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Cleanliness of dentinal walls following post space preparation using magnification

Key words *debridement, dental microscope, dentinal surface, magnification, post space*

Aim: The objective of this study was to assess, by means of a scanning electron microscope (SEM), the cleanliness of canal dentine surfaces after post space preparation with the aid of two different magnification devices, either dental loupes or an operating microscope.
Materials and methods: Twenty extracted single-rooted human teeth (18 canines and 2 premolars) were selected. Root canals were cleaned, shaped using nickel-titanium instruments and filled with gutta-percha. Samples were divided into two groups (n = 10), according to the device used by the operator: A (microscope) and B (loupes). Gutta-percha/sealer fillings were removed using a sequence of low-speed post drills; root canal walls were also cleaned by means of tips for ultrasound and microbrush. SEM images of post spaces were taken, and the presence of both debris and open dentine tubules was evaluated using a three-step scoring system. Mean scores were calculated at three depth levels of post space.
Results: Residual debris was observed in all specimens. Statistically significant differences ($P < 0.05$) between groups were found at both coronal and apical levels, and better scores for debris and open tubules were obtained by group A.
Conclusions: The use of an operating microscope allowed the authors to achieve superior debridement scores at specific levels (coronal and apical levels) of the post space area, compared with the use of dental loupes.

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Introduction

Predictable, non-surgical root canal treatments can now be delivered with an excellent long-term prognosis and a high tooth retention rate. This allows for conservation of teeth that may previously have been extracted[1].

Intraradicular posts are placed in root-treated teeth that have lost an extensive amount of crown substance because of decay, failed fillings (restorations) or tooth fractures. Post and core systems can be metal or non-metal and provide a way to stabilise and support the core material in the tooth[2,3].

Translucent, tooth-coloured, direct fibre posts are used frequently in clinical practice for the restoration of root canal-treated; they may represent an alternative to indirect posts and cores either when aesthetics is a priority in restoration or when the number of treatment sessions should be reduced. Fibre posts have increased in popularity as a result of two important features: first, the modulus of elasticity is similar to that of dentine[4], thus enhancing stress distribution; and secondly, they show a favourable mode of failure in comparison with metal post systems[5].

When a fibre post is used, the bonding mechanism of adhesive systems to root dental walls is essentially micro-mechanical in nature, based on hybridisation of the demineralised surface and on resin tags and adhesive lateral branch formation[6,7].

In most cases, failure of fibre posts is a result of an adhesive or cohesive failure occurring at the cement–dentine interface[8]. It is in this region that the link could be optimised.

Post space preparation is a critical step to achieve clean dentinal surfaces for adhesion of the cementing medium. Therefore, complete removal of the root filling materials is essential to enhance the adhesive bond to the dentine and increase post retention[9,10]. Furthermore, the presence of residual gutta-percha and deficient dentine hybridisation may result in poor sealing of the resin–dentine interface, as reported by Perdigao et al[11]. Moreover, remnants of endodontic sealers, owing to their chemical compositions, may negatively affect post retention. For example, eugenol inhibits the free radical polymerisation reaction of chemically cured composite resins, which results in a weakened bond when zinc oxide-eugenol sealers are used. Studies that have looked at this phenomenon have also noted that this weakening occurs with cyclic loading of the experimental specimens[12,13]. Properties that most affect the ability to remove root canal sealers are adhesion to dentine, penetration into dentinal tubules, film thickness, dimensional stability and solubility[14].

Several techniques have been proposed for removing root canal filling materials, most of them used in root canal retreatment, such as chemical solvents (eucalyptol, xylol, chloroform and others), heat or hand files to soften and remove the gutta-percha, and rotary instruments (non-end cutting burs such as Gates-Glidden, Peeso reamers or nickel-titanium [NiTi] instruments), which represent the easiest method to clean root canal walls[15]. The final shape of the post space is achieved by means of accompanying twist drills provided by prefabricated post systems.

