poliol. The significance level was established at 0.05, and only the results for AH26 *versus* Dentinol were not significant.

After the 24-hour setting time, ranking was as follows: Kerr, Dentinol, Sealapex, Poliol, and AH26, and differences were significant, but for Kerr *versus* Dentinol. After the 60-hour setting time, ranking consisted of Kerr, Sealapex, Poliol, AH26, and Dentinol, with statistically significant differences for all data. Concerning the powder/base, ranking was

Table 4. Cytotoxicity (percent of incorporated chromium liberation, X±SD, n=10)

	4-hour contact material/cells					
	Fresh	Control	24-hour set	Control	60-hour set	Control
Poliol	47.5±7.4	12.9±1.3	18.1±1.4	12.9±1.3	19.6±1.7	12.9±1.3
Seal	52.4±5.3	7.2±0.8	56.8±2.9	7.1±1.3	64.9±1.8	6.5±0.6
Dent	70.3±6.3	6.8±2.1	8.6±1.4	6.6±1.1	8.7±2.0	4.6±0.9
AH26	72.4±6.1	9.9±1.8	11.9±1.5	6.7±1.1	9.8±3.4	9.3±2.6
Kerr	84.0±4.1	6.8±0.6	91.4±1.6	6.5±0.6	91.2±4.3	7.6±1.4

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Table 5. Cytotoxicity (percent of incorporated chromium liberation, X±SD, n=10)

	24-hour contact material/cells					
	Fresh	Control	24-hour set	Control	60-hour set	Control
Poliol	69.4±5.4	35.2±2.7	40.8±3.7	35.2±2.7	41.6±3.3	35.2±2.7
Kerr	84.0±4.0	24.8±0.6	91.4±1.6	24.8±0.6	91.2±4.3	24.8±0.6
Seal	90.3±3.8	25.0±1.5	56.9±3.4	25.0±1.5	64.9±2.2	25.0±1.5
Dent	94.8±1.9	24.8±0.6	90.6±2.6	24.8±0.6	24.4±0.9	24.8±0.6
AH26	95.1±2.5	24.8±0.6	33.1±2.3	24.8±0.6	36.4±1.9	24.8±0.6

found to be Poliol, Kerr, AH26, Sealapex, and Dentinol, with significant differences, except for Sealapex *versus* Dentinol, whereas for the liquid/accelerator, it was Kerr, Poliol, Sealapex, Dentinol, and AH26, also with significant differences, except for Sealapex *versus* Dentinol and Dentinol *versus* AH26.

DISCUSSION

The purpose of this work was to contribute to the search for a root filling material that presents better compatibility with living periradicular tissues.

The method used in this study is recommended by organizations[1,7] that are recognized and accepted by the international scientific community and that are concerned with testing standardization in order to guarantee that results are comparable. The influence of methods on the results is extremely important. The technique chosen to use a certain material is as important as the material itself, because an inadequate technique may damage or destroy an adequate material. There is consensus among investigators[15,21,22] in the sense that the material must be manipulated as recommended by the manufacturers and in the way they are used in daily practice. Considering that root canal sealers are prepared and introduced into the canal as pastes, and that hardening only takes place after some time, the testing method must allow the reproduction of this condition.

Although the radiochromium release test[27] may have generated controversial arguments related to the direct application of results to living tissues in the human body, there is full agreement concerning the ability of this test to establish the toxicity profile of a material. The test allows direct contact between cell and material when freshly prepared and after different setting times. It also gives a numeric value to the amount of chromium released, making comparisons between results possible.

The results of this study confirmed our previous findings that all root canal sealers are highly toxic when freshly prepared.[19] Furthermore, these results confirmed that there is a decrease in toxicity as the material hardens, and this variation is higher for resins, including Poliol.

The method employed in our study allowed the ranking of materials. It was shown that ZOE-based materials – Kerr Sealer and Sealapex – presented a high toxicity level during the entire experiment, which is due to its liquid formulation (eugenol) – this confirms our previous findings and those of RODRIGUES et al.[24] Conversely, resins – AH26 and Dentinol – were less toxic than ZOE-based materials, except when freshly prepared, when the toxicity reached the highest levels. After 24 and 60-hour setting times, the toxicity level of these materials decreased drastically and was close to that found in controls. Liberation of paraformaldehyde during the initial chemical reaction, as demonstrated by SPANGBERG et al.[30] is the cause for such toxicity. According to those authors, formaldehyde, which is not present as a free radical in the powder or in the liquid, is clearly present in freshly prepared materials. The quantity is doubled during the first 12 hours of setting time and increases 200-fold until 2 days after mixing; then it starts to decrease. This was confirmed by SCHWEIKL et al.[25] while studying the mutagenicity effect of AH26. They showed that the number of mutants was 7 to 10-fold higher when the material was freshly prepared, but it was clearly reduced after 1 week of setting time.

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However, our results do not confirm the findings of BRISENO and WILLERHAUSEN[5] and GEROSA et al.[9] The first authors found Kerr Sealer to be moderately toxic initially, but after 13 days, the fibroblasts present in the culture had recovered very well, whereas AH26 showed a severe reaction during the entire experiment. The second authors demonstrated that 1 and 2-week old AH26 solutions presented severe toxicity. Again, the method used and the preparation of materials influenced the results. The method used by the first authors tested the materials after 24 and 48 hours of setting time, and assessed recovery of human gingival fibroblasts through [L-14C] leucine incorporation. The second authors used spectrophotometry and material in solution, that is, they evaluated soluble and dispersible components only. Similar results were found by GEURTSEN et al.,[10] who tested the effects of AH26 and Sealapex on permanent 3T3 cells and periodontal ligament fibroblasts in primary cultures. Set materials were placed in contact with cells, and the assessment was made through the determination of cell proliferation. AH26 and Sealapex extracts caused moderate to severe growth inhibition.

The problem with these methods is the lack of direct contact between cells and materials, testing solutions and dispersible components, as well as the subjective evaluation of cellular damage using criteria not well-defined for cellular death. Considering that initial tests are meant to establish the toxicity profile of a material and its components, very little is achieved with the use of complicated methods, which involve subjective interpretation of results. The simplest way to evaluate a material is determining its toxicity through the analysis of a numeric value that corresponds to the amount of radioactive chromium liberated from the cytoplasm of dead cells in direct contact with freshly prepared, 24- and 60-hour set materials, as performed in this study. This way, we reproduced the daily use of materials by professionals in practice.

It is evident in the literature that when standardized testing methods are applied by different investigators, the results of *in vitro* toxicity can be compared and confirmed.[3,16,19,20,24,28-30]

Research work involving polyurethane resins derived from castor bean oil are recent, and there are no publications about *in vitro* cytotoxicity. In our study, the experimental sealer Poliol presented similar and comparable results to those of AH26 and Dentinol resins. The sealer was less toxic when freshly prepared, but toxicity was higher after 24 and 60 hours of setting time; differences were statistically significant. It is important to mention, however, that Poliol was tested as a pure resin, without the usual components that participate in the composition of sealers and that aim at obtaining improved physical characteristics. Further studies concerning the addition of necessary components and physical properties must be carried out. In addition, after a proper root canal sealer is obtained, biological properties should be evaluated again. Our results demonstrated that by simply replacing barium sulfate with calcium carbonate in the Poliol composition, toxicity was significantly reduced. These findings are very important for the development of new root canal sealers.

CONCLUSIONS

The results of this work yielded the following conclusions:

1) All sealers tested are irritants to the cells when freshly prepared.
2) Toxicity levels decreased after setting.
3) ZOE-based materials – Kerr Sealer and Sealapex – showed a high level of toxicity during the entire experiment due to eugenol.
4) AH26 and Dentinol showed high levels of toxicity when freshly prepared, but these levels decreased drastically after 24 and 60 hours of setting time.
5) The levels of toxicity observed in the experimental sealer Poliol were comparable to those of other resins.
6) The results demonstrated that the use of polyurethane resin Poliol as a root canal sealer should be further evaluated.

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Correspondence:
Elizeu Alvaro Pascon
124 Edward St
School of Dentistry – University of Toronto
Toronto ON Canada M5G 1G6

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MOLAR CONDUCTIVITY OF CALCIUM HYDROXIDE SOLUTIONS

Carlos **ESTRELA**, MSc, PhD, Chairman, Universidade Federal de Goiás, Goiânia, GO, Brazil.

Cyntia R.A. **ESTRELA**, MSc, Universidade Federal de Goiás, Goiânia, GO, Brazil.

Reginaldo Santana **SILVA**, MSc, Universidade de São Paulo, Ribeirão Preto, SP, Brazil.

Jesus Djalma **PÉCORA**, MSc, PhD, Chairman, Universidade de São Paulo, Ribeirão Preto, SP, Brazil.

Abstract

Intracanal medication is very important for the treatment of apical periodontitis. So, well-delineated studies are necessary in order to establish indications for the clinical use of medication. Studies on the antimicrobial effectiveness of calcium hydroxide pastes have shown the need to understand the mechanism of action of the paste and the interaction between its properties; this has provided a basis for the precise indication of calcium hydroxide pastes in different clinical situations. The objective of our study was to assess the molar conductivity of different calcium hydroxide-based solutions. We investigated the molar conductivity of 120 mg of calcium hydroxide combined with sodium lauryl ether sulfate at 0.1%, Tween 80 at 0.1%, and deionized, distilled water (100 ml). The results for the solutions – sodium lauryl ether sulfate at 0.1%, Tween 80 at 0.1%, and deionized water – combined with calcium hydroxide showed conductivity of 5057.74, 4976.87, and 4936.45 microsiemens (microS), respectively. These differences were not significant.

Key words: calcium hydroxide, vehicles, intracanal medication, conductivity.

INTRODUCTION

The worth of studies on intracanal medication is corroborated by the importance of medication in the treatment of apical periodontitis. Several substances and pastes have been suggested for use as intracanal medication. As a result, there is a clear need for well-delineated studies in order to establish indications for the clinical use of medication, thus providing a better understanding of its properties.

Studies on the role of vehicles as related to the antimicrobial effectiveness of calcium hydroxide pastes have resulted in the need to understand its mechanism of action[6,9] and the interaction between its properties; this understanding, in turn, has provided a basis for the precise indication of calcium hydroxide pastes in different clinical situations.

The dissociation of calcium hydroxide into a hydroxyl ion and a calcium ion, and the action of the latter two on tissue and bacteria allowed the understanding of their biological and antimicrobial properties.[9]

Calcium hydroxide is a strong base (pH 12.6) with little water solubility (1.2 g/l), obtained through calcination (heating) of calcium carbonate until it is transformed into calcium oxide (lime). Hydration of calcium oxide yields calcium hydroxide, and the reaction of the latter with carbon dioxide results in calcium carbonate.[6]

ESTRELA and PESCE[7] carried out a chemical analysis on the release of hydroxyl ions and calcium ions by calcium hydroxide pastes. Considering the molecular weight of calcium hydroxide (74.08) hydroxyl ions correspond to 45.89% of the weight, whereas calcium ions correspond to 54.11%. In this sense, when calcium hydroxide is used in the root canal, 45.89% and 54.11% of the compound dissociate into, respectively, hydroxyl ions and calcium ions.

