Integrated Master in Dentistry

Evaluation of root-end preparation with two different ultrasonic tips

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ABSTRACT

Introduction

The development of new instruments, materials and techniques has significantly enhanced the treatment outcome in periapical surgery. In order to obtain a better prognosis, a good apical cavity must be accomplished.

The aim of this study was to evaluate the time requirements and features apical cavity preparation performed with different ultrasonic tips from CVDentUS®: model TOF-2 and a prototype tip.

Materials and methods

Thirty-two freshly extracted single-rooted teeth were selected**,** cleaned, mechanically prepared**,** obturated. After apicoectomy, teeth were randomly divided into group 1 (TOF-2 tip) and group 2 (prototype tip), and the root-end cavity preparation was performed according the group. The preparation time was recorded.

Photomicrographs taken before and after apical preparation were coded and evaluated by two examiners. They assessed: the number, type and location of root surface cracking; the quality of root end cavity margins; and the presence of debris. Statistical analysis was carried out with Wilcoxon*,* Mann-Whitney and binomial tests and Spearman's rank correlation coefficient, using a software package (SPSS).

Results

Three types of microcracks were observed: intracanal, extracanal and intradentine. There was a significant difference among TOF-2 and prototype tips regarding the number of microcracks after apical preparation. There was also a statistical significant difference regarding the location of cracks – 87% were observed in the widest part of the root.

No significant differences were found regarding “marginal integrity”, “quality walls” and mean instrumentation time between the two groups.

Conclusion

In conclusion, the best results were obtained when TOF-2 tip was used for root-end cavity preparation. Good “marginal integrity” and “quality walls” can be achieved with both tips tested.

KEYWORDS: apical surgery / root-end cavity preparation / root-end cavity evaluation/ ultrasonic retrotip / CVD tips / retropreparation

INTRODUCTION

Nowadays, the success rate of orthograde root canal therapy is high (85% to 95%), and it is frequently applied to treat inflammation or necrosis of the contents of the root canal (1–3).

Nevertheless, when both root canal therapy and retreatment fail or it is not feasible, periapical surgery is often the only method of retaining teeth (4,5).

Periapical surgery enables complete debridement of the root canal and placement of a root-end filling. This goal should be achieved by periapical resection, root-end cavity preparation, and a bacteria-tight closure of the root canal system, preferably with a biocompatible and bioactive retrograde filling (6,7).

In addition, the periapical pathological tissue should be completely debrided by curettage to remove extraradicular infection, foreign body material, or cystic tissue (6).

Endodontic surgery has greatly benefited from continuing development and introduction of new diagnostic tools, instruments and materials (6,8,9).

For many years, the state of the art was the traditional approach, performed by means of root-end resection with a 45-degree bevel, retrograde preparation of the canal with bur, and amalgam or intermediate restorative material (IRM) for root-end filling, with a moderate success rate of approximately 60% (8,10,11).

The introduction of the dental operative microscope (DOM) in the early 1990 led to a new phase in surgical endodontics (10). Besides magnification and illumination, modern techniques incorporate also the use of ultrasonic tips, microsurgical instruments and more biocompatible filling materials such as SuberEBA, and mineral trioxide aggregate (MTA) (8–10). With regard to the outcome of apical surgery, inconsistent success rates ranging from 44% to 90% were reported prior to the introduction o microsurgical techniques (12). Nowadays, recent studies have shown success rates that approached or exceeded 90% (13).

A root-end preparation should be parallel to the long axis of the root, 3mm deep, and centered within the root, to offer adequate wall thickness and to retain a nontoxic biocompatible filling material (14,15).

The advent of ultrasonic tips has enhanced this preparation, because of the availability of tips with different shapes and angulations according to the root location (16,17). It also brought numerous advantages (15) including smaller osteotomy, minimal or inexistent bevel angles for root-end resection (18,19), thus reducing the number of exposed dentinal tubules and consequently the possibility of apical leakage (16,20). Moreover, they also enable the removal of isthmus tissue present between two canals within the same root (20–22). With these tips, a better shaped root-end cavity, which is more centrally placed and along the direction of the original root canal, smaller, cleaner and more retentive, can be achieved (19,23).

The first root-end preparation using modified ultrasonic inserts after an apicoectomy is attributed to Bertrand et al. (24). Since then, a large number of laboratory, but few clinical studies have investigated different aspects including the crack formation following root-end preparation (1).

Microcracks may increase the chance for apical leakage, and may jeopardize the overall strength of the root end. Even though this has not been formally proven, their occurrence constitutes a clinical concern (7,25,26). Apical resorption after healing may eliminate the surface defects and contribute to the overall success of treatment. Also, such defects can be removed by using finishing burs on the resected and retrofilled root-end (20,27).

Root cracks after the use of ultrasound-activated tips have been detected using different methods such as: visual magnification with or without the use of dyes (1,28,29), histologic cuts (30), fluorescence confocal microscopy (30), stereomicroscopy (7,22) and scanning electron microscopy (SEM) (16,17,25,31). They are the consequence of several factors, such as the use of dehydrated extracted teeth, absence of periodontal ligament, power settings of the ultrasound unit, and sputter-coating of specimens for SEM examination (14,31–33).

Recently some attempts to improve the performance of ultrasonic instruments have been made. The introduction of diamond-coated and zirconium-coated retrotips represents an important issue in this field (31) as well as the new CVD® technology (CVD-Vale, São José dos Campos, SP, Brazil): characterized by a thick layer of pure diamond forming a single stone covers the entire surface of the tip (16,33). The aim of this study is to evaluate the time requirements and features apical cavity preparation performed with different ultrasonic tips from CVDentUS®: model TOF-2 and a prototype tip.

MATERIALS AND METHODS

Specimen selection

Thirty-two freshly extracted single-rooted teeth were selected, with fully developed apices. All teeth were immersed in 1% NaOCl solution for 15 minutes, immediately after extraction. Afterwards, soft tissue and debris were removed from the surface of the roots by hand scaling.