Few studies have evaluated canal wall debridement of the post space. Serafino et al[16] focused on the effect of different irrigation regimens (with a final etching treatment using 35% phosphoric acid gel). Scanning electron microscope (SEM) analysis showed a thick smear layer, debris and gutta-percha residue covering large areas of root canal walls. Coniglio et al[17] compared two types of drills using different cleaning methods, including ultrasonic agitation, EDTA and phosphoric acid etching. No difference was found with the instrument used, but the greatest cleanliness was achieved by the ultrasound combined with EDTA regimen. A previous study reported that ultrasound agitation, followed by etching, was more efficient than etching alone in removing both smear layer and debris, and to open the dentinal tubules[18].

Despite the variety of different tools and techniques, removal of both debris and smear layer from the root canal appears to be difficult. No previous studies have assessed the effectiveness and benefits of using high magnification systems to perform post space preparation: it may or may not influence the cleanliness of post space walls. In other fields of dentistry and medicine in general, clearer vision of the operative field is related to higher quality work of an adequately trained clinician. In clinical practice it may be difficult for a clinician to see and to differentiate between well-compacted gutta-percha and dentinal walls of the root canal, especially in areas of anatomical irregularities. This may eventually lead to premature completion of the preparation. When the operative field is sharpened and enlarged, fine anatomical details are recognised. An operating microscope and other forms of magnification may be useful to enhance gutta-percha/sealer removal, by increasing root space visibility, and to obtain a dentinal canal wall better prepared for adhesive resin cementation in endodontically treated teeth.

The aim of the present study was to analyse by SEM the canal dentine surfaces after post space preparation with the aid of two different magnification devices, either dental loupes or an operating microscope. The null hypothesis tested was that no differences were detectable between amounts of root filling material debris on dentine surfaces obtained using the two different magnification devices.

Materials and methods

Tooth preparation

Twenty single-rooted human teeth (18 canines and 2 premolars) extracted for periodontal reasons were selected and stored in physiological saline solution until used (4 weeks). Criteria for tooth selection were as follows:

- no visible root caries, fractures or cracks on examination with a 4× magnifying glass
- no signs of internal or external resorption or calcification
- a fully formed apex
- teeth with excessive root canal curvature (15 to 35 degrees) were discarded.

For all samples, preoperative mesiodistal and buccolingual radiographs were taken to assess the existence of a single straight canal. Crowns were removed at the cementoenamel junction level, using a high-speed diamond bur cooled by air-water spray, perpendicular to the long axis of the tooth. The presence of the crown would have introduced more variables into the study, since the aim of the work was to evaluate the cleanliness of the post space. Canal lengths were determined by visualisation of a #10 K-file at the apex; working length used was canal length minus 1 mm. All samples were then embedded in acrylic blocks and stored in a humidity chamber (100% humidity and 37°C) when not being used. The twenty root canals were cleaned, shaped, filled and had post space prepared by a single operator.

Canals were instrumented using a sequential crown-down technique using NiTi rotary instruments (Profile® GT™ rotary files, Series 30, Dentsply Tulsa Dental Specialities, Tulsa, OK, USA) with descending taper (30/.10, 30/.08, 30/.06, 30/.04) mounted in a speed-reduction handpiece driven by an electric, torque control motor (ATR Tecnika, Pistoia, Italy), progressing to the full working length. Specimens were copiously irrigated by alternating 3 ml of 5.25% sodium hypochlorite (NaOCl) and 3 ml of 17% ethylenediaminetetraacetic acid (EDTA) after each instrument size used. Canals were completely dried with absorbent tapered paper points (Dentsply Maillefer, Baillagues, Switzerland); fillings were performed using both Thermafil® Endodontic Obturator (Tulsa Dental Specialities) and an epoxy resin root canal sealer seated into the canals with a lentulo spiral. All specimens were then radiographed in buccal and proximal views to evaluate the quality of fillings.

