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Detectability of residual Epiphany and gutta-percha after root canal retreatment using a dental operating microscope and radiographs – an *ex vivo* study

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Abstract

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Aim To compare the detectability of residual Epiphany and gutta-percha after root canal retreatment using a dental operating microscope and radiographic examination with the residual area measured after rendering the roots transparent.

Methodology Sixty extracted single-rooted maxillary central incisor teeth were enlarged to apical size 40. Thirty canals were filled using vertically compacted Epiphany, the remainder were filled with vertically compacted gutta-percha and AH Plus sealer. After re-instrumentation to apical size 50, radiographs of the roots were taken in buccolingual and mesiodistal direction. Residual filling material was categorized by three observers using the radiographs and a dental operating microscope. The area of remaining material that was made visible by radiographs was measured with the aid of a computer image analysis programme. After clearing the roots, areas of residual filling material on the root canal wall were measured using a microscope.

Results Computer image analysis of the radiographs showed significantly smaller areas of remaining gutta-percha and Epiphany compared with the analysis of the transparent teeth that revealed only one absolutely clean root (Epiphany). Especially in the gutta-percha group, the scores determined by the observers using radiographic examination gave an over-optimistic impression of cleanliness compared with the scores determined by the visualization through the microscope.

Conclusion Especially for remaining gutta-percha, the operating microscopes provided better detection of residual root filling material in retreated maxillary incisor teeth.

Keywords: Epiphany, gutta-percha, microscope, Resilon, root canal retreatment.

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Introduction

Nonsurgical root canal retreatment requires complete removal of the root filling material in order to regain access to the apical foramen and sufficient cleaning and shaping of the root canal system (Bergenholtz *et al.* 1979, Stabholz & Friedman 1988, Friedman *et al.* 1990). Removing as much filling material as possible from inadequately prepared and/or filled root canal systems is essential in order to uncover remaining necrotic tissues or bacteria that may be responsible for periapical inflammation and thus post-treatment disease. However, it remains unclear what method of evaluation indicates complete removal of filling material. In some retreatment studies, the criteria for

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completion of retreatment were: no evidence of gutta-percha or sealer on the files or paper points, the presence of clean filings and smooth canal walls (Sae-Lim *et al.* 2000, Betti & Bramante 2001, Ferreira *et al.* 2001). In other studies, radiographs were exposed and evaluated; when there was evidence of remaining material on the radiograph, the tooth was cleaned again until no more gutta-percha could be removed or until further radiographic examination revealed no radiopaque material (Hülsmann & Stotz 1997, Imura *et al.* 2000, Hülsmann & Bluhm 2004). However, a previous *ex vivo* study showed that radiographic examination provided an over-optimistic impression of cleanliness compared with examination of vertically split roots (Betti & Bramante 2001). Clearly, more efficient methods are required for detecting remaining root filling material.

The dental operating microscope is used increasingly *in vivo* for routine endodontic procedures because of enhanced visibility and lighting (Carr 1992, Pecora & Andreana 1993, Kim & Baek 2004). The reported advantages of using an operating microscope for conventional endodontics include improved visualization of root canal anatomy that enables the operator to investigate the root canal system and to clean and shape it more efficiently (Saunders & Saunders 1997).

Therefore, it may be argued that small remnants of filling material remaining after root canal retreatment may be detected using the microscope. Very little information can be found in the literature concerning removal of filling materials using operating microscopes during nonsurgical retreatment. A previous *ex vivo* study illustrated that 8.3% of the canal wall was covered with remnants after removal of gutta-percha and sealer in canines without the use of a microscope whereas 7.3% of the canal wall was covered with remaining filling material after retreatment with the aid of a microscope although the difference was not statistically significant (Baldassari-Cruz & Wilcox 1999).

In the present study, the hypothesis was tested that in straight root canals the use of an operating microscope increased detectability of remaining gutta-percha/sealer or Epiphany compared with radiographic examination.