The integrity of the roots was determined by using a dental operating microscope - DOM (Leica Microsystems© M300 DENT) at 16x magnification. Teeth were kept in 0,5% chloramine T during two weeks.

Specimen preparation

Teeth were decoronated using a high-speed diamond bur under continuous water spray. The working length of the root canal was determined by observing the emergence of a size 10 K-file at the foramen, measuring it and withdrawing 0,5mm.

Root canals were then cleaned and mechanically prepared up to F2 (ProTaper® universal; Dentsply Maillefer, Baillaigues, Switzerland) by using a crown-down technique. The canals were irrigated with 1mL of 1% NaOCl between each file, totaling 4mL. When the instrumentation was completed, the canals received a final flush with 2ml of 70% alcohol, and were dried with sterile absorbent paper points (Zipperer® Absorbent Paper Points, Endo Easy Efficient®, Munich, Germany).

The root canal filling was performed with a single cone technique, using a calibrated gutta-percha ProTaper® point F2 (ProTaper® universal; Dentsply Maillefer, Baillaigues, Switzerland) and AH Plus® (Dentsply, DeTrey, Konstanz, Germany) as the sealer. The gutta-percha cone was cut at the cement enamel junction (CAJ) with a warm instrument and vertically warm condensed in the coronal portion with a Buchanan System B Plugger (SybronEndo, California, USA).

Following obturation, each tooth was numbered and an X-ray image confirmed the good quality of obturation. The coronal two thirds of the roots were mounted on high viscosity silicone material - Coltène® Lab-Putty (Coltène/ Whaledent AG; Alstàtten, Switzerland). During all subsequent procedures, teeth and respective silicone blocks were stored in an incubator at 37°C and 98% humidity.

Apicoectomies

The section line was drawn at 3mm from the apex, and all the roots were resected at a 90^{o} angle in respect to their longitudinal axis. Each tooth was sectioned using a H 23 LR® (Komet ,USA) carbide tungsten operative bur and then smoothed with a H 375 R® (Komet, USA) carbide tungsten finishing bur

After apicoectomy, the teeth were checked to see the presence of any cracks and fractures by one examiner under a DOM at 16x magnification. Photomicrographs were made with a stereomicroscope (Nikon SMZ 1500) to the cutting plane of each root, first without and then with methylene blue dye 1% (Canal blue - Dentsply, DeTrey, Konstanz, Germany), applied directly to the surface during 5 minutes, and then rinsed with abundant water during 1 minute, to simplify the visualization of cracks.

Preparation

The 32 teeth were randomly divided in two equal groups using *stattrek.com* (34), according to the tips used to prepare the root-end cavity:

- 1: tip TOF-2 (CVDentus; Clorovale Diamantes Ind. E Com. Ltda Epp, São José dos Campos, SP, Brazil);
- 2: tip prototype (CVDentus; Clorovale Diamantes Ind. E Com. Ltda Epp, São José dos Campos, SP, Brazil);

Apical preparation was performed using the respective device, at the intensity recommended by the fabricant (30% of power), under constant distilled water irrigation. The specimens were kept in the putty silicone blocks and maintained wet throughout the procedures. Each tip was used on a maximum of 8 roots.

Instrumentation was performed using intermittent and minimal pressure, with in-and-out motion to start the preparation, then increasing the depth to 3mm from the resected surface and finally moving it circumferentially to complete the entire preparation. This was accomplished by a single experienced operator, under a DOM at 10x magnification and it was considered finished when the operator determined the preparation to be visibly free of debris. All preparations were class I (according to Black's classification). Time of preparation was measured using a stopwatch, counting only the time of actual instrument contact with the root.

Photomicrographs were made to the preparation of each root first without and then with methylene blue dye 1% (Canal blue - Dentsply, DeTrey, Konstanz, Germany), as described previously.

Data analysis

The preoperative and the postoperative photomicrographs were coded and blinded, and two examiners evaluated them.

The examiners assessed through the photomicrographs at 15x and 30x magnification:

- The number, type and location (in relation to dentinal walls) of root surface cracking;
- The quality of root end cavity margins produced by ultrasonic retrotips;

And through direct stereomicroscope visualization at 40x magnification:

- The presence of debris (superficial dentinal chips and/ or gutta-percha remnants).

Microcracks were recorded by type, adapted from Rainwater *et al.* (29) and De Bruyne e*t al.* (19):

- Incomplete cracks:
  - Intracanal cracks - originating from the root canal and radiating into the dentine;
  - Extracanal cracks – originating from the root surface radiating to the dentine;
  - Intradentinal cracks – confined to the dentine.
- Complete cracks: from the root canal to the root surface.

Also, it was checked if cracks were located either at the narrower or wider side of the remaining dentine surface.

The quality of root end cavity margins ('marginal integrity') produced by ultrasonic retrotip was assessed according to the following scores adapted from Taschieri *et al.* (31):

0 – The ideal preparation (0 defects);

1 – A single visible defect produced by the contact between the angle of the tip and the cavity margin;

2 – Chipped, ragged cavity margin;

3 – Chipped, ragged cavity margin plus some defects due to the tips bouncing off the root face during root end preparation.

The presence or absence of debris (superficial dentinal chips and/ or gutta-percha remnants) in the cavity ('quality walls') was classified according to the following scores adapted from Khabbaz *et al.* (1):

0 – Clean walls

1 – Debris on 1 wall

2 – Debris on 2 walls

3 – Debris on 3 walls

4 – Debris on 4 walls.

The scores and number of cracks in each root were assessed independently by two investigators. If the scores did not agree, they assessed again the images until a consensus was reached.

Statistical analysis was carried out to evaluate the difference between groups using a software package (SPSS).

In order to evaluate the incidence of microcracks before and after retropreparation, results obtained for each group were analyzed by Wilcoxon test.

Mann-Whitney test was carried out to verify the difference in microcracks, marginal integrity and quality walls between groups.

In order to determine the statistically significant differences after the intervention, relative to the number of microcracks at the widest and narrowest part of the root-end, a binomial test was carried out with a cutoff point of 50%.