Post space preparation

Between canal filling of samples and post space preparation, 7 days were allowed to obtain complete hardening of the sealer[19]. All samples were randomly divided into two groups, A and B, of 10 teeth each. Each group was treated by a single operator, creating post space suitable for a prefabricated double-tapered fibre post with a maximum coronal diameter of 1.8 mm, and leaving a minimum apical seal of 4 to 5 mm of gutta-percha. Preparations were performed by an endodontist experienced and calibrated in the use of both magnification devices equally.

Group A

Initial removal of gutta-percha filling was started using standard Peeso reamers and continued with a sequence of low-speed post drills (#1, #2 and #3 DT Light-Post® Drills, Bisco, Schaumburg, IL, USA) to achieve suitable canal shape for post placement. A dental excavator (31L Endodontic Excavator, Hu-Friedy, Chicago, IL, USA) and a microbrush (Microbrush X, Microbrush®, Grafton, WI, USA) were used as additional aids for debridement of canal walls. Copious irrigation was applied during post space preparation with 5.25% NaOCl, using an endodontic needle during progressive drill intervals; sonic irrigation (agitation of 3 ml of 17% EDTA as an irrigant for 30 s) by a circular diamond-coated tip (Kavo, Genova, Italy) mounted in a Sonicflex 2003L handpiece (Kavo) was then performed, followed by a rinse with 5 ml of water. To dry the canals, 70% isopropyl alcohol was also used. In this group, the procedure described above was conducted by direct visualisation through a dental operating microscope, with a magnification of 6× to 40×, depending on the required field depth (Leica M400 E, Leica Microsystems, Wetzlar, Germany).

Group B

In this group, the intraradicular procedures for post space preparation were identical to those previously described but conducted with Galilean loupes (Keeler SuperVu, Keeler, Windsor, UK) at 2.5x magnification. Clinical criteria for assessing complete removal of the root filling material were detection of smooth canal walls and absence of debris observed

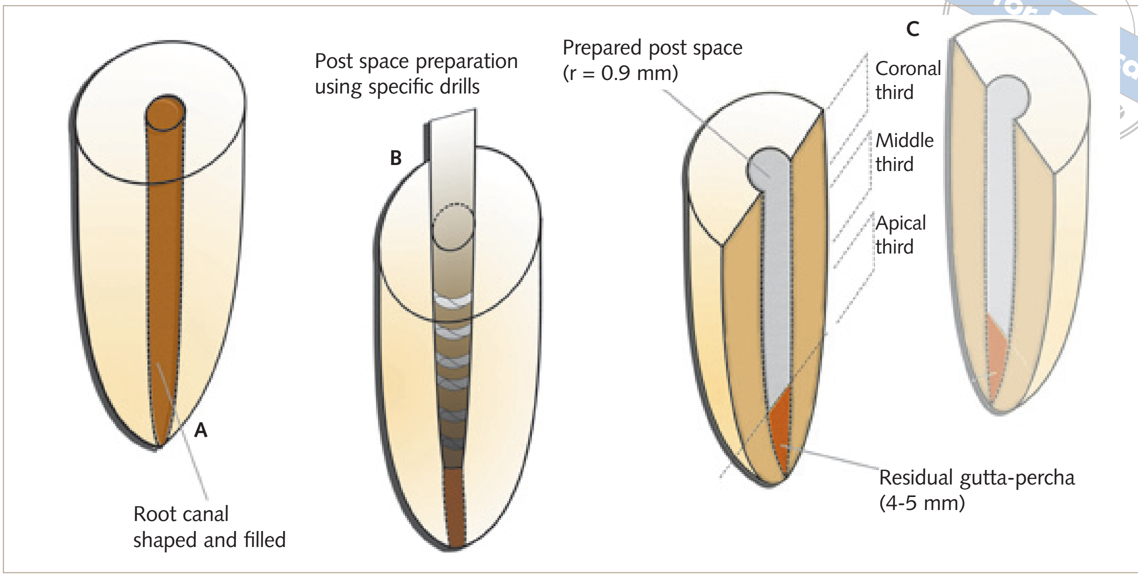

Fig 1 Main steps for sample preparation: standard root canal treatment (A); post space preparation (B); sectioned root halves before SEM examination (C).

in the instrument flutes or in the irrigating solution. A maximum time limit of 15 min was set to allow the operator to complete preparation of post space, regardless of obtaining adequate canal cleaning to meet the above-mentioned clinical criteria.