Materials and methods

Specimens

Sixty extracted straight human maxillary central incisor teeth used in a recent study evaluating the cleaning effectiveness of different instruments concerning removal of root canal filling material were used (Schirrmeister *et al.* 2006a). Original preparation was performed in a crowndown manner using FlexMaster instruments (Vereinigte Dentalwerke, Munich, Germany) until a size 30, 0.04 taper instrument reached working length. Apical enlargement was performed using size 35, 0.02 taper and size 40, 0.02 taper. The teeth were divided randomly into two groups of 30 teeth each. Thirty canals were vertically compacted with gutta-percha and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) using System B (Analytic Endodontics, Orange, CA, USA) and Obtura II (Obtura Spartan, Fenton, MO, USA). The other thirty canals were vertically compacted with Epiphany (Pentron Clinical Technologies LLC, Wallingford, CT, USA). One half of each group was retreated using Hedström files to size 50 whilst the other half was retreated using RaCe rotary instruments (FKG Dentaire, La Chaux-de-Fonds, Switzerland) to size 50, 0.02 taper. As the recent study showed that there was no significant difference ($P > 0.05$ in the gutta-percha group and in the Epiphany group) between both methods of reinstrumentation (Schirrmeister *et al.* 2006a), the instrumentation factor was disregarded in the analyses of the present study. Preparation was deemed complete when no filling material was observed on the instruments and no filling material could be detected inside the canal by the naked eye.

Two digital radiographs of each root were obtained: one in buccolingual and one in mesiodistal direction (Digora system; Soredex-Finndent, Orion Corp, Helsinki, Finland). Digora image phosphor plates (Soredex, Marietta, GA, USA) corresponding to the size of a conventional size 2 film were similarly exposed for 0.03 s at 65 kVp, 7.5 mA (Oralix 65 S; Philips, Milan, Italy). The image plates were parallel to the long axis of the roots, and both were perpendicular to the X-ray beam. They were scanned using the default setting in a calibrated Digora scanner and the acquired images were saved uncompressed using Digora for WINDOWS software.

Evaluation

For all roots, the following four types of data were recorded.

Scores of cleanliness evaluated by three observers using radiographs

Cleanliness of the canal walls was evaluated for remaining filling material using six modified categories

according to Hülsmann & Stotz (1997) and Hülsmann & Bluhm (2004):

1. Filling material completely removed.
2. One small remnant of filling material (<2-mm extension).
3. Two or three small remnants of filling material (<2-mm extension).
4. More than three small remnants of filling material (<2-mm extension).
5. Remnant of filling material (>2 and <5-mm extension).
6. Large remnant of filling material (>5-mm extension).

The evaluation of the digital radiographs was performed independently by three trained dentists. The images taken in buccolingual and mesiodistal direction were scored separately. A randomly laid-down image sequence was used so that the radiographs of one and the same root were not displayed in order. The observers were unaware of the method of retreatment and the type of filling material used. Each observer was given written and verbal instructions prior to scoring the radiographs.

The digital images were displayed enlarged to size 15×20 cm and simultaneously examined on a 15-inch TFT (thin film transistor) computer monitor operating at $1024 \times 768 \times 16$ bit in a darkened room to minimize glare. The observers were encouraged to change brightness and contrast, and to perform grey-scale inversion (positive/negative) in order to enhance image quality. No time limit was set for viewing.

Scores of cleanliness evaluated by three observers using an operating microscope

Using the same categories, the observers inspected the canals using an operating microscope with $15 \times$ magnification and a 300-W xenon light source (VM 500; Möller-Wedel, Wedel, Germany). No special training was performed for this study, but all observers had more than 3 years of clinical experience in the use of the operating microscope.

Canal wall cleanliness measured in mm^2 on radiographs

The area of remaining filling material on the canal walls found on the radiographs, taken in buccolingual and mesiodistal direction, was measured in mm^2 using IMAGE ANALYSER software (Comef 4.0; OEG Messtechnik, Frankfurt, Germany). Areas of radiographs taken in buccolingual and mesiodistal direction were computed separately.