To evaluate if the difference in time preparation between groups was statistically significant, a Mann-Whitney test was used. The possible association between the number of microcracks and time was evaluated by means of Spearman's rank correlation coefficient.

Ultrasonic tips analysis

One sample of each ultrasonic tips tested (before and after use) was analyzed under scanning electron microscopy (SEM).

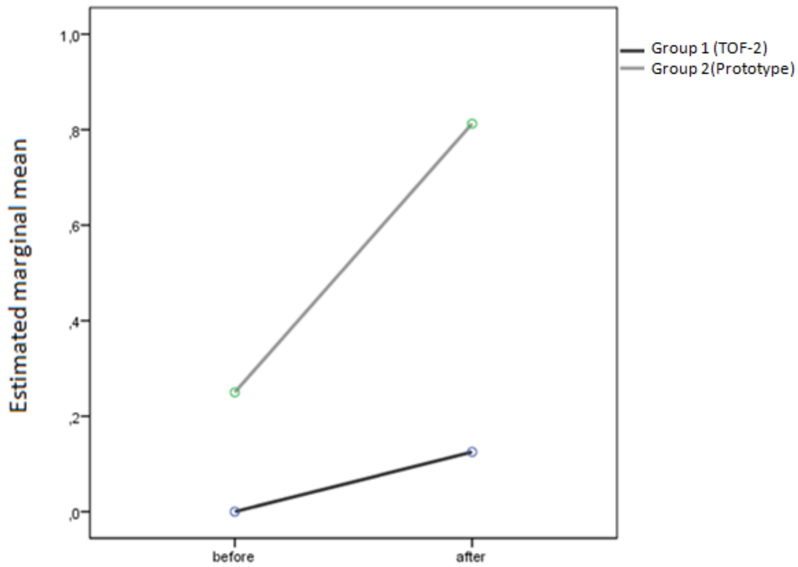
RESULTS

Table I shows the results of statistical analysis calculated in the two groups regarding the number, type and location of cracks, and some representative images are in annex (*figures 1* and *2*). The majority of the roots had no visible cracks after root resection, although microcracks were observed in three roots, belonging to group 2 - one root with two intracanal cracks and the other two roots with one intradentine crack each one. After root-end preparation, the roots that exhibited intradentine cracks developed extension of these cracks (one root developed an intracanal crack and the other root an extracanal crack). Of the 29 roots that did not have cracks after root-end resection, 2 roots for the group 1 and 6 roots for the group 2 showed the formation of new cracks after the root-end preparation procedure. Of the 8 roots that developed new cracks, only one root had an intradentine crack, while the other 7 roots had intracanal cracks (in a total of 10). No complete cracks were found.

Table I – Statistical analysis calculated in the two groups regarding the number, type and location of cracks.

		Group 1 (TOF-2)	Group 2 (Prototype)
Before	**Number of cracks** $\bar{x}$ /dp/max/min	0/0/0/0	0.25/0.58/2/0
	Type of cracks intracanal/extracanal/intradentine/complete	0/0/0/0	2/0/2/0
	Location of cracks narrower/wider	0/0	1/3
After	**Number of cracks** $\bar{x}$ /dp/max/min	0.13/0.34/1/0	0.81/0.83/2/0
	Type of cracks intracanal/extracanal/intradentine/complete	1/0/1/0	12/1/0/0
	Location of cracks narrower/wider	0/2	2/11

In group 1, no statistical significant differences were found (Z = -1414, p = 0.157) in the number of cracks before and after preparation, whereas in group 2, there are statistically significant differences (Z = -2251; p = 0.024) before and after. *Graph 1* shows the variation of the estimated marginal mean for the two groups.



Graph 1 – Variation of the estimated marginal mean for the two groups.

At the moment ‘before' there are no statistically significant differences (U = 104.00, Z = -1789, p = 0.074) in the number of microcracks in the two groups. However, at the time 'after', there are statistically significant differences (U = 68.00, Z = -2692, p = 0.007) in the number of microcracks comparing the two groups.

Regarding the ‘marginal integrity’ (*table II*), most teeth were scored as ‘0’, and the maximum value was ‘2’ (one root in group 1 and two roots in group 2). Moreover, we cannot observe statistically significant differences (U = 110.00, Z = -0.767, p = 0.443) between both groups.

Table II – Frequency and percentage calculated in group 1 (TOF-2) and group 2 (prototype) regarding the ‘marginal integrity’.

	Frequency		%	
	Group 1	Group 2	Group 1	Group 2
0	10	8	62,5	50,0
1	5	6	31,3	37,5
2	1	2	6,3	12,5
Total	16	16	100,0	100,0

In our evaluation of the 'quality walls' (*table III*), most teeth were also scored as '0', and the maximum value was '1' (three roots in group 1 and four roots in group 2). There aren't also statistically significant differences (U = 120.00, Z = -0421, p = 0.674) comparing the two groups.

Table III – Frequency and percentage calculated in group 1 (TOF-2) and group 2 (prototype) regarding the 'quality walls'.

	Frequency		%	
	Group 1	Group 2	Group 1	Group 2
0	13	12	81,3	75,0
1	3	4	18,8	25,5
Total	16	16	100,0	100,0

The frequency of microcracks observed in the widest part of the root was 87% which was significantly different from the frequency of microcracks observed at the narrowest part (p = 0.007).

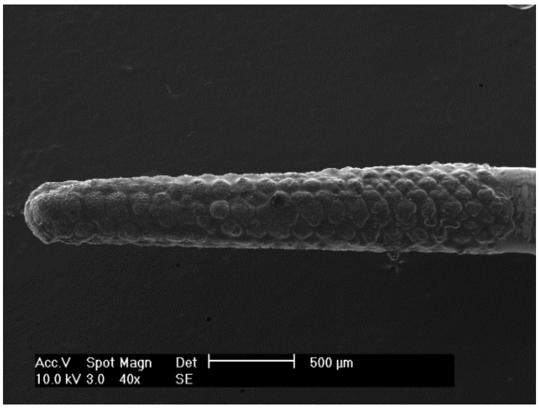
Table IV presents some statistical values regarding the instrumentation time. No statistically significant differences (U = 98.00, Z = -1133, p = 0.257) of the time between the groups tested were found, and there is no correlation (CC = 0.184, p = 0.314) between time of preparation and number of microcracks.