All canals from both groups were etched with 35% phosphoric acid gel for 15 s, rinsed with 5 mL of water for 10 s and then dried again with paper points.

Preparation of specimens for SEM evaluation

All roots from both groups were sectioned in the mesiodistal direction using a water-cooled diamond saw on an Isomet machine (Buhler, Lake Bluff, NY, USA). Forty root halves, obtained from groups A and B, were coded, mounted on metallic stubs, gold-sputtered and examined by with an SEM at 1000x original magnification. Root halves were evaluated at coronal (2 mm), middle (6 mm) and apical (10 mm) levels of the post space, each of them characterised by five random microscope observations, in order to rate dentine debris and open tubules using a three-step scale. Figure 1 shows the three main steps followed in sample preparation.

The quantity and dimension of debris present were graded between 0 and 2, according to the study of Serafino et al[16]:

- Score 0 – no debris present
- Score 1 – small quantity of debris present, the largest diameter < 20 µm
- Score 2 – large quantity of debris present, the largest diameter > 20 µm.

The amount of open dentinal tubules, as compared with sealer/gutta-percha remnants and smear layer, was graded between 0 and 2:

- Score 0 – all dentinal tubules open and no smear layer or debris visible
- Score 1 – some dentinal tubules open and a thin smear layer covers the openings of the cut dentinal tubules
- Score 2 – all dentinal tubules covered by smear layer or debris.

SEM evaluation was performed by the same person (who did not take part in the tooth preparation), who was not aware of the techniques and devices used to exclude observer bias. On each of the 20 specimens, the evaluation was replicated twice at two different times (i.e. the second evaluation was performed after 7 days using frames that had been acquired by SEM the first time) to ensure intra-examiner consistency. In case of a discrepancy between values obtained from the two evaluations, the score showing the highest amount of debris was considered valid. Figure 2 shows representative SEM photomicrographs obtained during debris evaluation. Mean debris and open tubule scores were calculated for groups A and B. Statistical analyses were performed using the non-parametric Kruskal–Wallis test and Mann–Whitney U test by means of SPSS® v.16 (SPSS, Chicago, IL, USA) at $P < 0.05$ to detect differences.

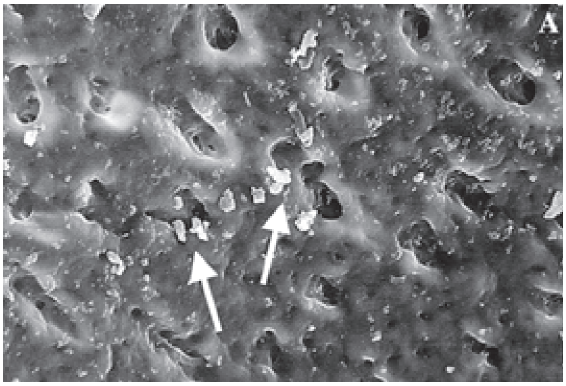

Fig 2a Dentine surfaces appears clean; a small amount of debris is present (arrows) but not covering tubular openings. A debris score of 0 was assigned.

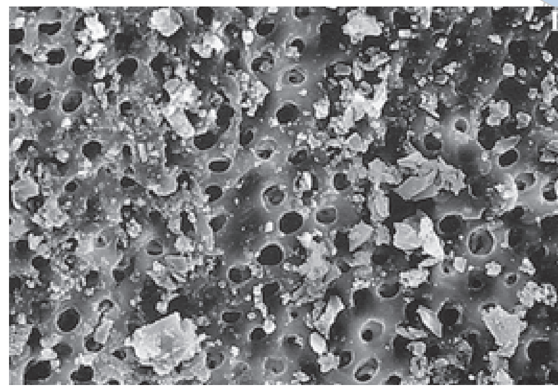

Fig 2b Extensive areas of dentine surfaces are covered by larger amounts of debris; tubular openings are still visible. A debris score of 1 was assigned.