Canal wall cleanliness measured in mm^2 in transparent roots

After reinstrumentation, the specimens were decalcified in 5% nitric acid for 72 h, washed for 4 h and dehydrated in increasing concentrations of alcohol (80% for 12 h, 90% for 1 h, and 99% for 3 h). The roots were subsequently cleared using methyl salicylate. Preliminary tests of the present study did not show an influence of the clearing procedure using the concentrations of nitric acid, alcohol and methyl salicylate on the area of remaining filling materials within the root canal. The amount of filling material on the canal walls was imaged in a standardized way on a black background in buccolingual and mesiodistal directions and measured in mm^2 using IMAGE ANALYSER software (Comef 4.0) connected to a stereomicroscope with $6.5 \times$ magnification via a charge coupled device (CCD)-sensor. The material was automatically detected by the software. The blackened background allowed easy detection of residual filling material (e.g. white Epiphany, light yellow AH Plus). Areas of images taken in buccolingual and mesiodistal direction were computed separately. All measurements were performed by one person who was unaware of the group assignment.

Analysis

The upper and lower confidence limit for the mean was calculated to show significant differences between the areas measured in mm^2 using radiographs and the transparent roots for mesiodistal and buccolingual perspectives separately. In addition, statistically significant differences were evaluated using a paired *t*-test. The degree of correlation between measurements was determined using Spearman's rank order correlation.

Kendall's Tau_b was calculated to determine inter-examiner agreement concerning the scores of remaining filling material using the radiographs and evaluation using the microscope.

Spearman's rank order correlation coefficient was used to determine the correlation between the area of remaining filling material measured in the transparent roots and the scores determined by the observers using the radiographs and the microscope, respectively.

Furthermore, confidence limits and paired *t*-tests were used to show statistically significant differences between scores given after radiographic and microscopic examination. The degree of correlation between scores of both examinations was determined

using Spearman's rank order correlation. Level of significance was set at $P < 0.05$. All statistics were performed using SAS 8.2 (SAS Institute Inc., Cary, North Carolina, USA).

Results

Transparent root versus radiograph: comparison of measured areas

Means and SD of areas of remaining gutta-percha and Epiphany measured in the transparent roots and on the radiographs are shown in Table 1. Only one root which was in the Epiphany group was free of any remaining filling material after examining the transparent roots in both directions.

Lower and upper confidence limits and paired *t*-test showed that analysis of the radiographs revealed significantly smaller areas of remaining filling material than analysis of the transparent teeth ($P < 0.001$, Table 2, Fig. 1).

Correlation between areas of remaining filling material measured on radiographs and areas measured in the transparent roots was moderate (Table 2, Fig. 1).

Observers scoring

Kendall's Tau_b for inter-examiner correlation amongst the three observers was between 0.80 and 0.86 for evaluation of radiographs in the mesiodistal direction, between 0.62 and 0.71 for evaluation of radiographs in the buccolingual direction, and between 0.61 and 0.66 for detection of residual filling material using the microscope.

The correlation of the measured area in the transparent root with the scores using radiographs and the microscope was moderate to low (Table 3, Fig. 2).

Table 1 Means and SD [mm^2] of areas measured in transparent roots and on radiographs

		Transparent root		Radiograph	
Direction	*n*	Mean	SD	Mean	SD
Gutta-percha					
Mesiodistal	30	3.47	2.12	1.07	2.20
Buccolingual	30	3.23	1.97	0.83	1.60
Epiphany					
Mesiodistal	30	1.54	1.36	0.52	0.67
Buccolingual	30	1.61	1.39	0.55	0.67