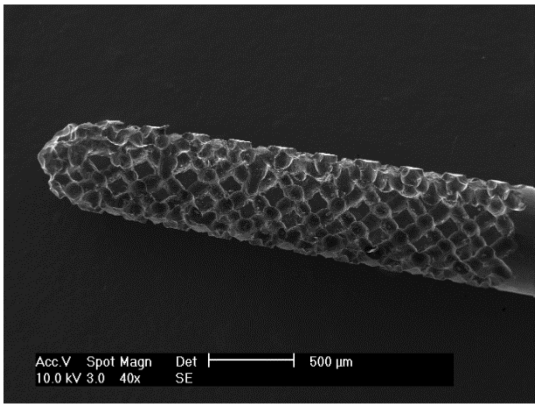
Table IV - Minimum, maximum, mean and standard deviation (SD) calculated in the two groups regarding the intrumentation time.

	Minimum	Maximum	Mean	SD
Group 1	11,0	60,3	38,644	15,1320
Group 2	29,0	82,8	48,513	17,7394

One of the prototype tips (group 2) fractured at the second use, being substituted with a new one, which was used in seven roots.

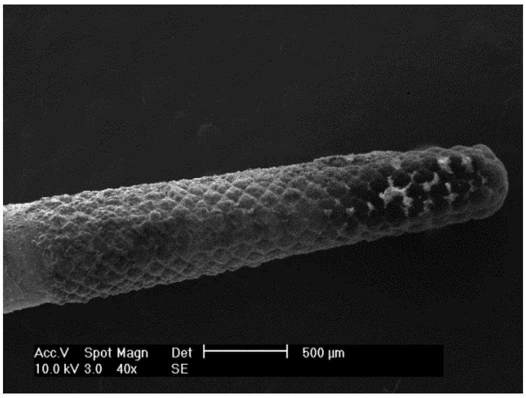
Figure 1 and *2* depicts the images of the ultrasonic tips obtained by SEM examination, before and after 8 retropreparations, respectively.

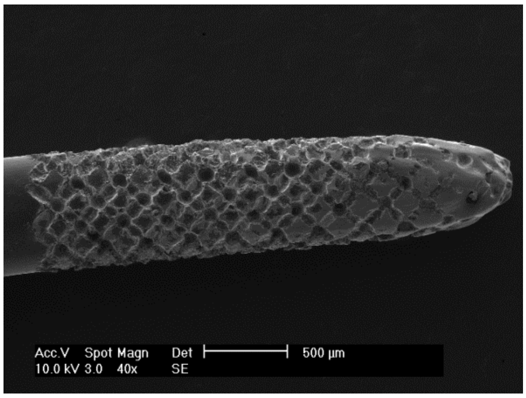




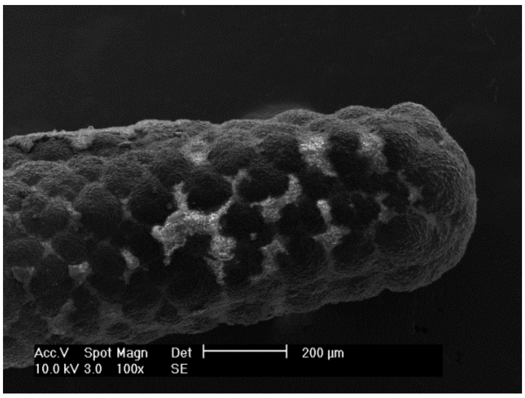
a) b)

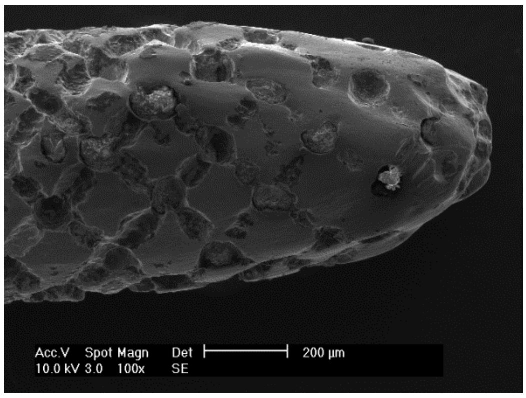
Figure 1: a) – TOF-2 tip before use (40x magnification); b) - Prototype tip before use (40xmagnification).





a1) b1)





a2) b2)

Figure 2: a1) / a2) – TOF-2 tip after use (40x and 100x magnification); b1) / b2) - Prototype tip after use (40x and 100x magnification).

DISCUSSION

Since the introduction of ultrasonic tips for root-end cavity preparation during endodontic surgery in the 1990's, several studies have compared this strategy with conventional root-end cavity preparation using rotary burs in a microhandpiece.

Many authors (1,2,15,35–38) have confirmed the technical improvement afforded by ultrasound – the specific advantages being: (a) beveling: unnecessary reduction of the corono-root proportion is avoided, and the risk of periodonto-endodontic communication is minimized, with preservation of the dental and bone structure, securing an improved environment for healing; (b) cavity preparation: a smaller bony access is required, with easier buccolingual extension, parallel to the long axis of the root.

A great concern to the clinician is the formation of cracks or microfractures following root-end resection or root-end preparation. The significance of root-end cracking would seem to be increased susceptibility to root fracture, the inability to seal the root-end preparation properly, and the possibility of additional site of bacterial contamination (26). The frequency of root-end cracking during apical preparation has been investigated extensively, and is the object of our study.

Some studies results indicate that ultrasonic devices are responsible for generating cracks at the root-end surface (14,26,36,39) but other results indicate the opposite (21,38,40,41).