Fig 2 Representative SEM photomicrographs showing different amounts of debris at 1000× magnification.

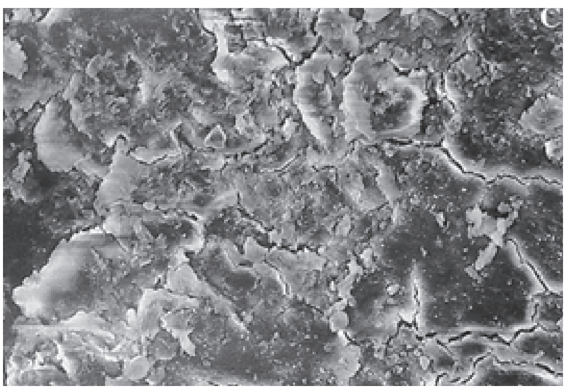

Fig 2c Dentine surfaces are fully covered by thick, irregular debris; tubular architecture is no longer visible. A score of 2 was assigned.

■ Results

Figure 3 shows the distribution of scores obtained from the evaluation of both parameters: root canal debris and open dentine tubules. Means and medians are presented in Tables 1 and 2. Unless otherwise specified, the terms 'coronal', 'middle' and 'apical' used in the present study relate to the thirds of the post space, not to the whole canal length; the same applies for the terms 'level' and 'area'.

Means for the operative microscope were consistently lower (closer to zero) than those observed for dental loupes: this was true when comparing the same level from both groups and for both parameters.

When the amount of debris was considered, the total count of completely cleaned dentine surfaces was higher within the microscope group. Eight samples out of ten received one or more zero scores, correlating to 14% of the total scores assigned (22/150). Two samples out of ten in the loupe group received three zero scores each, which was 4% of the total scores assigned (6/150). The frequency of score 2, which was recorded when a large amount of debris was present, was lower for the microscope group: 42.6% (64/150) vs. 59.3% (89/150).

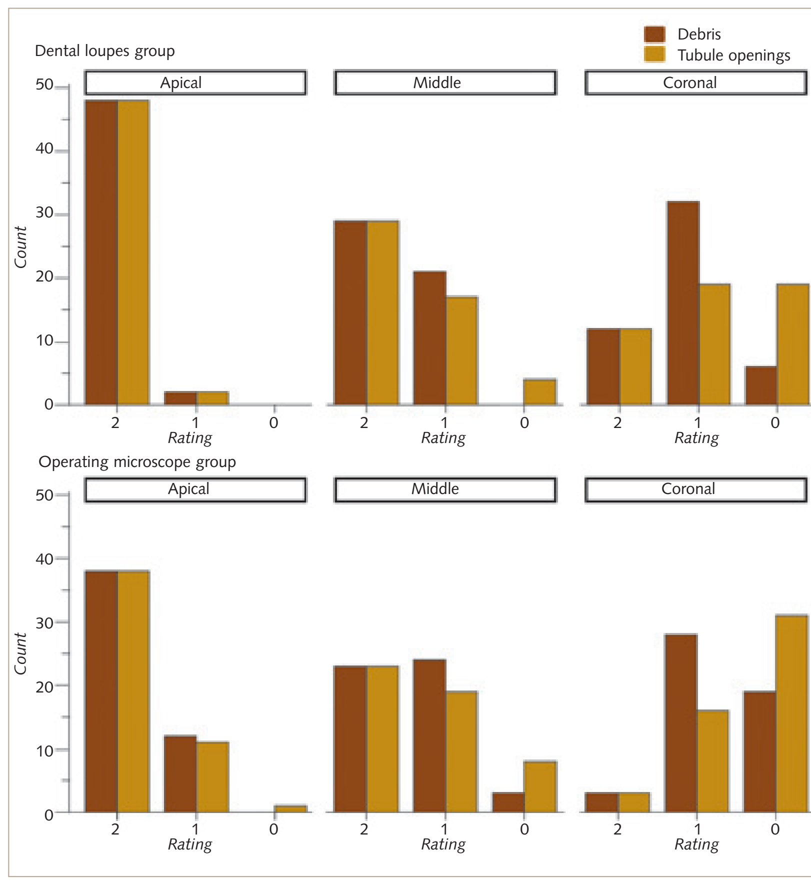

Fig 3 Distribution of scores obtained using the two magnification devices.