Table 2 Difference [mean, SD, and 95% lower confidence limit (LCL) and upper confidence limit (UCL)] between areas of remaining filling material measured on radiographs and in the transparent root; *P*-value showing significant differences (*P*) between areas measured on radiographs and in the transparent roots, and Spearman's rank order correlation (rS)

		$Area_{(radiograph)} - area_{(transparent\ root)}$ [mm^2]					
Direction	*n*	Mean	SD	LCL	UCL	*P*	rS
Gutta-percha							
Mesiodistal	30	−2.40	1.59	−2.99	−1.79	<0.001	0.46
Buccolingual	30	−2.40	1.25	−2.88	−1.93	<0.001	0.52
Epiphany							
Mesiodistal	30	−1.02	1.01	−1.40	−0.63	<0.001	0.66
Buccolingual	30	−1.06	1.01	−1.44	−0.68	<0.001	0.61

The median scores given by the three observers during the radiographic examination revealed significantly less remaining gutta-percha than microscopic examination, even if the correlation was low (Table 4, Fig. 2). To clarify the results, Table 4 shows paired differences, even if strictly speaking these scales should not be regarded as linear. Regarding the Epiphany group, only one observer gave significantly higher scores after microscopic examination than after radiographic examination.

Discussion

Canals were reinstrumented using endodontic hand and rotary instruments that are often used to remove filling material (Wilcox 1989, Friedman *et al.* 1990, Teplitsky *et al.* 1992, Hülsmann & Stotz 1997, Imura *et al.* 2000, Sae-Lim *et al.* 2000, Betti & Bramante 2001, Ferreira *et al.* 2001, Baratto Filho *et al.* 2002, Hülsmann & Bluhm 2004, Schirrmeister *et al.* 2006a–c).

For evaluation of remaining filling material, the categories according to Hülsmann & Stotz (1997) and Hülsmann & Bluhm (2004) were modified. Gutta-percha and sealer were considered equivalent as there is unlikely to be a difference if gutta-percha or sealer covers necrotic tissues and bacteria in terms of the outcome. Furthermore, it would have been impossible to distinguish between core material and sealer using radiographs. In the Epiphany group, the difference between core material and sealer cannot be identified because of the formation of a 'monoblock' (Teixeira *et al.* 2004).

In the present study design, canal preparation was considered complete when there was no filling material

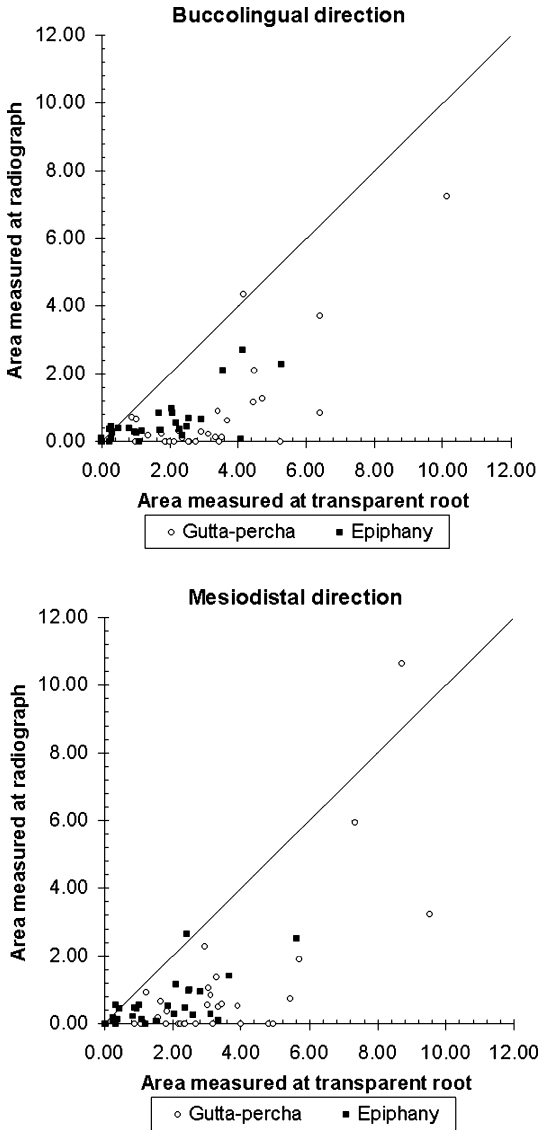

Figure 1 Area of remaining filling material measured in the transparent root and on the radiograph with line of equality.