Wuchenich *et al.* (37) compared ultrasonic and bur root-end cavity preparations with regard to cleanliness and root canal parallelism, and found that cavities prepared with ultrasonic tips were cleaner, deeper, and had more parallel walls than those prepared by burs. However, these authors did not refer to microfractures.

Almost all later studies have demonstrated microfractures in the roots of extracted teeth in which root-end cavities were prepared with ultrasonic tips (1,17,19,23,25,29,31,42). It is possible that the propagation of the observed microfractures was enabled by the *in vitro* conditions in which these studies were performed: dehydration, lack of periodontal support, stresses exerted during extraction, inappropriate storing, and careless handling of the extracted teeth (4,7,21,39).

Therefore, in the present study we could have obtained an overestimation of cracks, despite all the efforts that have been made to prevent this - only freshly extracted teeth were used and attention was paid to keep the samples moist during the root-end preparations, as suggested by other authors (31).

Abedi *et al.* (14) compared root-end cavities prepared with bur and with ultrasonic tips attached to two different ultrasonic units. Their findings showed a significantly higher incidence of crack formation in the walls of root-end cavities prepared by ultrasonic tips, and the average time for preparation was also greater (2 minutes against 10 to 15 seconds in the bur group). They concluded that the formation of cracks is a function of the power of the unit, time of application, presence or absence of preoperative microcracks, and the thickness of surrounding dentin, indicating that ultrasonic tips shouldn't be applied to thin walls (<1mm).

Other *in vitro* study (22) compared the quality of root-end preparations between ultrasonic retrotip and conventional microhandpiece bur. They analyzed the shape and size of preparation, as well as the loss of tooth structure after root-end preparation, under a stereomicroscope in association with an image processing system. The results were significantly better for the ultrasonic group, which produced more conservative and less perforated cavities.

Lloyd *et al.* (41) reported poorer results with ultrasound versus micro-handpieces and burs, due to the appearance of marginal cracks.

In a clinical study (3), the overall success rate in the ultrasound group was 80,5% and in the group treated with a bur was 70,9%. In molars, the difference in success rate was significant. They concluded that the use of an ultrasonic device in apical surgery improved the outcome of treatment, but the main disadvantage is microfractures and chipping.

In other retrospective evaluation (43), there was also a great difference in outcome of treatment in favor of the ultrasonic technique (85% versus 68%).

On a clinical and radiological study (44) the results were obtained with different periapical surgical techniques, and the better clinical and radiological success rate after one year was achieved when ultrasound was used for root-end preparation, comparing with rotary instruments (conventional technique).

To avoid artifacts and to obtain results clinically more relevant, some authors argue that investigations should preferably be performed *in situ* (2,7,19,26,30).

Min *et al.* (30) suggested that the use of cadavers might be more clinically relevant. They concluded, by histologic examination, that root-ends prepared with ultrasonic devices had a statistically greater number of fractures than both the control and conventional (microhead handpiece) groups. On the other hand, confocal microscopic evaluation did not show significant differences, and the argument was that the magnification used (40x) did not permit the differentiation of preexisting fractures: all fractures were included in the statistical analysis, while in the histologic study, fractures considered as preexisting due to the presence of sealer particles in the cracks were excluded.

Other study that used human teeth in cadavers (2) compared ultrasonic and high-speed bur root-end preparations in relation to the size of bony crypt, the minimum depth of root-end filling, the length of the root-end filling along the resected root surface, and the root-end resection bevel angle, concluding that ultrasonic root-end preparations are significantly better considering these aspects (deeper root-end preparation, less bevel, maintain the direction of the canal space and less bony crypt size).

Regarding the presence of microfractures, Calzonetti *et al.* (7) suggested that *in situ*, roots may absorb some of the ultrasonic impact and prevent the propagation of microfractures, circumventing the tooth desiccation and brittleness associated with work *in vitro* and thus reduce the chance of artifacts. In fact, they did not find any microfractures after ultrasonic root-preparation. This agrees with the results obtained by De Bruyne and De Moor (19), which found the amount of cracking to be statistically different between extracted and cadaver teeth (fewer cracks).

Gray *et al.* (26) compared the frequency of cracking and chipping in cadaver and extracted teeth under scanning electron microscopy with indirect resin replicas using a high-speed bur or an ultrasonic tip at either high or low intensity. The results did not show significant difference between any groups in terms of cracking of root-ends. The only significant difference was seen in extracted teeth where ultrasonic preparation caused more chipping than rotary preparation. Varying the intensity was not significant. This was also supported by other studies: manipulation at high power also did not produced a large number of microcracks (23,40). On the contrary, these results do not agree with several studies - significantly more canal cracks per root occurred when the ultrasonic tip was used on the high-frequency setting for root-end preparation than when the ultrasonic tip was used on the low power setting (31,39,40).

In the present study we did not vary the intensity of the power setting, as we always used the value recommended by the manufacturer (30% of the maximum power). Further research is required to determine the optimum power for root-end preparation with the tips tested on this study and with *in situ* conditions.

Layton *et al.* (39) observed fractures after high-speed cavity preparation, a phenomenon not observed at low speeds (100 to 200mHz less than the high-speed).

They observed three types of cracks on the resected root-ends: canal cracks, intradentin cracks and cemental cracks. In contrast, Chou *et al.* (38) reported fewer fissured teeth with ultrasound than with micro-handpiece.

Rainwater *et* al. (29), besides intracanal and extracanal cracks, also found communicating cracks, without significant differences between the three groups: conventional ultrasonic (CUS) tips, diamond-coated ultrasonic (DUS) tips, and high-speed stainless-steel burs (HSB). They argued that even though the majority of the cracks were not observed after root resection, disruptions could have been made during this process that became apparent during the root-end preparation. They also studied the dye penetration and found no difference between DUS and CUS.