Regardless of the device used, the mean debris score for each level was statistically significantly different ($P < 0.05$) within the samegroup; furthermore, it got worse (further from 0) from the coronal to the apical third.

Table 1 Average results for debris scores in dental loupes and operating microscope groups.

Post space level	Dental loupes		Operating microscope		*P* value
	Mean	Median	Mean	Median	
Coronal	1.12	1	0.68	1	0.0005
Middle	1.58	2	1.40	1	0.1534
Apical	1.96	2	1.76	2	0.0041

Table 2 Average results for tubular openings scores in dental loupes and operating microscope groups.

Post space level	Dental loupes		Operating microscope		*P* value
	Mean	Median	Mean	Median	
Coronal	0.86	1	0.44	0	0.0054
Middle	1.50	2	1.30	1	0.1683
Apical	1.96	2	1.74	2	0.0041

Between groups, means for debris scores across different depths of the post space were statistically different ($P < 0.05$) only at the apical ($P = 0.0041$) and the coronal third ($P = 0.0005$); effectiveness of both magnification devices was the same in the middle area ($P = 0.1534$).

Analogous statistically significant differences were found for the three levels of the post space regarding open dentine tubule scores (apical, $P = 0.0041$; middle, $P = 0.1683$; coronal, $P = 0.0054$).

Discussion

Magnification devices have been successfully used to carry out important steps of endodontic procedures that include access cavity preparation[20], detection of root canal orifices[21] and retrieval of broken files[22]. The dental operating microscope has some additional features compared with loupes. In addition to a higher level of detail that can be obtained using a dental operating microscope, powerful illumination from its integrated fibre-optic light source, which is parallel to the line of sight, is added to the operative field. These factors may, at least in part, help to explain differences in results between groups.

Taking into account debris scores from the same group, either A (microscope) or B (loupes), some important observations can be made as follows:

- scores of 0 were all at coronal level in group B, while they were also assigned at middle level in group A
- distribution of scores followed a repetitive scheme for both groups, starting from the deepest area of post space up to the coronal level: scores of 2 decreased, while the other scores, i.e. 0 and 1, increased.

A clear inverse relationship existed between the degree of cleanliness and post space depth, irrespective of the magnification device tested. This was in agreement with the debris distribution observed under SEM analysis in the study by Serafino et al[16]. Briefly, high scores were recorded apically, while low scores were present at the coronal level. In the present study, regardless of the group, no sample obtained a score of 0 in the apical region of the post space for the debris variable. Anatomical irregularities, impaired access of instruments to the deepest level, and different degrees of etchant/irrigant penetration along the root walls may explain the debris distribution observed. A positive control group was not included in the present study: post spaces were not prepared and analysed in canals without using endodontic obturation. However, the best post retention has reportedly been achieved when no gutta-percha/sealer filling was performed[23–25]. Cleanliness of dentinal walls, which was higher in control groups, has been suggested to be related to post retention.

Root canals of teeth, including canines and premolars, have different cross-sectional morphology, also presenting oval shapes[26]. Generally, a long diameter decreases apically, indicating that the canal tends towards a round shape. It may be inferred that recesses in the middle region of the post space cannot be directly visualised by the operator and are not suited to the design of instruments chosen for preparation (burs and brushes have a round cross section). Such discrepancies prevent complete debridement of dentine surfaces and lead to statistical differences between groups in that area; the same problem is observed during endodontic treatment of oval canals[27,28]. In the present study, post space was prepared with the aim of maximum conservation of tooth structure. Excessive instrumentation of canal dentine can increase removal of root filling materials in recesses, but weakens the tooth and may impair the fit of the post.