Ionic dissociation and diffusion are fundamental for the activity inside canal ramifications. Changes in the dentine pH related to hydroxyl ions are slow and depend on several factors: water solubility or not of the vehicle used, difference in viscosity, acid-base characteristics, dentine permeability, and calcification.[2-4] Measurements on the external surface of the dentine after use of calcium hydroxide pastes have shown a pH of around 7.0 to 8.0, depending on the cervical third. Moreover, the measurements showed that calcium hydroxide pastes maintained a pH of 12.6 inside the root canal during the 60 days of observation.[11] However, some difficulties for the correct analysis of pH in mineralized structures still remain. In this sense, it is necessary to establish and develop an applicable methodology in order to reproduce, with more precision, the transport of hydroxyl ions through dentinal tubules and consequently favor the exact measurement of pH.[3,6,11]

We underscore the importance of the chemical analysis of calcium hydroxide in view of its essential aspects, such as: pH analysis of vehicles and pastes,[5,6] influence of the vehicle on the velocity of ionic dissociation,[3,4] the required duration of dentinal diffusion to achieve adequate pH levels for the control of microbes and resorption,[4,11] the action of tissue and atmospheric carbon dioxide on calcium hydroxide, which, in turn, interferes with the antimicrobial and mineralizing effects of calcium hydroxide.[8]

Calcium hydroxide has been combined with different vehicles: distilled water, saline solution, anesthetic solution, methyl cellulose, detergent, glycerin, propylene glycol, polyethylene glycol, camphorated paramonochlorophenol (CMPC), and chlorhexidine; and also with different substances: iodoform, barium sulfate, corticosteroid-antibiotic, and antibiotics.[2-11,13-18]

The water solubility of vehicles favors an increase in the velocity of ionic dissociation and diffusion inside dentinal tubules and can thus influence the antimicrobial effect.[3-7]

The choice of the detergent (sodium lauryl sulfate) as a vehicle for calcium hydroxide was based on the understanding that it favors a decrease in surface tension, which in turn could influence diffusion through bacterial membranes and the number of molecules that interact with the membrane.[19] FEIRER and LEONARD[12] reported that a decrease in the surface tension would determine the diffusion of medication through the cellular membrane of bacteria, thus increasing its bactericidal power.

BARBOSA and ALMEIDA[1] suggested the association of a detergent, namely sodium lauryl ether sulfate at 0.125% (Tergentol®, 20 ml) with calcium hydroxide at 0.2% (80 ml) as a root canal irrigation solution for human teeth. However, it is important to emphasize that the target synergic effect is not achieved in all associations.

Considering the need for comparative studies on vehicles combined with calcium hydroxide, the objective of our study was to assess the molar conductivity of different calcium hydroxide-based solutions.

MATERIALS AND METHODS

Our objective was to assess the molar conductivity of solutions containing calcium hydroxide. Solution samples included: sodium lauryl ether sulfate at 0.1%, Tween 80 at 0.1%, and 100 ml of deionized, distilled water, all associated with 120 mg of calcium hydroxide (Merck, USA).

Molar conductivity was investigated during a 160-day period (Analion conductivity meter, São Paulo, Brazil), and results were recorded in an electronic spreadsheet. All tests were repeated three times.

RESULTS

The results for the molar conductivity of the solutions used in our study – sodium lauryl ether sulfate at 0.1%, Tween 80 at 0.1%, and deionized water – combined with calcium hydroxide were 5057.74, 4976.87, and 4936.45 microsiemens (microS), respectively, as shown in Figures 1 and 2. These values showed no significant differences.

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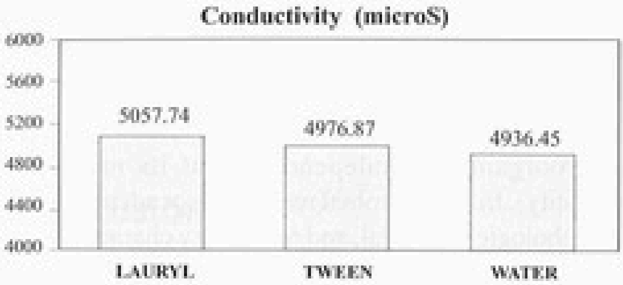

Figure 1 - Molar conductivity of solutions combined with calcium hydroxide

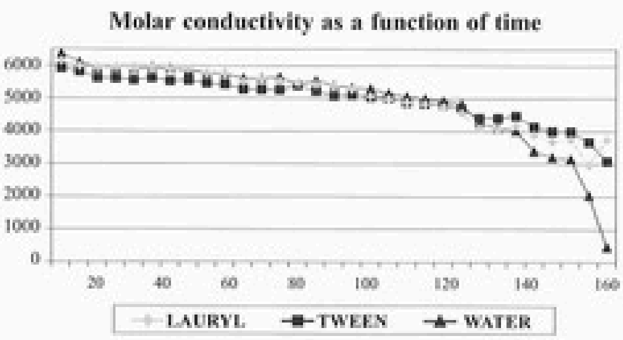

Figure 2 - Molar conductivity of solutions combined with calcium hydroxide

DISCUSSION

The literature shows results similar to ours for the pH analysis of different calcium hydroxide solutions during 160-day periods. In the study by ESTRELA et al.,[5] calcium hydroxide pastes were associated with the following vehicles: deionized water, propylene glycol, sodium lauryl ether sulfate at 0.1%, Tween 80 at 0.1%, CMPC, and CMPC + furacin. The pH of nonphenolic compounds was measured using a digital pH meter, while the pH of phenolic compounds (CMPC and CMPC + furacin) was measured using a pH paper (graded from 0.0 to 14.0). Results showed that pastes combined with nonphenolic vehicles (deionized water, propylene glycol, sodium lauryl ether sulfate, and Tween 80) had elevated pH levels (>12.0), whereas those combined with CMPC maintained a pH of around 7.8 throughout the study period. CMPC, in turn, maintained a pH of 5.0. The CMPC + furacin vehicle maintained a pH of 7.0 throughout the study period, and the paste associated with CMPC + furacin maintained a pH of 10.0.[5]

SAFAVI and NAKAYAMA[18] assessed the influence of different vehicles (glycerin and propylene glycol) on the dissociation of calcium hydroxide in solution, considering the variety of vehicles that have been combined with the compound. The results showed that the conductivity of calcium hydroxide in pure glycerin or glycol propylene was nearly zero. In this sense, taking into consideration that *Enterococcus faecalis* (an important bacterium in apical periodontitis) can resist to a pH of 11.9, the authors concluded that the use of high concentrations of glycerin or propylene glycol as vehicles for calcium hydroxide can decrease the effectiveness of the latter as an intracanal medication.

BARBOSA and ALMEIDA[1] assessed the antimicrobial effect of pure calcium hydroxide solution, of a detergent (Tergentol), and of two calcium hydroxide solutions combined with a detergent (sodium lauryl sulfate) at 10 and 20%. The microorganisms studied were *Enterococcus faecalis*, *Streptococcus sanguis*, *Streptococcus mutans*, *Streptococcus salivarius*, *Neisseria* sp., *Lactobacillus* sp., *Candida albicans*, *Staphylococcus epidermidis*, *Bacillus subtilis*, *Staphylococcus aureus*, and diphtheroids. Antimicrobial analysis was carried out adding 0.5-ml bacterial suspensions to 5.0-ml test solutions at 1, 3, 5, 10, 30, and 60 minutes. Next, 0.1-ml samples were collected and seeded onto culture medium plates. After 72 hours, the authors investigated the presence/absence of bacterial growth. They concluded that the 10% and 20% of detergent solutions showed antimicrobial effect, whereas the pure calcium hydroxide solution did not show antimicrobial activity against the microorganisms tested.

However, other studies have reported different results with the use of detergents as a vehicle for calcium hydroxide. ESTRELA et al.[4] investigated the antimicrobial effect of calcium hydroxide combined with different vehicles (saline solution, CMPC, chlorhexidine, detergent, and otosporin) and in direct contact with cultures (absorbent paper cones) on microorganisms, namely *S. mutans*, *E. faecalis*, *S. aureus*, *Pseudomonas aeruginosa*, *B. subtilis*, *C. albicans*, and a mixed culture. After 1 minute, 48 hours, 72 hours, and 7 days, results showed that the vehicles used did not influence the time of microbial inactivation. So, they play only a secondary role in ionic dissociation, as is case of water-soluble vehicles.

ESTRELA[2] studied the effectiveness of root canal irrigation solutions (sodium hypochlorite at 1, 2, and 5%, chlorhexidine digluconate at 2%, calcium hydroxide solution at 1%, and calcium hydroxide

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solution combined with sodium lauryl sulfate at 20%) on *S. aureus*, *E. faecalis*, *P aeruginosa*, *B. subtilis*, *C. albicans*, and a mixed culture of these microorganisms. With the aim of determining the minimum inhibitory concentration (MIC) of the solutions, the authors carried out serial dilutions at the rate of 10. The antimicrobial effect of irrigation solutions was evaluated by direct exposure at intervals of 5, 10, 15, 20, and 30 minutes. Results showed that the MIC for sodium hypochlorite at 1, 2, and 5% was 0.1% for *S. aureus*, *E. faecalis*, *P. aeruginosa*, and *C. albicans*, and 1% for *B. subtilis* and the mixed culture. All microorganisms were inactivated by the solutions at all study intervals. The MIC for chlorhexidine digluconate at 2% was 0.000002% for *S. aureus*, 0.002% for *P. aeruginosa*, and 0.02% for *E. faecalis*, *B. subtilis*, *C. albicans*, and the mixed culture. Direct exposure showed antimicrobial effectiveness of the solution in all intervals against *S. aureus*, *E. faecalis*, and *C. albicans* and ineffectiveness against *P. aeruginosa*, *B. subtilis*, and the mixed culture. The MIC for calcium hydroxide at 1% was 1% for *P. aeruginosa* and greater than 1% for the remaining microorganisms and the mixed culture. Direct exposure showed antimicrobial effect against *S. aureus*, *E. faecalis*, and *P. aeruginosa* at 30 minutes and ineffectiveness against *B. subtilis*, *C. albicans*, and the mixed culture at all study intervals. The MIC for the calcium hydroxide solution combined with sodium lauryl sulfate was 4.5 ml for *S. aureus*, *P. aeruginosa*, *B. subtilis*, *C. albicans*, and the mixed culture, and greater than 4.5 ml for *E. faecalis*. Direct exposure showed antimicrobial effectiveness of the solution against *S. aureus* at 20 minutes, and against *E. faecalis* at 30 minutes. The solution was ineffective against the other microorganisms (*P. aeruginosa*, *B. subtilis*, *C. albicans*, and the mixed culture).

In an attempt to correlate the release of hydroxyl ions by calcium hydroxide with the enzyme activity of microorganisms, ESTRELA et al.[10] explained the mechanism of action of the compound. Considering that vital functions (metabolism, growth, and cell division) require the participation of the cytoplasmic membrane, which is the site of important enzymatic systems, alterations in the physiological activity of microorganisms can be directly influenced by the release of hydroxyl ions. In this sense, these ions are capable of affecting the integrity of the cytoplasmic membrane by means of causing biochemical injuries to the organic components of the membrane and interference with the transportation of nutrients, or by means of destroying phospholipids or unsaturated fatty acids, leading to saponification.

Calcium hydroxide releases hydroxyl ions that act on the enzymes of the cytoplasmic membrane. So, depending on the amount of these ions, this medication can act against a broad and diverse range of microorganisms (independently of its metabolic capacity). In the microbial realm, independently of the morphologic, tinctorial, and respiratory characteristics, membranes are similar. In this sense, the pharmaceutical acts in similar ways on aerobic, anaerobic, gram-positive, and gram-negative bacteria – conversely to what occurs on the cell wall, whose chemical and structural characteristics are distinct according to the reactivity to gram staining. Consequently, the choice of vehicles should be directed to those that accelerate ionic dissociation and diffusion, such as water-soluble vehicles (distilled water, saline solution), thus interfering with the enzymatic system of bacteria and tissues.

The combination of a water-soluble vehicle (such as saline solution) with calcium hydroxide pastes has shown better results when compared to CMPC. HOLLAND et al.[15] evaluated the repair of periapical tissues with different preparations of calcium hydroxide using Calen (polyethylene glycol 400), Calen + CMPC, and Ca(OH)2 + anesthetic on dog teeth. After a 6-month period for the formation of the periapical lesion, and another 6-month period for the histopathological evaluation following treatment, the results showed that the association between CMPC and Calen did not improve treatment results, and that the average total repair for the three groups was 50%.