Waplington *et al.* (40) noted chipping on all the ultrasonically prepared root-end cavosurface margins. On the contrary, the bur prepared group did not show cracks or chipping. Engel *et al.* (21) reported more centered and smaller preparations on the canals and isthmus, with the ultrasonic device comparing to the burs. On the other hand, traditional and combined techniques resulted in greater debridement. They claim that ultrasound might be a useful adjunct to surgical endodontics, particularly in cases where a high risk of perforation exists or when limited access to the root apex is a considerable constrain. Moreover, ultrasound preparations are more conservative and deeper (22). The increased cavity depth that can be achieved with ultrasonic tips might be a significant factor for controlling apical leakage (1).

Therefore, the only apparent inconvenience is the presence of microfractures. Cracking and chipping may lead to long-term failure of the surgical procedures because of increasing risks for apical leakage (1,31). This issue needs to be evaluated in further leakage studies to clarify the relation of chipping to long-term sealing at the apex. In fact, the influence of root-end microfractures on the periradicular healing process and apical leakage should be clarified (25).

Diamond-coated tips have been introduced in the hope of minimizing dentinal fractures through their ability to abrade dentine more quickly, reducing the time that the instrument spends in contact with the root-end (45,46). Although, no significant differences concerning microfractures or marginal chipping among stainless steel, diamond coated and zirconium coated tips have been observed (23,29,45,47). New ultrasonic tips for apical preparation continue to be studied, developed and introduced on the market, such as Jetip, which is made completely of stainless steel (17), and CVD (16,48), which was the subject of research in the present study.

The direct CVD diamond deposition on molybdenum tips allows a fabrication process that exhibits high adhesion characteristics of the diamond coating (49). This new technology deposits a thick layer of pure diamond, forming a single stone that covers the entire surface of the tip, (16).

In a study by Bernardes *et al.* (16), they compared three different ultrasonic diamond tips. They verified that Satelec and Trinity tips, which have small-sized diamond crystals embedded in a joining material, have losses in the amount of diamond after utilization, something which was not verified with CVD tips. These tips have been shown to have a greater cutting efficiency than conventional ultrasonic diamond tips and presented the shortest root-end cavity preparation time compared with other brands of ultrasound-activated diamond tip (16,48). These results were corroborated by other study that used CVD tips in apical preparation without any injury to the root-end surface (33).

This *in vitro* study investigated the effect of two different ultrasonic retrotip surfaces related to the number, type and location of cracks, the quality of root end cavity margins, the presence or absence of debris, and the time of preparation.

Despite the study of Beling *et al.* (50), where no significant difference with regard to the number or type of cracks after root-end resection or root-end preparation was found between gutta-percha filled and uninstrumented roots, it was considered better to root fill the teeth first, because it reproduces the clinical situation, and because we wanted to evaluate the presence of gutta-percha remnants in the cavity walls.

It was observed that after the extraction procedure of the cadaver roots, a number of extra cracks arose, indicating that the extraction procedure damaged the roots before root-end resection and preparation (19). As such, the use of a fixing apparatus to minimize the absence of periodontal ligament, as suggested in the study by Gondim *et al.* (25) to reduce the chances for artifacts would not suffice.

Despite this fact, an effort was done in our research to simulate the periodontal ligament support of the root to be prepared by using putty silicone blocks. Other study used resin blocks (1). As mentioned before, the effect of these mechanisms in the prevention of microfractures has not been proven.

Methylene blue dye was used in this study, as it has been shown by Cambruzzi et al. (51) to be an aid in the detection of fractures. Methylene blue was used to decrease the optical activity of dentin and to stain cracks for easier microscopic identification, although this was not verified.

1. Number, type and location of cracks

The incidence of microcracks in this study was 12,5% for group 1 and 56,25% for group 2. These results do not correspond with the study of Bernardes *et al.* (16), who reported no incidence of cracks or fractures in any specimen (they used three different diamond tips, including CVD).

An incidence of 2,1% was found in the study of Peters *et al.* (42), who used ultrasonic diamond-coated or stainless steel smooth retrotips to prepare 48 root-end cavities in molar teeth mimicking clinical conditions. Teeth were examined under SEM and craze lines, visible at 300x magnification or higher, were not considered microcracks.

Microcrack incidence of 16,95%, 28,85% and 41,6%, respectively, was found at magnifications of 25x, 50x and 30x when root-ends were prepared ultrasonically (7,14,36)

Although it has been reported that the number of microcracks on the resected surfaces increased after preparation with ultrasonic retrotips, Ishikawa *et al.* (23) only found four microcracks (not defining the type) in eighty-five teeth, that were evaluated by SEM. Their possible explanation for such low rate of cracks is the use of a saline bath during preparation.

Khabbaz *et al.* (1) did not found any cracks at close inspection immediately after cutting the root apex, and after the root-end cavity preparation all cavities were photographed. No complete cracks were found. Small intradentinal cracks were detected in 7% of the small roots of group A (micromotor), 20% of the large and 21% of the small roots in group C (ultrasonic smooth). Groups B (ultrasonic diamond) and D (sonic diamond) did not showed any cracks.

Taschieri *et al.* (31) found 20 out of 45 teeth with cracks under evaluation with SEM photographs at magnification of 48x and up to 1550x if the two blind examiners did not agree. Only the specimens treated with a stainless steel retrotip at half power did not show complete or incomplete dentinal fractures. Conversely, three complete canal fractures were found when using diamond tips at the full power setting. However, no significant differences were found between diamond tips and stainless steel at both power settings tested.

Rainwater *et al.* (29), using a stainless steel and a diamond retrotip and setting the ultrasonic device at low power, found no significant difference between the two kinds of tips for both the number and the type of cracks. Most cracks consisted of intracanal or extracanal types, and a lower number were of communicating type.

In the present study, most microcracks consisted of intracanal type, and no complete (communicating) cracks were found.

It is difficult to compare the results of studies with dissimilar experimental design. In fact, the use of different types of retrotip design, materials and evaluation methods, represents an important source of variability. Different apical diameter of the specimens used in the various studies could also lead to increased variability in outcomes. Until standardization in experimental study design is achieved, the comparison between different reports may lead to biased conclusions.