evident on the instruments. However, except for one root in the Epiphany group, all canals revealed remnants of filling material. Thus, it is evident that the lack of filling material on the instruments is not a valid criterion to demonstrate complete removal of filling material from canal walls.

The area of remaining material was smaller when measuring areas on the radiographs than on images of the transparent roots. In a previous study, radiographic examination also gave an over-optimistic impression of cleanliness compared with examination of vertically split roots both for evaluation by observers and for computer evaluation (Betti & Bramante 2001). Moreover, especially in the gutta-percha group, the observers in the present study detected more remaining filling material in the retreated canal by microscopic versus radiographic examination. In these straight canals, the observers could detect Epiphany (white) and AH Plus sealer (light yellow) on the canal walls with the aid of the microscope. Consequently, using only radiographs, many root canals with remaining gutta-percha, AH Plus or Epiphany would have been considered clean. Even though the correlation between the scores given after microscopic examination of the roots and the area measured in the transparent root was low, the microscope with its increased illumination and magnification seemed to facilitate detection of remaining filling material that may cover necrotic tissues or bacteria and therefore may be responsible for post-treatment disease. Illumination of the microscope is improved because the light is parallel to the line of sight and will provide two to three times the light of a surgical headlamp (Carr 1992). Furthermore, the use of a microscope during nonsurgical endodontic treatment appears essential to detect canals, which could not be found during original root canal treatment (Stropko 1999, Gorduysus *et al.* 2001, Baldassari-Cruz *et al.* 2002, Buhrley *et al.* 2002).

Table 3 Correlation between scores [using radiographs and the operating microscope (OPMI)] and the areas measured in the transparent roots (Spearman's correlation coefficient)

Observer	$Score_{(md\ radiograph)}$ and $area_{(md\ transparent\ root)}$	$Score_{(bl\ radiograph)}$ and $area_{(bl\ transparent\ root)}$	$Score_{(OPMI)}$ and area (md transparent root)	$Score_{(OPMI)}$ and $area_{(bl\ transparent\ root)}$
Gutta-percha				
Obs I	0.55	0.46	0.43	0.47
Obs II	0.44	0.41	0.41	0.42
Obs III	0.44	0.51	0.29	0.38
Epiphany				
Obs I	0.74	0.65	0.49	0.45
Obs II	0.61	0.49	0.58	0.50
Obs III	0.50	0.51	0.51	0.46