In another study, HOLLAND et al.[13] studied the process of repair in 60 tooth roots with periapical lesion using calcium hydroxide in combination with saline solution, calcium hydroxide in combination with CMPC, CMPC combined with furacin, and CMPC alone. Results showed better results with the use of calcium hydroxide associated with saline solution (approximately 60% of total repair and 40% of partial repair). In the case of calcium hydroxide associated with CMPC, results showed 20% of total repair, 70% of partial repair, and 10% of unsuccessful repair. Treatment carried out in a single session showed 40% of unsuccessful repair, 40% of partial repair, and only 20% of repair.

It is important to underscore that while carrying out a study on intracanal medication, it is important to investigate the microbiota of the infected root canal, the response of the host, and the mechanisms of action of the medication to be indicated. For the elimination of bacteria, it is important to allow a minimum amount of time for the antimicrobial medication to show its effect, act at a considerable distance from the application site, and neutralize residues from the aggressors.

CONCLUSIONS

After the assessment of our results and according to the methods employed, the results for the solutions – sodium lauryl ether sulfate at 0.1%, Tween 80 at 0.1%, and deionized water – combined with calcium hydroxide showed conductivity of 5057.74, 4976.87, and 4936.45 microsiemens (microS), respectively. These differences were not significant.

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Correspondence:
Prof. Carlos Estrela
Rua B 1, Quadra 6, Lote 2, Setor Bueno
Goiânia, GO - Brazil
74210-108
E-mail: estrela3@terra.com.br

IMMEDIATE RESTORATION OF ENDODONTICALLY TREATED TEETH - A SUCCESSFUL THERAPY FACTOR

Wilson Tadeu **FELIPPE**, MSc, Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil.

Mara Cristina Santos **FELIPPE**, MSc, Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil.

Luiz Narciso **BARATIERI**, PhD, Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil.

Abstract

Recent literature has shown that appropriate coronal sealing after endodontic treatment is essential for a successful therapy. The intention of this paper is to review the literature and to warn practitioners about the possibility of coronal bacterial microleakage, which may occur if the tooth is not soon restored.

Key words: dental leakage, restoration, endodontics, operative dentistry.

INTRODUCTION

There is no doubt in that the adequate obturation of the root canal system is necessary for a successful endodontic treatment.

In spite of studies demonstrating the importance of proper apical sealing following obturation,[8,28] one of the causes suggested for failure in treatment is microleakage due to inadequate (or inexistent) coronary seal.[19,24,29,33,34]

SWANSON and MADISON[29] warned about the importance that coronal microleakage has in the prognosis of endodontic treatment, mainly in those cases where final restoration is performed too long after endodontic therapy has been concluded.

According to the authors, right after obturation and prior to definite restoration, root canals may be recontaminated under specific circumstances: breaking or loss of the temporary restoration, tooth structure fracture, or cases of canal preparation for a prosthesis where the existing obturation shows to be inadequate.[29] If one of the situations above occurs, the coronal region of the root canals and the obturation become exposed to the oral flora and fluids. Under such conditions, saliva may solubilize the cement between the cones and between these and the canal walls, making it possible for bacteria to penetrate both the canal and the filling material mass.[12]

In view of the perspective of eventual contamination caused by microorganisms that possibly permeate through the obturation, the question will be how fast the canal will become contaminated – or recontaminated – to the point of making retreatment necessary.

LITERATURE REVIEW

In order to assess the period of time along which the filling material could remain exposed to artificial saliva before compromising the seal integrity, SWANSON and MADISON[29] evaluated filled canals in which the coronal portions had been exposed to

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saliva for varying periods of time with subsequent 48-hour immersion in Pelikan ink. The authors observed that significant marginal infiltration had occurred after a 3-day lapse of time. In all samples, the stain leaked to between 79 and 85% of the root length.

The study carried out by MADISON et al.[17] showed that ink penetrated 33 to 80% of the root length in teeth exposed to artificial saliva for 7 days, depending on the type of filling cement employed. An *in vivo* assessment of microleakage[18] did not confirm former *in vitro* studies. Some teeth without filling cement did not show microleakage, whereas those with temporary restorations showed penetration by the stain.

TORABINEJAD et al.[33] evaluated *in vitro* microbial penetration in endodontically treated teeth left without a seal. The coronal portions of canals that had been filled using lateral condensation with gutta-percha and cement were placed in contact with microbial cultures. The authors observed the time (in days) it took *S. epidermidis* to reach the apex; this time varied between 15 and 51 days, with an average of 24.1, advancing 0.4 mm/day. After 19 days of contact with that microorganism, 53% of all the canals were completely contaminated. It was also observed that it took *P. vulgaris* from 10 to 73 days to reach the apex throughout the 10 millimeters of filling material. The average time was 48.6 days, with a progression of 0.2 mm/day. After a 42-day exposure, 50% of the canals had been completely contaminated.

MAGURA et al.[19] assessed coronal microleakage in filled root canals *in vitro*. Following histologic examination, stain penetration analysis, and bacterial culture, those authors came to the conclusion that penetration of saliva into the canal was clinically significant after a 3-month period. They suggested that endodontic retreatment must be performed in canals that have been exposed to the oral cavity for that length of time.

CHOW et al.[7] investigated endotoxin penetration in freshly extracted single-root teeth. After canal obturation, the coronal portions of unsealed teeth were exposed to endotoxins extracted from *A. Actinomycetem comitans (Aa)*. In 31.25% of the roots, it took the bacterial lypopolysaccharide 20 days to leak into filled canals.

In that same year, KHAYAT et al.[14] demonstrated *in vitro* that root canals obturated with gutta-percha and cement using the lateral and the vertical condensation techniques presented apical contamination 30 days after they had had their coronal portion exposed to human saliva.

BARRIESHI et al.[3] measured coronal infiltration in anterior teeth after the canals had been obturated and prepared to receive posts. Ninety days after the experiment, 80% of the canals showed infiltration by *F. nucleatum* and *C. retus*. Bacterial penetration in the 5 millimeters of the remaining filling material happened between 48 and 84 days after obturation. In that study, the authors demonstrated the occurrence of coronal infiltration after the loss of coronal seal.

CHAILERTVANITKUL et al.[6] conducted an *in vitro* study and showed that root canals filled with the lateral condensation technique presented bacterial infiltration after the seventh day, irrespective of the cement used. Complete contamination by *S. sanguis* and *P. intermedia* had installed in 50 to 70% of the canals after 90 days had elapsed. The conclusion reached by those authors was that the lateral condensation of thermoplasticized gutta-percha, associated with various kinds of cement, did not impede the coronal infiltration of microorganisms.

PISANO et al.[22] showed root canals filled with gutta-percha and receiving a coronal seal of Cavit, IRM or super-EBA, which presented significantly less leakage when compared to teeth filled without a coronal seal.

BACHICHA et al.,[2] using a fluid filtration system, investigated microleakage in endodontically treated teeth restored with posts. They showed a significant difference in microleakage between the different cements used – zinc phosphate showed the highest incidence of leakage. There was no difference between stainless steel and corbon-fiber posts. The authors concluded that both posts, when cemented with resin cements, exhibited less leakage than when cemented with glass ionomer or zinc phosphate.

DISCUSSION

As we can observe, the majority of studies cited above were conducted *in vitro*, possibly presenting limitations when compared to *in vivo* situations. Therefore, animal-model studies should be carried out, with the aim of simulating clinical conditions whereby the level of infiltration could be measured in filled root canals exposed to the oral medium.

If we accept the methodologies used in *in vitro* studies as valid to simulate conditions existing in the oral medium, the microleakage observed after short periods of time must be seen as a potential etiologic factor for the failure of the endodontic treatment and should be prevented. The clinician should be able to analyze each particular case, and special consideration should be given to the quality of an existing filling.

From the literature review, it can be seen that authors found a significant variation on the time required by bacteria to penetrate the whole length of the root canal. Such variation may be related to the way canals were prepared, the type of cement used, and the nature of the microorganisms tested.[17,29]

It should be noted that post-prepared canals lose a considerable amount of filling material, and the remaining portion may become twisted, dislodged, and even broken, compromising the seal. So, with an improperly sealed tooth, the time required for penetration will probably be shortened.[19] According to GHASSAN et al.,[9] the apical seal is enhanced by vertical condensation of the filling material after the coronal gutta-percha has been removed.

Contamination can be effectively reduced in teeth whose canals were prepared to receive a core[23] or prevented by sealing the canal openings with different materials (Cavit, IRM, SuperEBA, amalgam, etc.). Ideally, such seal should have a thickness of 2 to 4 millimeters.[10,22]

In regard to restorative procedures, it is important to keep in mind that improperly performed restorations may account for twice as many failures after 1 year.[30] Endodontic success was observed in 91.4% of teeth with good restorations, whereas in unsatisfactory restorations, success reached 44.1% at most.[34]

A 23-month clinical evaluation showed that success was more frequent in teeth permanently restored following endodontic treatment.[24] Therefore, adequate restoration is a step in endodontic therapy not less important than coronal access, chemical-mechanical preparation, and filling.[20,25]

In cases where endodontic treatment is conducted on teeth presenting deficient restorations, these must be replaced in order to avoid patchings and to guarantee a better seal.

It should be noted that an endodontic treatment is likely to require several appointments whenever an adequate coronal seal is necessary, which aims at avoiding recontamination (LIM).[16] In case the access cavity can not be restored immediately at the end of treatment, an adequate temporary restoration must be instituted.

A few studies have reported that zinc oxide-eugenol (ZOE) cements are liable to allow for infiltration;[11,21,31] some authors advocate a minimum layer thickness of 4 mm for such temporary restorations.[19]

Cavit, applied for short periods (up to 7 days) promotes a good seal.[1,21,31] In addition, when used in a 4 mm-thick layer, Cavit shows to be efficient in preventing leakage for up to 3 weeks.[4] When used for longer periods (42 days), Cavit shows rapid deterioration and results in leakage.[5,13,15]

In an extrapolation to clinical practice, it is recommended the temporary restoration with Cavit be limited to as short as possible. Thus, it becomes important to perform temporary restorations capable of resisting to mastication forces and presenting adhesion to the tooth structure and/or impeding microleakage. In that respect, we would like to point out a few studies that show that eugenol-containing provisional restorative materials inhibit polymerization of resin; thus, their use as a lining agent is not recommended before a definite restoration is carried out.[26,27] Incomplete polymerization of resin reduces the bonding strength of the adhesive to the tooth structure, facilitating marginal leakage.[26]

On the other hand, when eugenol-containing cements are used as temporary restoratives only, an adequate cleaning of the cavity using pumice and water, followed by a 30-second application of 37% phosphoric acid, will ensure the complete removal of eugenol residues, returning the enamel to its original condition.[27]

According to TAYLOR et al.,[32] the use of 17% ethylenediaminetetraacetic acid (EDTA) to remove the smear layer, associated with the vertical condensation of the filling material, will cause a cumulative effect on the reduction of coronal leakage.

Once the endodontic treatment is concluded, it becomes mandatory to "protect" the canal against a possible leakage, with the aim of ensuring a favorable environment, where repair can be obtained and preserved.

ROGHANIZAD and JONES[23] suggested an amalgam coronal seal in the canal entrance immediately after endodontic treatment. The authors came to the conclusion that when a 3-mm thick layer of amalgam was placed in the canal opening, only 3.6% of the teeth presented total leakage after having been submitted to thermocycling and dye infiltration. According to the authors, this coronal seal prevents microleakage, extending the time interval until a definite restorative treatment will be initiated. The placement of this seal should not prevent the definite restoration of the tooth. On the other hand, we should consider the kind of material to be used, so as to the facilitate its removal when preparing the canal to receive posts.