Baldassari-Cruz and Wilcox[29] evaluated the effectiveness of gutta-percha/sealer removal both with and without a microscope in root canal retreatment, drawing conclusions partially in contrast with the present results. The use of magnification resulted in better removal of root filling materials, although the difference between groups was not statistically significant (percentage of canal walls covered by remnants was 7.3% when the microscope was used and 8.3% in the other group). This may be due to a problem that was also encountered in the present study during sample preparation with the use of magnification. In some cases, remnants could not be reached and removed even though they were visualised. Therefore, after several attempts, they were left in the canal.

A number of studies indicate that bond strength between root dentine and fibre post systems is affected by the depth of prepared post space[11,30,31]. Lower bond strength values are generally reported towards the apical segment. Possible factors that account for this may include:

- incomplete polymerisation of the bonding material and its non-uniform adaptation[32]
- difficult access to post space walls for both the etching procedure and application of adhesive agents[11]
- anatomical features of the tooth[33].

The number of dentinal tubules per mm^2 decreases from the coronal to the apical part of the root canal (from an average of 40,000 to 14,400)[34]. There is a reduced penetration of adhesives towards the apex due to lower tubule density. Based on results from the present study it may be assumed that the operating microscope may enhance adhesion in the most critical area of the post space, by improving cleanliness in the apical segment and increasing the surface (free of remnants) for hybridisation.

Although the operating microscope helps the operator in debris recognition and removal, this is a more time-consuming procedure than preparation performed either wearing loupes or using no magnification aid (i.e. prolonged identification of debris may lead an operator to spend more time cleaning the canals).

The clinical advantages of post space cleanliness could be counterbalanced by the detrimental effects of root canal irrigants on post adhesion. Morris et al[35] found significant reductions in bond strength of a resin cement (C&B Metabond, Parkell, Edgewood, NY, USA) to endodontic surfaces after treatment with 5% NaOCl or RC-Prep (Premier, Plymouth Meeting, PA, USA), compared with controls. The mechanism proposed for oxidation of some components in the dentine matrix, which was critical to polymerisation of C&B Metabond, was by either the oxidising action of NaOCl or the presence of hydrogen peroxide in RC-Prep. However, treatment with either 10% ascorbic acid or 10% sodium ascorbate restored bond strengths to control values. Similar conclusions were reported by Erdemir et al[36], in an evaluation of the effects of 5% NaOCl, hydrogen peroxide and their combination on bonding to root canal dentine. The authors also tested the irrigation of canals with 0.2% chlorhexidine gluconate, which showed the highest bond strength values. In fact, chlorhexidine slows down the degradation of resin-bonded dentine both *in vitro* and *in vivo*.

Despite the above problems of incomplete debridement, region-dependent distribution of remnants into the post space and adverse effects of some irrigants, survival of endodontically treated, post-restored teeth is excellent. A recent study[37], based on questionnaires collected from private practitioners, reported a mean survival time of 11 years. Another study[38] showed that the most common causes of clinical failure included either loss of post retention followed by post fracture or fracture of the root and post.

Further studies are being carried out to clarify how different characteristics of post spaces, obtained in the present study using either loupes or a microscope, may affect the bond strength of fibre posts to root canal dentine. After adhesive cementation, post retention differences will be evaluated by performing a tensile bond strength test. Limitations of the present *in vitro* study may be related to the oversimplified operating procedures in comparison to those used in clinical practice.

Conclusions

The root canal dentine surfaces of teeth in group A (microscope) achieved superior cleanliness scores (qualitative evaluation of debris and open dentine tubules). Thus, the initial null hypothesis must be rejected.

Compared with the use of dental loupes, the use of an operating microscope permitted the same operator, following standard protocols, to obtain better root canal cleanliness.

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