In our study, we found microcracks before ultrasonic preparation, which was also found in previous studies (39,50). In contrast, the preoperative analysis in other studies refer no cracks or marginal chipping during resection alone (1,25).

In the present study, we found more cracks in the wider dentine walls -13- than in the narrower walls -2-, which is statistically significant and is in agreement with the results obtained by De Bruyne *et al.* (19), where only few cracks were situated at the narrower side of the remaining dentine. This was in contrast to results of former studies, where most cracks developed in the thinnest walls surrounding the root-end cavity preparations (14) or small diameter roots developed more cracks (52). As no limitation time was set, it could be that the time of preparation may have contributed to the number of cracks.

During evaluation of the images it was observed that existing cracks sometimes did enlarge after apical preparation. This fact was also documented in other studies (19,29).

<u>Magnification</u>

Magnification is a factor to be considered in the detection of microfractures. Some studies use low magnifications (x16-50), which might prevent the detection of existing microfractures (4,40). In the present study, we used low magnification (10x) during the apical preparation, because in clinical practice it is very difficult to attain a good field of view with magnification. We used magnifications (15x, 30x and 40x) which proved to be enough for the details we wanted to evaluate. Although, according to Gondim *et al.* (25), the use of higher magnification (x150) caused a significant increase (more than double) in the number of microfractures detected.

Studies that compare the impact of magnification in different evaluation methods are needed.

2. **Quality of root end cavity margins (marginal integrity) and presence or absence of debris (quality walls)**

Apart from cracks, chipping was also referred as a consequence of ultrasonic or sonic root-end preparation (1,19,25,26,40,41). The importance of chipped margins is unclear but it may affect the marginal seal produced when a root-end filling is placed.

Few teeth showed chips between the angle of the tip and the cavity margin or ragged margins, as well as debris in the cavity walls. This is in contrast with the results obtained by Khabbaz *et al.* (1), where all methods produced dentine chips in the walls of cavities. However, the amount of produced debris was significantly different, with values ranging from 0 to 90%, with the highest frequency on the cavity walls prepared with the bur on the micro contra angle slow-speed handpiece, which may be attributed to the fact that preparations were made under no water spray, whereas the sonic and ultrasonic tips were supported by irrigation.

The effects of residual gutta-percha remnants on treatment outcome are unknown and require further clinical studies. Bernardes *et al.* (16) found fewer regular preparations with CVD tips, comparing with Satelec and Trinity tips. This is in accordance with the present study, where cavity walls were clean and free of debris in most cases.

In the present study, very few chipped margins were found. Taking this fact into consideration, no correlation may be attempted with preparation time. This result is in accordance with the findings of Taschieri *et al.* (31). It is possible that the longer the preparation time the higher the chance of producing chipped margins, but this issue needs further investigation.

3. **The instrumentation time**

Time of preparation in the clinical practice is something to take into high consideration (1,21,23,36,40,42).

A longer instrumentation time was necessary for group 1, possibly because the cutting efficiency of these tips is lower than the prototype tip due to a smaller diameter.

The mean time was higher when compared with the study of Bernardes *et al.* (16), who found the following mean times for apical cavity preparation: 45,57s (Satelec), 44,83s (Trinity), 17,94s (CVD). Nevertheless, these values are very low comparing with other studies.

Ishikawa *et al.* (23) reported 181,80s (KiS), 204,60s (CT-5), 69,10s (diamond-coated). Engel and Steiman (21) found that preparation time with bur was similar to that of smooth ultrasonic tips.

Peters *et al.* (42) reported that, using diamond-coated and smooth ultrasonic tips, the preparation times ranged from 25 to 361 seconds and were significantly lower for the diamond-coated that the stainless steel smooth ultrasonic tips. They also found a correlation between the incidence of cracks and the time needed to accomplish root-end preparation. In the present study no correlation was observed between preparation times and the incidence of cracks using the given power setting.

Khabbaz *et al.* (1) found that the time needed to prepare a root-end cavity with rotary instrumentation was very short compared to the sonic and ultrasonic tips, which agree with Waplington *et al.* (40), who found that the rotary preparation is more rapid than the ultrasonic one. However, in clinical practice, sonic or ultrasonic instruments may be faster because they have better accessibility to the root-end and require less bone removal.

Taschieri *et al.* (31) observed that cavity preparation with diamond-coated retrotips is faster that stainless steel ones.

4. Tips evaluation

The robustness to use of CVD tips presented by the only study that compare these new tips in retropreparation (16) was not verified. In fact, by SEM analysis it is possible to verify the surface alteration of the tips, with loss of particles (smoothness of the surfaces) particularly in the active point. Besides that, during the active cutting process, one prototype tip (group 2) fractured. The same happened in other studies. Paz *et al.* fractured two ET-20D tips and attributed this to the thinner makeup of the ET-20D tip in comparison with the CPR-2D. This was also in agreement with Walmsley *et al.* (53) who found in their study that thinner tips were more prone to fracture during cutting.

CONCLUSIONS

Based on the conditions of this study, the following conclusions can be drawn.

1. Cracks were produced at the root-end face, mainly when the prototype ultrasonic retrotip was used, with statistically significant differences. Due to the high amount of cracks produced with the prototype tip, its use in apical preparation is questionable, although more studies are needed, particularly with *in situ* conditions.
2. No significant differences were found regarding the location and type of cracks.
3. The marginal quality, as also as the quality of the cavity walls was very good for both tips tested. No significant differences were found comparing the results of the prototype and TOF-2 tips regarding these parameters.
4. Prototype ultrasonic tip was faster than TOF-2 tip for the given power setting (recommended by the fabricant), but the difference is not statistically significant.