Finally, follow-up visits are fundamentally important, as patients are unable to identify leakage.

At this time, in addition to verifying the periradicular status, practitioners should make sure that no leakage is present due to deficient restorations.

CONCLUSIONS

1) Many studies have been developed to evaluate coronal leakage, using stains, radioisotopes, and bacterial penetration parameters. Regardless of the evaluation system used, a consistent finding of such studies is that coronal leakage does occur – the only differences are related to the degree of this occurrence.
2) Neither the materials nor the techniques used in the obturation of root canals are capable of promoting the desired "hermetical seal."
3) Although leakage may occur for short periods of time, it must be seen as a potential etiologic factor in the failure of endodontic treatment. Once leakage is found, endodontic retreatment must be carried out.
4) Facing the possibility of leakage, definite restoration of endodontically treated teeth must be considered as a conclusive stage of treatment, to be carried out without further delay.

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Correspondence:
Prof. Wilson Tadeu Felippe
Rua Presidente Coutinho, 179/702
Centro
88015-230
Florianópolis, SC - Brazil

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COMPARATIVE ANALYSIS OF THE QUALITY OF ROOT FILLINGS USING TAPER 0.04 AND 0.06 MASTER CONES

José Antonio Poli de **FIGUEIREDO**, DDS, MS, PhD, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil; Coordinator, Graduate Program in Dentistry, Universidade Luterana do Brasil, Canoas, RS, Brazil.

Camila Porto Alegre **BRAGA**, dental student, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil.

Eduardo Pizzamiglio **KAPPEL**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Enguer **CHARÃO**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Mariele Diná **MILDNER**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Rômulo Echevarria **CARNIEL**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Aluí **BARBISAN**, DDS, MS, PhD, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Tania **DREMHER**, DDS, MS, PhD, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Abstract

We carried out a study *in vitro* to evaluate the quality of root fillings in which the master cone presented the same taper number as rotary nickel-titanium instruments. For this purpose, we selected 20 human teeth (10 straight and 10 curved root canals) divided into two groups, with the same amount of straight and curved roots. In group A, root canals were instrumented using 0.04 taper, and in group B, 0.06 taper. Root canal filling was carried out by lateral condensation without sealer. In group A, the root canals were filled using either 0.02 or 0.04 taper master cones; in group B, 0.02 and 0.06 taper master cones were used. Our results show that 0.04 and 0.06 taper yielded optimal fillings and required less accessory cones in comparison to the more traditional 0.02 taper. These differences were statistically significant.

Keywords: endodontics, root canal filling materials, gutta-percha.

INTRODUCTION

Recent advancements in endodontics, especially with the new nickel-titanium instruments, have resulted in changes in the speed and predictability of root canal preparation. In comparison to the traditional stainless-steel 0.02 mm taper, rotary instruments present the advantage of being available in different tapers; more specifically, starting at the tip, the diameter of the instrument increases 0.02 mm per mm of the active part of the file.

Currently, there are 0.04 and 0.06 taper rotary files available for apical preparation. More recently, the practice of using master cones with the same taper number as that of nickel-titanium instruments has been suggested. The advantage of this practice is that it would require less accessory cones and consequently result in faster lateral condensation, in addition to ensuring solid obturation of the root canal and favoring the use of thinner layers of cement.

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Our objective was to compare the number of accessory cones required to achieve a snug fit for the master cone in the root canal; in this comparison, we used 0.02, 0.04, and 0.06 taper cones and assessed the percentage of space filled.

According to GROSSMAN,[9] gutta-percha cones are available in several different lengths and diameters. Similarly, the taper of gutta-percha cones also varies.

BERGER[2] wrote that master cones are chosen according to the compatibility of their size with the surgical diameter of the apical third. Sizes should correspond to those of the endodontic instruments used. DE DEUS[4] indicated that the master cone is initially chosen according to the instrument used in the preparation of the canal and the working length.

Based on studies carried out by FIGUEIREDO and ESTRELA[7] on the diameter of points in the choice of master cones, there is great importance in testing whether the cone is fit at working length (which depends on the diameter). Hence, the points whose diameter size is closer to that of the last file or instrument used in the apical third yield better results.

BORDIN[3] underscores that one of the difficulties found in the practice of endodontic therapy is to achieve a snug fit for the master cone when the apical preparation is not well-delineated – due to the use of inadequate techniques or instruments – thus giving rise to shortcomings that may compromise the success of the treatment.

According to BERBERT,[1] the cone should penetrate the whole instrumented length of the canal, and it should not be deformed nor exceed the length when a small force is exerted apically. Also, the cone should present a small resistance to removal from the root canal.

SIDNEY et al.[13] posited that the testing of cones should be carried out with visual, tactile, and radiographic examinations. The visual examination indicates whether the master cone penetrates the whole instrumented length of the canal. The tactile examination indicates adaptation of the cone to the canal walls (tug-back). Finally, radiographic examination is used to confirm the fit.

While studying the influence of apical preparation on the achievement of a snug fit for the master cone, BORDIN[3] observed that it is obtained earlier in curved than in straight root canals.

HABITANTE et al.[10] showed that when the master cone is fit, there is a significant reduction in the marginal leakage in canal obturations. This, in turn, allows for better chances of a successful apical and periapical repair. Root canals whose obturations are not fit present higher prevalences of leakage, thus rendering the success of the treatment uncertain.

As to the preparation of curved root canals, ESTRELA and FIGUEIREDO[5] underscored the difficulty in qualifying and judging a well-prepared canal. ESTRELA et al.[6] presented, in detail, a technique for cervical preparation that can be used as an alternative to overcome the influence of the apical root curvature. The technique involves instrumenting the cervical third in order to better standardize its final form and to achieve better effectiveness in its preparation. The standardization is related to the need for a well-delineated preparation, by tapering the diameter apically, which would allow for better adaptation of the obturation material. This alternative was compared to several other techniques and showed satisfactory results in relation to maintaining a continuously tapered funnel preparation and smooth walls, and to being an easy technique.

BORDIN[3] emphasizes the importance of achieving smooth canal walls, even wall contours, and continuous tapered funnel preparation when shaping the root canal; moreover, the author emphasizes the importance of preserving the apical foramen's original shape and position. The instrumentation of the apical third should be aimed at achieving the most circular shape possible, allowing for better adaptation of and a snug fit of the master cone.

In relation to the most frequent shortcomings of root canal preparation, such as the elbow and zip, FIGUEIREDO et al.[8] showed that the stepback preparation technique is much more efficient that the traditional technique in avoiding such shortcomings (especially the incidence of zip). The stepback technique aims at achieving a continuous tapered preparation and at preserving the original root canal shape and original position of the apical foramen; it also yields a more hermetic obturation of the canal.

The current techniques for root canal preparation, as well as the new instruments used, yield a more precise, uniform tapering and the use of master cones of the same taper number as the instruments. Hence, it would allow for a decrease in the number of accessory cones necessary for canal obturation.

MATERIALS AND METHODS

Our study was carried out at the laboratory of histology of the Dental School at Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil. We selected 20 single-rooted teeth (10 curved, 10 straight

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roots) with lengths between 15 and 18 mm and whose crowns were sectioned. The internal diameter of the root canal was of the same taper number as files #10, 15, or 20.

Root canals were prepared as follows:

Group A: Five straight and five curved canals were prepared using 0.04 taper nickel-titanium rotary files (Profile, Maillefer) in the crown-down technique. The working length was prepared up to the size of a 10 K-file (Dentsply), with canals penetrated into the foramen. Using tweezers, the file was fastened to the orifice of the canal, and the working length was measured using a millimeter ruler; the file was introduced up to 1 mm from the working length. Initial crown-down enlargement was prepared with rotary GT files running at 180 rpm, which was the standard speed for all files. The GT files were not inserted into the canal to more than 3 mm; the procedure was carried out regressively using files #30, 25, 20, and, finally, 15, all with 0.12 taper. Next, lubricant was applied to the canal, and size 40 files (Profile) were inserted without stopping the rotation and with light touch; the anatomy of the canal remained unaffected. The same routine was followed for the subsequent file sizes, regressively from size 35 to 15. If file #15 did not reach the full working length, the whole series was repeated until that objective was accomplished. To each file that reached the working length, two larger files of subsequent sizes were added for the apical preparation. A stainless steel hand file (K-file, Denstsply) #10 was used as a patency file. When files were replaced, irrigant sodium hypochlorite was delivered at 1.5%, and the overflow was suctioned with an aspirator.

Group B: The same procedures were carried out and the same variables were used, but one: a taper 0.06 file (Profile) was applied instead.

We carried out the master cone-fitting procedure in both groups, testing whether the master cone was fit at working length and resistant to traction for removal from the root canal. We applied 0.02 taper cones (traditional) in controls; in groups A and B, 0.04 and 0.06 taper cones were applied, respectively. Accessory cones (Dentsply) were added to the fit master cones until there was no space left for other cones in the root canal. The teeth were then radiographed in a mesio-distal plane for straight roots, and in a bucco-lingual plane for curved roots. The equipment (Sens-A-Ray) was placed at a 10-cm distance, and we used 0.1 second as the exposure time. The digital images were stored in a file. Once image quality was verified, the cones were removed and the procedure was repeated using 0.02 taper cones (controls).

Image brightness and contrast (20% and 30%, respectively) were adjusted. A dental surgeon blinded for group allocation evaluated the images.

We recorded the amount of accessory cones necessary to fill the canal and the quality of the obturation on a 0 to 10 scale, with each value corresponding to 10% of the total space in the canal. More specifically, a score of 6, for example, corresponded to approximately 60% of the canal filled with obturation.

RESULTS

As shown in Table 1, a total of 21 accessory cones were used for filling straight root canals with 0.04 taper instruments (average of 4.2 accessory cones per sample). When 0.02 taper cones were used in the same root canals, the total number of accessory cones reached 32 (average of 6.4 accessory cones per sample).

As shown in Table 2, a total of 15 accessory cones were used for filling straight root canals instrumented with 0.06 taper and master cone of the same number taper (average 3 accessory cones per sample). When 0.02 taper master cones were used in the same root canals, the total number of accessory cones increased to 33 (average 6.6 accessory cones per sample).

Table 3 shows the average and standard deviations for data from Tables 1 and 2, and the results of the comparison using Student's t test. The differences in averages were statistically significant ($P<0.03$).

Table 1. Number of accessory cones used

Root number identification	Master cone taper Accessory cones	
	0.04	0.02
1	5	7
2	7	11
3	2	5
4	3	4
5	4	5
Total	21	32
Average	4.2	6.4

Table 2. Total number and average of accessory cones used for filling straight root canals prepared with 0.06 taper instruments and using 0.02 and 0.06 taper master cones

Root number identification	Master cone taper Accessory cones	
	0.06	0.02
1	4	9
2	5	7
3	1	4
4	3	8
5	2	5
Total	15	33
Average	3	6.6

Table 4. Total number and average of accessory cones used for filling curved root canals prepared with 0.04 taper instruments and using 0.02 and 0.04 taper master cones

Root number identification	Master cone taper Accessory cones	
	0.04	0.02
1	4	6
2	3	6
3	4	5
4	4	5
5	3	4
Total	18	26
Average	3.6	5.2

Table 4 indicates that curved roots prepared with 0.04 taper instruments and master cone of the same taper number required a total of 18 accessory cones (average of 3.6 accessory cones per sample). When 0.02 taper master cones were used in the same root canals, the total number of accessory cones increased to 26 (average of 5.2 accessory cones per sample).

Table 5 indicates that curved roots prepared with 0.06 taper instruments and master cone of the same number taper required a total of 19 accessory cones (average of 3.8 accessory cones per sample). When 0.02 taper master cones were used in the same root canals, the total number of accessory cones reached 35 (average of 7 accessory cones per sample).

Table 5. Total number and average of accessory cones used for filling curved root canals prepared with 0.06 taper instruments and using 0.02 and 0.06 taper master cones

Root number identification	Master cone taper Accessory cones	
	0.06	0.02
1	7	10
2	2	5
3	3	6
4	3	7
5	4	7
Total	19	35
Average	3.8	7

Table 3. Comparison of average and standard deviation of accessory cones used for filling straight root canals prepared with 0.04 and 0.06 taper instruments and using 0.02, 0.04, and 0.06 taper master cones (Student's t test)

Preparation	Master cone taper			P
	0.02 average±SD	**0.04** average±SD	**0.06** average±SD	
0.04	6.4±2.79	4.2±1.92	–	0.02
0.06	6.6±2.07	–	3±1.58	0.004

Table 6 shows the average and standard deviations for data from Tables 4 and 5, and the results of the comparison using Student's t test. The differences in averages were statistically significant ($P<0.016$ and $P<0.000$).

Table 7 shows that the total difference in the filling of straight root canals prepared with 0.04 taper instruments was +6 in the comparison of the use of, first, 0.04, and next, 0.02 taper master cones in the same root canals.

Table 8 shows that the total difference in the filling of straight root canals prepared with 0.06 taper instruments was +6 in the comparison of the use of, first, 0.06, and next, 0.02 taper master cones in the same root canals.

In curved canals, the total difference in the filling of the canals prepared with 0.04 taper instruments was +3 in the comparison of the use of, first, 0.04, and next, 0.02 taper master cones in the same root canals, as shown in Table 9.

Table 10 shows that the total difference in the filling of curved root canals instrumented with 0.06 taper was +1 in the comparison of the use of, first, 0.06, and next, 0.02 taper master cones in the same root canals.

The results of our analysis of variance indicate that the taper used was important for the two variables measured (total number of accessory cones and percentage of space filled). The results indicate that different tapers yield different results.

As to the variable related to the number of accessory cones, we observed a difference only in relation to the taper number. As shown in Table 11, the greatest number of accessory cones was required for 0.02 taper master cones in the group of teeth prepared with 0.06 taper instruments. The smallest number of accessory cones was required for 0.06 taper master cones in teeth instrumented with the same taper number. Comparison of other instrument and master cone tapers yielded intermediary results, according to the Tukey test.

Table 6. Comparison of average and standard deviation of accessory cones used for filling curved root canals prepared with 0.04 and 0.06 taper instruments and using 0.02, 0.04, and 0.06 taper master cones (Student's t test)

Preparation	Master cone taper			P
	0.02 average±SD	0.04 average±SD	0.06 average±SD	
0.04	5.2±0.84	3.6±0.55	–	0.016
0.06	7±1.87	–	3.8±1.92	< 0.000

Table 7. Filling score of straight root canals prepared with 0.04 taper instruments and using 0.02 and 0.04 taper master cones

Root number identification	Master cone taper		Difference in filling score
	0.04	0.02	
1	6	5	+1
2	9	7	+2
3	7	5	+2
4	8	7	+1
5	7	7	0
Total	37	31	+6

Table 8. Filling score of straight root canals prepared with 0.06 taper instruments and using 0.02 and 0.06 taper master cones

Root number identification	Master cone taper 0.06	Master cone taper 0.02	Difference in filling score
1	9	7	+2
2	7	4	+3
3	8	7	+1
4	8	7	+1
5	7	8	-1
Total	37	31	+6

Table 9. Filling score of curved root canals prepared with 0.04 taper instruments and using 0.02 and 0.04 taper master cones

Root number identification	Master cone taper 0.04	Master cone taper 0.02	Difference in filling score
1	8	8	0
2	8	8	0
3	7	8	-1
4	8	7	+1
5	10	7	+3
Total	41	38	+3

Table 10. Filling score of curved root canals prepared with 0.06 taper instruments and using 0.02 and 0.06 taper master cones

Root number identification	Master cone taper 0.06	Master cone taper 0.02	Difference in filling score
1	8	8	0
2	8	8	0
3	8	8	0
4	9	8	+1
5	9	9	0
Total	42	41	+1

Table 12 shows that, according to the Tukey test, the taper number used and the type of root canal (straight or curved) were important for the results of percentage of space filled. Curved root canals always presented a greater percentage of space filled in comparison with straight root canals. The highest mean of space filled was observed for root canals prepared with 0.06 taper instruments and whose master cone was of the same taper number. The lowest average was observed for root canals prepared with 0.04 taper instruments and whose master cone was of 0.02 taper. Comparison of other instrument and master cone tapers yielded intermediary results.

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Table 11. Comparison of averages of accessory cones used for filling straight and curved root canals prepared with 0.04 and 0.06 taper instruments and using 0.02, 0.04, and 0.06 taper master cones (Tukey's test)

Roots	0.04 taper Master cone taper		0.06 taper Master cone taper	
	0.04	0.02	0.06	0.02
Straight	4.2	6.4	3.0	6.6
Curved	3.6	5.2	3.8	7.0
Average	3.9[bc]	5.8[ab]	3.4[c]	6.8[a]

Numbers with the same superscript letter do not differ according to Tukey's test at a 5% probability.

Table 12. Comparison of percentage of space filled using 0.02, 0.04, and 0.06 taper master cones according to accessory cones, straight and curved cones prepared with 0.04 and 0.06 taper instruments (Tukey's test)

Roots	0.04 taper Master cone taper		0.06 taper Master cone taper	
	0.04	0.02	0.06	0.02
Straight	74	62	78	66
Curved	82	76	84	82
Average	78[ab]	69[b]	81[a]	74[a]

Averages with the same letter in the cell do not differ according to Tukey's test at 5% probability.

DISCUSSION

The advancements in endodontics, especially with new nickel-titanium rotary instruments, have given rise to a series of changes in therapeutic procedures and endodontic materials.

The classical idea of instrument standardization has been abandoned. In other words, the standardization of tapers suggested by the International Standards Organization (ISO), in which a 0.2-mm increase is suggested for every subsequent millimeter (0.02 taper cones) applies only to stainless steel instruments. Nickel-titanium instruments, due to their great elasticity, produce files with increased tapers and without any loss in safety.[5,11,12]

Root canals, traditionally prepared manually, can thus also be prepared using engine-driven rotary instruments that allow 360-degree rotary movements. As a result, these instruments allow for more cone-like preparations, which, in turn, allow for an easier introduction of the obturation. These instruments also respect the most critical part of the endodontic treatment, namely, the apical region:[5] they cause less debridement in the apical region, and a more effective debridement in the cervical region. In addition, the most important advantage is that the preparation is better centered, even in curved root canals, thus resulting in a smaller incidence of shortcomings, such as zip and other undesirable changes.

Though the new method for root canal shaping has been used for approximately one decade in endodontics, only recently did the adaptation of obturation to this new reality catch the attention of professionals. The changes in the taper of gutta-percha cones resulted from the fact that endodontic professionals noticed that a greater number of accessory cones was necessary when using the lateral condensation technique to obturate.[4]

The concern with the adaptation of the cone to the preparation was based on whether the instrument taper would actually determine the final shape of the root canal. Clearly, the anatomic particularities of root canals[4] often require the use of particular obturation strategies for each patient. For example, there is a well-known technique that applies rolled cones to better adapt the master cones to the obturation of wide and large-volume root canals. The use of this technique corroborates the need to better fill the root canal, reducing the use of accessory cones.[4]

In our study, the analysis of variance indicated that the taper was important for both variables measured (number of accessory cones and percentage of space filled). This indicates that different tapers yield different results. The assessment of our results showed that the new cones, with the same taper number of the instruments used, not only render a better filling of the root canal but also require less accessory cones. This, in turn, leads to a faster and more reliable obturation.

Some aspects presented in the literature are also worthy of mention. The choice of both straight and curved root canals resulted from studies reporting that rotary instruments were of great value, especially for curved root canals.[5] Good preparation of straight canals was obtained with both new and more traditional techniques.

Other authors were concerned with verifying whether the same taper instrumented in straight root canals could be instrumented in curved canals.[5] The inherent difficulties of working with curved canals may result in cutting the dentin and thus in an inferior taper when compared to that of a straight canal. Consequently, this would represent an extra difficulty for the adaptation of the cone. However, ESTRELA and FIGUEIREDO[5] showed that this is not the case; on the contrary, the authors observed that cones inserted in curved root canals were better adjusted than those in straight root canals.

It is important to mention that we X-rayed the straight roots in a mesio-distal plane and the curved roots in a bucco-lingual plane. These two different planes were used due to our concern with examining the most critical part of the canal: the apical region. Curved roots and their preparation could not be observed in a mesio-distal plane, since most of the roots and preparations would not appear in the radiographs. Conversely, in the case of straight root canals, the mesio-distal plane favored the imaging of most of the canal's diameter; this allowed the examination of spaces that would not appear in a bucco-lingual plane.

Another aspect that deserves attention is the use of digitized images. These images can be enhanced in terms of contrast and brightness – conventional radiographs cannot be changed. In the latter case, image quality depends on the development of radiographs. The use of an automated image processing technique would discard this variable in the assessment of images. In our study, all tooth samples were submitted to the same exposure time and examined through images presenting the same contrast and brightness, which rendered the job of the evaluator easier in terms of being able to clearly examine cones, the dentin, and the space between the two.

We were able to score the quality of root canal fillings; this favored the quantitative assessment carried out in the study.

We would have achieved a better filling of spaces if teeth had been obturated with cement in addition to the cones. However, our objective was to assess the space filled by cones, and not the final result of root canal obturations. It is understood that less cement and more cones render a better sealing of the root canal.[7] In addition, if endodontic cement were to be used, it would have been impossible to repeat the procedure on the same tooth samples, thus reducing the number of variables in the study.

All cones used presented fit when tested for pressure and traction exerted apically. This is in agreement with an important premise in the literature,[1,7,10] and indicates that none of the groups were favored in the study.

Our most important results are the reduction in the number of accessory cones and a greater predictability regarding the root canal filling. This, in turn, makes it easier to carry out the lateral condensation technique and offers an additional advantage to the use of rotary nickel-titanium instruments, which, unmistakably, hold a prominent position in endodontics in this new millenium.

CONCLUSION

Considering the methodology applied and the results obtained, we came to the following conclusions:

1) There was a need for less accessory cones to fill root canals prepared with 0.04 and 0.06 taper instruments when compared to those prepared with 0.02 taper instruments.
2) The best results regarding quality of obturation were obtained with 0.04 and 0.06 taper cones in comparison to 0.02 taper cones.

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Correspondence:
José Antonio Poli de Figueiredo
Rua Luciana de Abreu, 20/201
90570-060 Porto Alegre – RS – Brazil
Phone/Fax: + 55 51 3346.2197
E-mail: endofig@terra.com.br

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AN *IN VITRO* STUDY OF THE ADAPTATION OF THERMAFIL PLASTIC CARRIER TO CANAL WALLS

Caroline Rodrigues Alves **VALOIS**, DDS, Universidade Estácio de Sá, Rio de Janeiro, RJ, Brazil.

Antonio José Ribeiro de **CASTRO**, DDS, MSc, PhD, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

Abstract

The Thermafil technique consists of the use of a carrier coated with plasticized gutta-percha in root canals previously lubricated with a sealer. The objective of this study was to evaluate *in vitro* the adaptation of the plastic carrier to the root canal walls. For this purpose, 56 canine teeth were instrumented 1 mm short of the apical foramen with the ARM technique, using #2, 3, and 4 Gates Glidden burs and K-type files up to #50. Afterwards, the teeth were filled using Thermafil Endodontic obturators, following the manufacturer's recommendations. Root-filled teeth were then maintained at 37 °C, 100% humidity, for 7 days. The teeth were cleaned, and the material in contact with the root canal walls was observed with the use of a stereomicroscope. The authors concluded that the tooth/filling interface was frequently occupied by the Thermafil plastic carrier in the apical third of the obturation, and that the apical seal was achieved with the carrier in 27% of the studied specimen.