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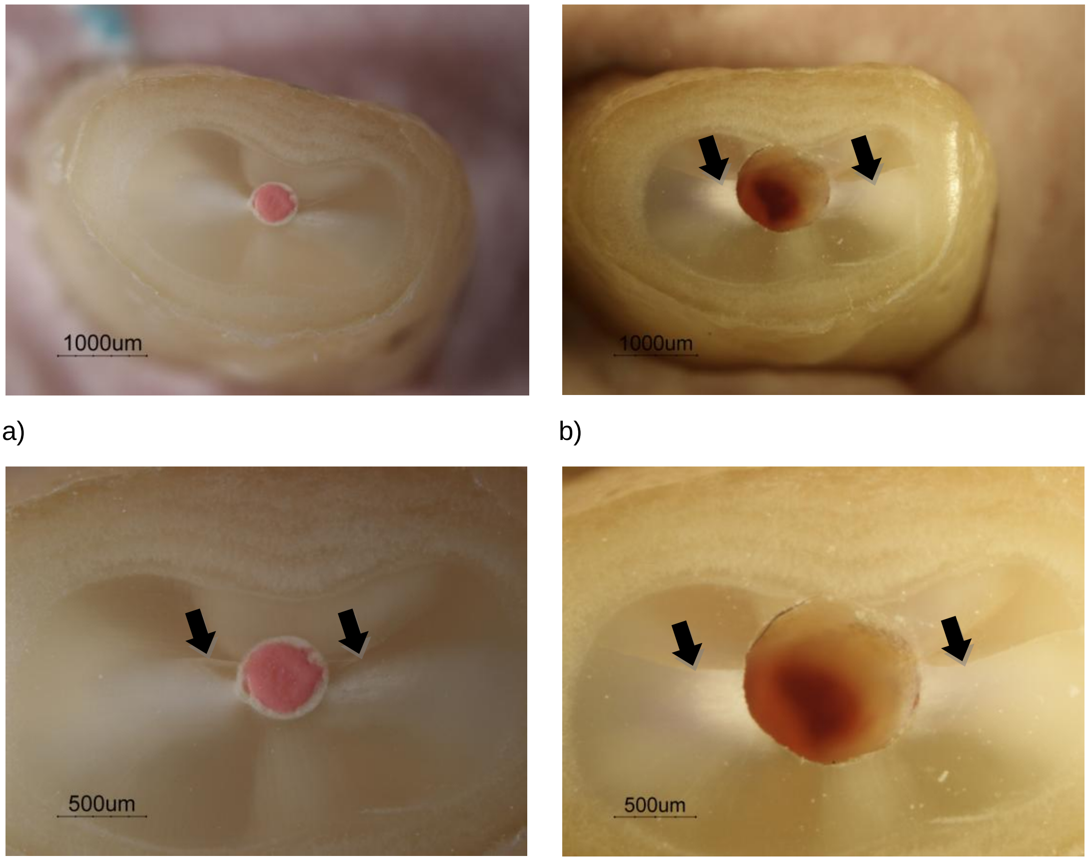
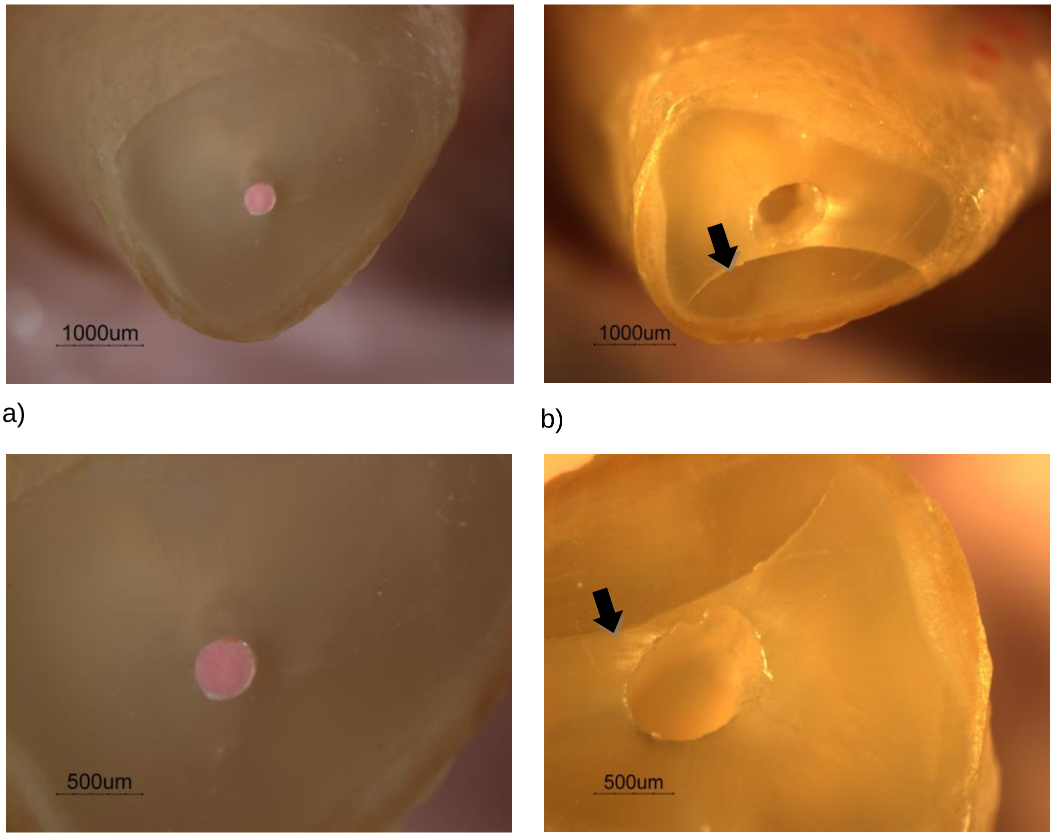
ANNEXES



a) b) c) d)

Figure 1: Photomicrographs of one tooth belonging to group 2, before (a, c) and after (b, d) root-end cavity preparation. Two intracanal cracks are visible before (arrows in c), and they become evident after root-end cavity preparation (arrows in b and d).



a) b)

c) d)

Figure 2: Photomicrographs of one tooth belonging to group 1, before (a, c) and after (b, d) root-end cavity preparation. No cracks are visible before, and one intradentine crack becomes evident after root-end cavity preparation (arrow in b and d).

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