Key words: Thermafil, gutta-percha, root canal obturation.

INTRODUCTION

Gutta-percha is a material in the solid state, which is most commonly used for the filling of the root canal system. A great many techniques have been suggested over the years, in order to better adapt and fill the root canal using this material.[11,17,19] In 1978, JOHNSON[11] described an innovative approach that eliminates the necessity for adaptation of the master cone and the use of accessory cones.

Some years later, an obturating system using the technique described by JOHNSON[11] was introduced with the name of Thermafil Endodontic Obturators. The principle of this technique is the utilization of a carrier of the same size as the last instrument used in the apical preparation, coated with gutta-percha in the alpha phase. After the material is thermoplasticized by means of specific equipment, the canal is filled with sealer and the set is inserted into the root canal in a single movement, with strong apical pressure, transporting the gutta-percha as far as the working length previously established.[12]

The manufacturer considers that, when used correctly, this technique can provide a fast, dense, homogeneous, and three-dimensional filling of the root canal system[12]. BEATTY et al.[1] observed that apical leakage is significantly less with Thermafil than with the lateral condensation and single cone techniques. HATA et al.[8] and DUMMER[6] failed to confirm these findings, demonstrating that there is no significant statistical difference in the apical seal provided by the lateral condensation and Thermafil techniques.

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Questions have been raised, however, about the possibility of gutta-percha becoming dislodged from the carrier during the execution of this technique, thus compromising the quality of the filling.[10,13,15] Mc MURTREY et al.,[15] observing the leakage of dye in curved canals obturated using this system, related that in around 30% of studied cases, the metal carrier seemed to be uncovered in the middle third of the root canal. JUHLIN et al.[13] confirmed these findings when evaluating the filling provided by the Thermafil system in curved canals simulated in resin blocks.

Given these doubts, the objective of this study was to evaluate *in vitro* the adaptation of the Thermafil plastic carrier to the root canal walls, using the irrigation technique.

MATERIAL AND METHODS

Fifty-six human canines with a single root canal, checked by radiographs, were selected for this study. The teeth were stored in saline solution until use. After pre-surgery x-ray, conventional access preparations were performed, and a #15 K-type file (Maillefer, Switzerland) was introduced into the root canal until the tip of the instrument was visible at the radiographic apex. The working length was established by subtracting 1 mm from this measurement. The canals were prepared for obturation using K-type files (Maillefer, Switzerland) and Gates-Glidden burs (Maillefer, Switzerland) #2, #3 and #4, using the dynamics of the alternated rotary motions technique (ARM), as described by SIQUEIRA Jr.[18] Apical preparation was done at working length with a #50 K-type file (Maillefer, Switzerland). Irrigation with water was performed at each change of instrument. After preparation, the root canals were irrigated with 17% ethylenediaminetetraacetic acid (EDTA) (Herpo Produtos Dentários Ltda., Brazil) and 2.5% sodium hypochlorite (Johnson, Brazil) to remove the smear layer.

Obturator size was confirmed using the appropriate Size Verification Carrier, which went to length with no significant resistance or twisting. The root canals were then dried with paper points, and Sealer 26 (Dentsply, Brazil), mixed according to the manufacturer's instructions, was placed 1 mm short of the working length with a #55 K-type file (Maillefer, Switzerland). A #50 obturator, which had been heated in a ThermaPrep oven (Tulsa Dental, Tulsa, USA) for a minimum of 5 minutes, was inserted with firm apical pressure to the previously determined working length. Following insertion, the shaft of the carrier was severed and the gutta-percha compacted, as recommended by JOHNSON.[12]

The access openings were sealed with Coltosol (Vigodent S.A. Indústria e Comércio, Brazil) and the teeth stored in 100% humidity at 37 °C for 7 days to allow the sealer to set. The openings were then cleared, as described by SANTA CECILIA et al.[16] Analysis of obturation was performed through visual reading of the samples, using a stereomicroscope (100 X, Inlay, Mexico), which had been previously calibrated, and by two independent evaluators. The component of the Thermafil system in contact with the walls in the cervical, middle and apical thirds of the root canal was observed, as well as that present in the 1 mm apical segment. Data obtained from the different sources were compared, and no contradictions were found.

RESULTS

The results obtained from observation of the adaptation of Thermafil components to root canal walls are shown in the Table 1. According to this data, it can be observed that the distribution of material – gutta-percha, plastic carrier or sealer – was relatively uniform in the cervical and middle thirds of the root canal. In the apical third, however, the tooth/filling interface was frequently occupied by the Thermafil carrier, which was identified in 43% of the samples (Figure 1).

In no sample was the carrier completely uncovered in any of the three thirds of the root canal. Gutta-percha and/or endodontic sealer could always be observed covering all or part of this material (Table 2). Apical seal in the 1 mm apical segment, however, was made solely with the Thermafil plastic carrier in 27% of the specimens studied (Table 3).

DISCUSSION

In the Thermafil technique, plasticized gutta-percha, together with the endodontic sealer, is introduced into the root canal in a single apical movement by means of a carrier.[12] It can easily be imagined that the pressure on the plasticized gutta-percha would allow this material and/or the sealer to occupy the root canal system easily, and in greater quantity. However, this movement could also dislodge the gutta-percha and sealer, leaving the tooth/filling interface occupied only by the Thermafil carrier.

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Composed of polysulfone plastic, the Thermafil carrier presents a certain rigidity, which prevents it from adapting to the irregularities of the root canal. It seems correct to say that in the areas where contact with the tooth is made by means of the plastic carrier, unsealed spaces will be present, and this fact, as described in the literature, can compromise the long-term success of the endodontic therapy.[5,9]

Analyzing the results obtained in the present study, it can be observed, as JUHLIN et al.[13] and McMURTREY et al.[15] had shown previously, that there is a tendency for the gutta-percha to separate from the carrier during the execution of this technique (Figure 1). Contrary to the observations of these same authors, however, the apical third of the carrier was the part most frequently exposed in our study, being partially uncovered in 43% of the cases (Table 1). It is probable that the different methods used, the curvature of the elements studied, the carrier type, the source of heat used to plasticize the gutta-percha, and the different skills of the operators caused conflicting results.

It has been demonstrated that gutta-percha fills the root system more effectively when in a plastic state.[2,17] Comparative studies also show that thermoplastic techniques provide a better apical seal and a denser and more homogeneous obturation when compared to those provided by other techniques, such as lateral condensation.[12,20]

In the present study, the radiographic evaluation of the obturation of the root canal corroborates these findings, in that no faults in the root canal filling were observed. However, the evaluation of the component of the Thermafil system in contact to the root canal walls in the three thirds of the canal revealed that the tooth/filling interface was frequently (and inadequately) occupied with the Thermafil plastic carrier (Table 1). The carrier was never completely uncovered in any of the three thirds of the root canal, and was always at least partially covered by gutta-percha and/or sealer (Table 2).

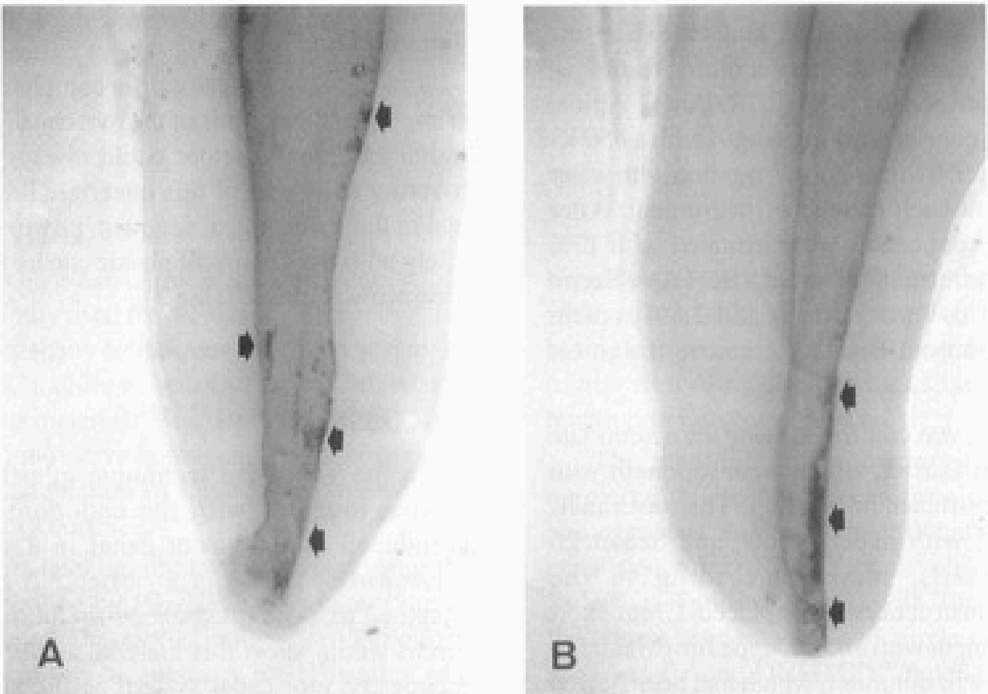

Figure 1. Regions of exposure of the Thermafil plastic carrier in the root canal

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Table 1. Materials present in the tooth/filling interface

Third of root canal	Plastic carrier (%)	Gutta-percha (%)	Sealer (%)
Cervical	21	100	54
Middle	27	100	58
Apical	43	89	45

Percentages do not add up to 100% because more than one material may be present in each third of a tooth.

Table 2. Coverage of Thermafil plastic carrier in the three thirds of the root canal

Third of root canal	Completely covered* (%)	Partially covered* (%)	Completely uncovered (%)
Cervical	79	21	0
Middle	73	27	0
Apical	57	43	0

* By gutta-percha and/or endodontic sealer.

The 1 mm apical segment was sealed only by the Thermafil plastic carrier in 27% of the studied specimens (Table 3). Given that the physical characteristics of the carrier do not allow it to fill in the irregularities present in the apical region of the root canal, this finding leads us to believe that the apical seal would be inadequate in these cases. This rate of dislodgment of gutta-percha and root canal sealer in the apical segment may be responsible for the higher apical dye leakage reported by some authors when using the Thermafil system.[3,4,14,15]

Table 3. Evaluation of the material present in the 1 mm apical segment

Obturator material in 1 mm apical segment	
Plastic carrier	27%
Gutta-percha	39%
Endodontic sealer	34%

In recent studies, HATA et al.[7,8] demonstrated that the utilization of Thermafil combined with an endodontic sealer provides an adequate apical seal. In this study, this situation was not observed. However, when the sealer does not impede the coronal dislocation of gutta-percha and lead to inadequate contact between root canal walls and the plastic carrier, its use seems to be advantageous.

The findings of the present study indicate that the Thermafil system, in spite of being a fast and simple method, is not safe for the filling of the root canal system, because the tooth/filling interface is frequently occupied by the carrier. Another technical problem is that, although the dislocation of gutta-percha and the endodontic sealer from the apical portion of the carrier is a common event, the professional has a false x-ray impression of a hermetic filling. Consequently, this technique has serious limitations, and new studies must be undertaken to improve it.

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Correspondence:
Caroline Rodrigues Alves Valois
AOS 2 bl G apart 101, Área Octogonal Sul
Brasília - DF
70660-027
Phone: +55-61-233-6832
E-mail: cravalois@uol.com.br

EFFECT OF CHLORHEXIDINE AS AN ENDODONTIC IRRIGANT ON THE APICAL SEAL

Milton Carlos **KUGA**, DDS, MSc, PhD, Universidade do Sagrado Coração, Bauru, SP, Brazil.

Sheila Cristina Silva **LEITE**, DDS, Universidade do Sagrado Coração, Bauru, SP, Brazil.

Marco Antonio Hungaro **DUARTE**, DDS, MSc, PhD, Universidade do Sagrado Coração, Bauru, SP, Brazil.

Sylvio de Campos **FRAGA**, DDS, MSc, PhD, Universidade do Sagrado Coração, Bauru, SP, Brazil.

José Carlos **YAMASHITA**, DDS, MSc, Universidade do Sagrado Coração, Bauru, SP, Brazil.

Maria Vitória Lauris **FAYAD**, DDS, MSc, Universidade do Sagrado Coração, Bauru, SP, Brazil.

Abstract

The aim of this *in vitro* study was to evaluate the effect of a number of irrigation regimens on the apical seal. The canals of 60 single-rooted canines were prepared under copious irrigation in one of six experimental groups. Three irrigants were used, both alone and in conjunction with of 1 minute of ultrasound treatment, as follows: group I (1.0% NaOCl); group II (1.0% NaOCl plus ultrasound); group III (0.12% chlorhexidine gluconate); group IV (0.12% chlorhexidine gluconate plus ultrasound); group V (2.0% chlorhexidine gluconate) and group VI (2.0% chlorhexidine gluconate plus ultrasound). All specimens were obturated, subjected to dye infiltration and then sectioned longitudinally. Lower levels of leakage were found in groups VI, V and IV, but the differences were not statistically significant ($P>0.05$).

Key words: chlorhexidine, ultrasound, irrigants.

INTRODUCTION

One of the primary aims of endodontic treatment is to remove all debris from the root canal system, so as to produce a smooth surface prior to placing a root canal filling. This is usually achieved by a combination of mechanical instrumentation and irrigation.[1] It is known, however, that the prepared canal surfaces are covered by an amorphous layer of debris known as the smear layer.[8] This layer is produced by the reaming action of instruments on the dentin walls and the dissolving effect of the irrigating solution. The smear layer can be eliminated or at least reduced with the use of chemicals such as ethylenediaminetetraacetic acid (EDTA).[4] The influence of the smear layer on the sealing ability of root canal obturation is controversial, but when it is eliminated chemically, results show a significantly larger number of filled lateral canals[5] and a greater penetration of sealing materials into dentinal tubules.[18]

It is, however, impossible to clean the pulp space of all tissue debris and bacteria.[9] In view of this, it would seem advantageous to have for endodontic use a therapeutic agent with a broad antibacterial spectrum, minimal toxicity, and possible residual, long-term antimicrobial ability. Chlorhexidine has been shown to meet these general criteria.[3] Previous studies comparing 0.2% chlorhexidine with sodium hypochlorite produced uncertain results.[3,13] With 2.0% chlorhexidine, however, the numbers of post-irrigation positive cultures and of colony-forming units in positive cultures were lower than those obtained from teeth treated with 5.25% sodium hypochlorite.[6]

The purpose of this study was to compare the sealing of obturated root canals irrigated with chlorhexidine gluconate (0.12% or 2.0%) and with sodium hypochlorite (1.0%), both alone and with the aid of ultrasound treatment.

MATERIAL AND METHODS

Sixty freshly extracted single-rooted human canines were used in this study. Conventional access was prepared through the crowns, and the pulp tissue was removed with an H-file whenever possible. A size 20 K-file was passed into the canal, and working length was visually established 1.5 mm short of the length at which the file tip appeared at the apical foramen. The teeth were divided into six groups of 10 teeth. Each group was prepared according to a different irrigation regimen, as detailed below, which was used throughout the instrumentation procedure. The canals were instrumented with K-files up to size 50 at the working length and were flared throughout the entire filing process by a circumferential filing action. Copious irrigation was performed between each file, the solution delivered via a hypodermic syringe and a 30 x 5 needle.

The irrigation regimens were as follows. For group I (1.0% NaOCl), the canals were irrigated with 1.0% NaOCl solution between each file and as a final flush. For group II (1.0% NaOCl + ultrasound) the canals were prepared and irrigated as in group I, with the addition of ultrasound treatment after hand instrumentation. Ultrasound irrigation was performed using a size 20 ultrasonic file in an ENAC system (Osada Medical, Co., Japan), without the flow-through irrigation system. The canal was filled with 1.0% NaOCl solution and the ultrasonic file was placed into the canal at working length without touching the canal walls, so that it could vibrate freely. The ultrasonic file was activated at power setting 3 for intervals of 15 seconds. Between each interval, the canal was flushed by introducing the irrigation needle into the canal as far as possible without binding on the canal walls. The canals were then re-filled with 1.0% NaOCl solution. This procedure was repeated four times, so that the total ultrasonic irrigation time was 1 minute. For groups III and IV, the same procedures were used as for groups I and II, respectively, except for the fact that the irrigant was 0.12% chlorhexidine gluconate (Periogard, Colgate Palmolive, São Paulo, Brazil). For groups V and VI, the same procedures were again used, except that the irrigant was 2.0% chlorhexidine gluconate (Farmalabor, Bauru, São Paulo, Brazil).

After the final irrigant flush, the canals were dried with paper points. Root canals were obturated with a size 50 gutta-percha point (Tanari, São Paulo, Brazil) and zinc oxide-eugenol sealer using a standard method. The external root surfaces were coated with three layers of nail polish. Immediately after preparation, each group was immersed in 2.0% methylene blue, at 37 °C, for 1 week. After this time, the roots were sectioned vertically, and the deepest dye penetration point was recorded with a measuring microscope (Nikon, Osaka, Japan). A Kruskall-Wallis analysis was performed to evaluate statistical differences between the experimental groups.

RESULTS

The mean and standard deviation of dye penetration measurements for all groups are shown in Table 1. Table 2 shows the results of the Kruskall-Wallis test. Although group I (1.0% NaOCl) presented the highest infiltration by methylene blue (5.3748 mm), and group VI (2.0% chlorhexidine gluconate + ultrasound) presented the lowest (2.9415 mm), the differences in length of apical leakage between the six groups were not statistically significant (P>0.05).

Table 1. Extent of apical leakage (mm)

Group	n	Mean	SD
I	10	5.3748	2.36864
II	10	4.1320	1.97310
III	10	4.6908	1.86569
IV	10	3.7148	1.50141
V	10	3.6285	1.49501
VI	10	2.9415	1.17428

Table 2. Σ score and mean score of the experimental groups

Group	Σ scores	Mean score
Group I	37.8	5.3748
Group II	27.4	4.1320
Group III	39.1	4.6908
Group IV	29.7	3.7148
Group V	28.0	3.6285
Group VI	21.0	2.9415

H_{crit} = 11.07 (5%); H_{obs} = 7.672135 (no significance P>0.05)

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DISCUSSION

The use of irrigating agents which act on the dentinal surfaces to remove the smear layer tends to favor the apical sealing of endodontic fillings.[10] EDTA, particularly, has been preconized for this purpose.[4,8] Several other substances, including chlorhexidine, have also been employed in the biomechanical preparation of root canals. Chlorhexidine is a cationic detergent which can be prepared in the form of several salts, including acetate, hypochlorite, and gluconate.[17] Microbiologically, it has an immediate action and a mediate action known as substantivity. JEANSONNE and WHITE[6] observed positive culture reduction immediately and 24 hours following the use of 5.25% NaOCl or 2.0% chlorhexidine gluconate, with no statistically significant difference between the effectiveness of the two substances. RINGEL et al.[13] observed a higher efficiency for 2.5% sodium hypochlorite when compared to 0.2% chlorhexidine gluconate. Comparing concentrations of 0.2% and 2.0% of both chlorhexidine gluconate and sodium hypochlorite on dentin infected by *E. faecalis*, results were shown to be similar for the same concentrations.[15] Similar results were obtained by PARSONS et al.[11] Chlorhexidine gluconate, however, acts basically at the microbiotic level. Dissolution of material present in the root canal is a recognized desirable action of sodium hypochlorite,[14] but this is questionable for chlorhexidine.

It appears that the cleaning effectiveness of different irrigants is reflected in levels of apical marginal leakage after endodontic obturation. Although no significant statistically differences ($P>0.05$) were observed between the experimental groups in the present study, the average infiltration was lower in the groups that employed 2.0% chlorhexidine gluconate, either aided by ultrasound (group VI) or alone (group V), and 0.12% chlorhexidine gluconate with ultrasound (group IV). The results produced the following descending order of effectiveness:

- *Group VI:* 2.0% chlorhexidine gluconate and ultrasound;
- *Group V:* 2.0% chlorhexidine gluconate;
- *Group IV:* 0.12% chlorhexidine gluconate and ultrasound;
- *Group III:* 0.12% chlorhexidine gluconate;
- *Group II:* 1.0% sodium hypochlorite and ultrasound;
- *Group I:* 1.0% sodium hypochlorite.

LEONARDO[7] reports that cationic detergents tend to produce deposits on the dentinal walls because they are negatively loaded. Hypothetically, being a cationic detergent, chlorhexidine gluconate would deposit on the dentinal walls, and would consequently add to the marginal leakage in the root canal filling, acting together with the debris at the interfaces. In fact, marginal leakage in the groups that employed 2.0% chlorhexidine was lower than in the sodium hypochlorite groups. PINTO,[12] in a scanning electron microscope study, found that the anionic detergent Tergentol provided a greater cleaning action than sodium hypochlorite, although the difference was not significant. It can therefore be assumed that detergents can present similar characteristics regarding the retention of debris on the dentinal wall, regardless of their electrical load. It has also been demonstrated that the level of dentinal cleaning provided by Dhyquart A (cationic detergent) is similar to that of Tergentol, and that both are superior to levels obtained with Dakin's solution, although the differences were not statistically significant.[2]

With all the irrigants, the final ultrasound application reduced apical leakage, suggesting that it provides better cleaning than the purely manual technique. Superior cleaning is obtained with the manual method followed by ultrasound.[12]

Thus, assuming that lower marginal infiltration is a consequence of better dentinal wall cleaning and consequently better adaptation of the filling material to the dentin, we believe that chlorhexidine, due to its substantivity, stability and safety,[16] should be investigated as an endodontic irrigating agent at a physical, chemical and biological level. From the results obtained, we can conclude that 2.0% chlorhexidine gluconate with final ultrasound, 2.0% chlorhexidine gluconate alone, and 0.12% chlorhexidine gluconate with final ultrasound are good options for irrigating root canals during biomechanical preparation.

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Correspondence:
Milton Carlos Kuga
Rua Raposo Tavares, 4-45/113
Bauru, SP - Brazil
17013-450
Phone: +55-14-223-4222 or +55-14-234-6147

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MORPHOLOGICAL ANALYSIS OF THE MESIOVESTIBULAR ROOT OF THE FIRST AND SECOND UPPER MOLARS

José Antonio Poli de **FIGUEIREDO**, DDS, MS, PhD, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Cláudia Pereira **LIMA**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Daniela da Silva **SPADOTTO**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Karine **BAGATINI**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Letícia Azzi de **WALLAU**, dental student, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Aluí **BARBISAN**, DDS, MS, PhD, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Tânia **DREHMER**, DDS, MS, PhD, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Abstract

This study analyzes the number and shape of mesiovestibular root canals of upper molars. The cervical, middle, and apical thirds of 21 roots were cross-sectioned and analyzed using a metallographical PES A35 microscope (Union, Japan) at the Histology Laboratory of the Dental Medicine School of Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil. We observed that in the three thirds, most roots (61.9%) presented one canal, and the non-round shape was predominant in the cervical (60%) and middle (70.4%) thirds, while in the apical third there was a prevalence of the round shape (77.4%).

Key words: molar, root canals, morphology.

INTRODUCTION

Upper molars are usually considered a challenge to dentists due to their inappropriate position for some specific procedures, in addition to their complex inner anatomy.

The mesiovestibular roots are particularly complex, since they present a accentuated distal curvature, and most first molars have a second canal. The presence of lateral, collateral and apical delta canals in the mesiovestibular root contributes to the occurrence of negative results in endodontic treatments.

The clinical viewing of the second canal, which is located in a palatal position in relation to the main mesiovestibular canal, becomes difficult. Sometimes, the search for those canals may result in root perforations. According to some authors, in approximately 80% of the cases, the second canal joins the main canal in the apical region.[5,8] However, this finding remains controversial, since there are doubts about the shape of the extremity of those canals. The expected round shape is sometimes replaced with an elliptic shape, as it is usually observed in lower incisors.

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An accurate knowledge about the anatomy of upper molars helps the dentist to perform endodontic treatments and avoid the failure of surgical procedures.

Different authors do not agree regarding the number of canals found in upper molar roots. SLOWEY et al., mentioned by COHEN,[4] state that in most cases, there are four canals, and two of these canals are in the mesiovestibular root. On the other hand, APRILI and FIGUN[2] report that 68% of the cases have one canal in each root, and that 28% have four canals, two of them in the mesiovestibular root. PUCCI[13] observed the presence of one canal in each root in 16.5% of the cases, with a total of four canals; they also observed that two of those canals were separated in the mesiovestibular root (25.5%) and two were joined (51%).

IMURA et al.[8] mention WEINE, who has classified the mesiovestibular roots as:

- Type I: one canal for each root.
- Type II: two canals that join in the apex, forming a simple root canal with one foramen.
- Type III: two holes with separated canals up to the root end (on the canal of the mesiovestibular root).

DE DEUS[5] stated that in most cases (70%), there are two root canals, which are narrow and difficult to access. In 32.8% of those cases, both canals were very different and presented two foramens, while in 37.2% of them, the canals joined at the apical third level, forming only one foramen.

The second canal of the mesiovestibular root is always smaller than the others, and it is often more difficult to clean and mould. According to LEONARDO et al.,[10] the second canal is difficult to be recognized through radiography, since one canal is located in a vestibular position and the other one is in a lingual position, which results in overlapped images.

DE DEUS[5] affirms that 55% of the second upper molars have three separated roots, 10% have three partially fused roots, 10% have three totally fused roots, and 25% have two fused roots. That author also states that 18.3% of the second upper molars have two different canal with foramens, 20% have two canals that join in the middle third of the root, and 11.7% join in the apical third of the root.[5]

LASALA[9] concludes that 50% of the mesial roots present convergent canals (incomplete bifurcation) with fusion of the canals in the apical area, since two thirds of second molars have only one central canal in the mesial root.

According to PICOSSE,[12] several methods have been used with the aim of studying the root canal. One of them used longitudinal and cross-sectional cuts, and was later replaced with the abrading method using pumice. This type of examination reveals the general configuration of the coronary chamber and the root canal. The radiographic method is another possibility. The use of radiographs serves as an accurate auxiliary to verify the shape, number and deviation of the pulp canals.

The transparency method created by OKUMURA, mentioned by FIGUN and GARINO,[7] allows keeping organic substance in the canals, which is stained with India ink and gelatin, providing a clear contrast between the content and the container.

ALANO et al.,[1] confirms the great importance of the transparency method for the purpose of viewing root canals. BJORNDAL et al.[3] employed X-ray computed microtomography with tridimensional reconstruction in order to verify the inner and outer morphology of upper molars.

Regarding root shape, according to DE DEUS,[5] in most the cases (54%), the mesiovestibular root is regularly curved to the distal position and usually presents two narrow canals that join near the apex.

FACHIN[6] assessed the mesiovestibular canal of the first upper molar by means of cross-sectional cuts, highlighting the alteration in diameter caused by age.

Due to all these different findings, the aim of this study was to assess the number and shape of the mesiovestibular root in the cervical, middle, and apical thirds of the first and second upper molars.

MATERIAL AND METHODS

The study was performed in the Histology Laboratory of Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, by students of the second semester of Dental Medicine.

First and second upper molars were studied. Twenty-one teeth were identified with numbers from 1 to 21. Teeth were extracted due to several reasons and collected in hospitals, dental offices, and at the rural labor union of Vacaria.

Teeth preparation involved the following procedures:

- The mesiovestibular roots were cross-sectioned longitudinally by means of a carborundum disk and, afterwards, the remaining crown connected to the root was extracted using the same disk.

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- The roots were immersed in 1.5% sodium hypochlorite for 24 hours in order to remove the organic content from the root canal.
- On the second day, a solution with 10-volume hydrogen peroxide was added to the hypochlorite at a proportion of 1:1 for 20 minutes. Effervescence allowed the dirt to be removed. Then, the teeth were washed in running water for 15 minutes and dried using crescent alcohol solutions in the following concentrations: 70% during 1 hour, 90% for 1 more hour, and finally, 1 more hour with 99.6% alcohol.
- Teeth were wrapped with gauze for a period of 4 hours in order to dry up.
- A rodamine B solution was injected by means of an insulin syringe until the liquid content passed through the apical foramen.
- Teeth remained in the laboratory during 48 hours; after this period, 2-millimeter cross-sectional cuts were performed (using the carburundum disk) in the following portions: at 2 millimeters from the entrance of the root canal, at 10 millimeters and 2 millimeters before the apical foramen (apex).
- The sections were magnified by means of a PES A35 metallographic microscope (Union, Japan), with a 10x-magnification ocular lens containing a millimetric scale, and a magnifying glass with 5x magnification, totalizing a magnification of 50x.

Two aspects were analyzed: first, the number of canals. The observer registered the existence of one or two identifiable canals and the root third of the corresponding section. Data collection was quantitative. The second aspect refers to the root canal shape, which was classified as round or non-round. This item was registered in a qualitative manner.

RESULTS

The results are presented in Tables of absolute and relative values.

According to Table 1, most teeth presented only one canal in all the three thirds. Concerning shape (Table 2), most of the teeth presented a non-round shape in the cervical and middle thirds, while the round shape was more common in the apical third.

Table 1. Canal distribution according to number in the first and second upper molars (Histology Laboratory, Universidade Federal do Rio Grande do Sul, 1999)

Third	Number of canals							
	One		Two		Three		Total	
Cervical	12	57.15%	9	42.85%			21	100%
Middle	15	71.42%	6	28.58%			21	100%
Apical	12	57.15%	7	33.33%	2	9.53%	21	100%

Table 2. Canal distribution according to shape in the first and second upper molars (Histology Laboratory, Universidade Federal do Rio Grande do Sul, 1999)

Third	Number of canals					
	Cervical		Middle		Apical	
Round	12	40%	8	29.6%	24	77.4%
Non-round	18	60%	19	70.4%	7	22.6%
Total	30	100%	27	100%	31	100%

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DISCUSSION

The study of the inner anatomy of root canals is a subject that fascinates investigators. This becomes evident when we analyze the proposal of BJORNDAL et al.[3] related to the morphologic reconstruction of roots using tridimensional digital images.

Authors do not agree regarding the frequency of root canals in the mesial roots of upper molars. A possible explanation for this controversy is the population used for the collection of dental samples. We should expect that general anatomic differences found in different ethnic groups could also result in alterations in the inner topography of root canals.

However, the crucial aspect here seems to be the difference among the methods employed to assess roots. While DE DEUS[5] and ALANO[1] employ the transparency method, OKUMURA[11] and PICOSSE[12] use X-rays, PICOSSE[12] uses longitudinal cuts, and BJORNDAL et al.[3] employ tridimensional digital images. The method used in our study differs from the techniques used by other authors: we employed cross-sectional cuts in the cervical, middle and apical thirds.

We intended to obtain segments from different thirds in order to accurately assess each portion of the canal, since the 50x magnification makes it easier to view the canal when compared to an analysis performed without the help of any magnifying tool.

The previous injection of rodamine B facilitated the definition of the limits of root canal spaces as well as the correct evaluation of their shape. This is one of the reasons why this study seems to have found different molars when compared to other studies.[1,2,5]

We verified that the cervical third of the teeth involved in this study presented one canal in 57.15% of the cases. In the middle third, this percentage increased to 71.72%, and in the apical third, the percentage was the same as the one found for the cervical third. A possible explanation for such a large number of teeth with one canal is the fact that we did not separate first and second molars. Other studies[9] have pointed out that second molars present only one canal in 50% of the cases, and that in some cases, these roots join other roots. Two canals were found in the cervical third in 42.85% of the cases. This percentage diminished to 28.58% in the middle third and increased again to 42.85% in the apical third, including two teeth that presented three canals in the apical portion. This means that the root may begin with two canals that join in the middle third and become two again in the apical third.

Actually, the differences found in each tooth surprised the authors of this study. We did not expect to find teeth with three canals in the apical portion. This could be explained by the formation of apical delta, which could have a division of the same diameter as the diameter of a root canal identified by the microscope.

The didactical aspect of these findings consists in the great difficulty that dentists have to face in order to appropriately prepare the root canal for endodontic procedures. The bifurcation or even trifurcation areas in the apex would hardly be touched by an endodontic instrument. Thus, the chemical auxiliary would be in charge of cleaning the root canal system, which sometimes does not show satisfactory results.

Another remarkable aspect of this study concerns the shape of root canals. A larger number of teeth with a round shape was expected in the apical and middle thirds. Twenty-four out of 31 canals were elliptic or ovoid in the apical third. It is important to point out that when two or three canals were present, these canals were round. We would like to emphasize this aspect because it leads to the following conclusion: most of the time, the root canal system imposes some difficulties. Those difficulties may be expressed either by the number of canals or by the canal shape in the apex, which can be different from the round shape of the endodontic instrument, which makes the preparation of the canal walls more difficult and allows for the storage of dirt, with a potential danger to develop bacterial colonies in the undercut.

This study does not close the discussion about the anatomy of mesiovestibular roots of upper molars. It presents an alternative evaluation that can be repeated and further investigated in other studies.

CONCLUSIONS

1) A greater incidence (61.9%) of teeth with one canal was observed in the cervical, middle and apical thirds.

2) There was a prevalence of non-round canals (60%) in the cervical and middle thirds, while in the apical third, most canals were round (77.4%).

3) A great variety in the shape and number of canals was found in the different thirds.

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Correspondence:
José Antonio Poli de Figueiredo
Rua Luciana de Abreu, 20/201
90570-060
Porto Alegre, RS - Brazil
E-mail: endofig@terra.com.br

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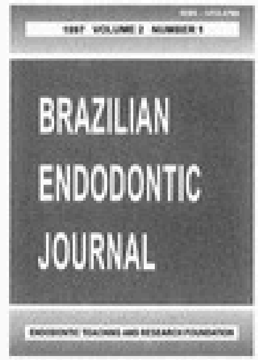

ERRATUM

The paper **"Fused Gutta-Percha Technique: Root Canal Filling Procedure with Thermoplasticized Low-Temperature Gutta-Percha"**, by Abilio Albuquerque Maranhão de Moura, Alex Yoshiharu Otani, and Harry Davidowicz, which appeared in the *Brazilian Endodontic Journal* 1999/2000;4(1/2):29-32, contained an error regarding the authors' affiliations. The correct affiliations are as follows:

Abilio Albuquerque Maranhão de **MOURA**, DMD, MDSc, PhD, School of Dentistry, Universidade Paulista and Universidade de São Paulo, Brazil.

Alex Yoshiharu **OTANI**, DMD, MDSc, School of Dentistry, Universidade Paulista, São Paulo, Brazil.

Harry **DAVIDOWICZ**, DDS, MDSc, PhD, School of Dentistry, Universidade Paulista, São Paulo, Brazil.