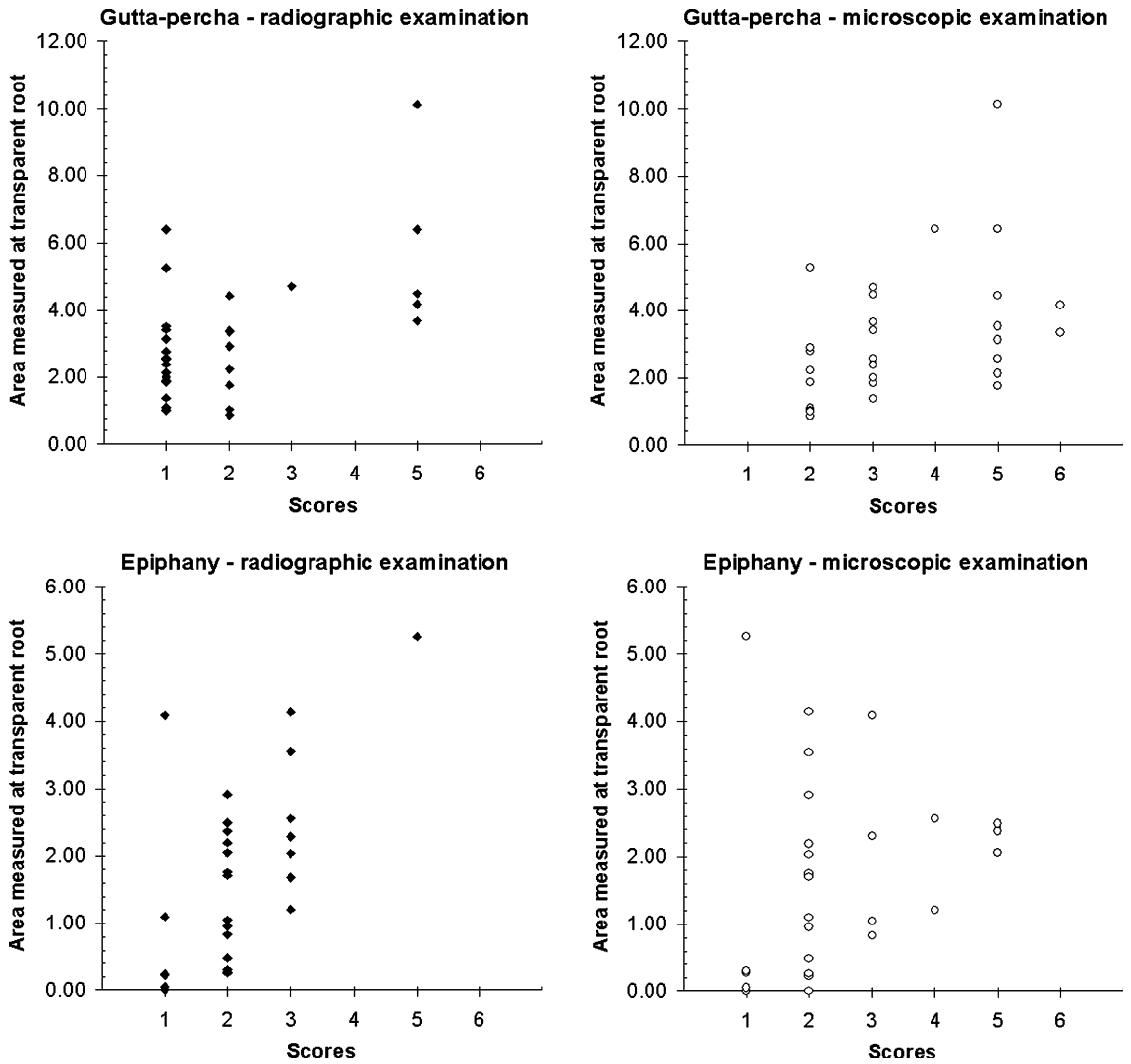

Figure 2 Median scores of the three observers for examination using the operating microscope and the radiographs taken in buccolingual direction compared with the area of remaining obturation material measured in the transparent root imaged in buccolingual direction. The pattern for imaging in mesiodistal direction was similar.

According to the outcome of the present study, it should be expected that less filling material remains after removal with the aid of an operating microscope than without. In a previous *ex vivo* study, less gutta-percha was found in 20 teeth after removal with the aid of a microscope compared with a group without although the difference was not statistically significant (Baldassari-Cruz & Wilcox 1999). A larger sample size could have led to a significant difference. Another reason might be that some remnants could not be removed even though they were visualized with the microscope.

The lack of detectability of remaining gutta-percha, sealer or Epiphany using radiographic examination may be explained by the radio-opacity of thin layers of filling material being similar to dentine. It can be expected that the lack of detectability of remaining filling material using radiographs would have been even worse *in vivo*, where lamina dura and cancellous bone is superimposed on the root. Furthermore, it is obvious that radiographic examination in mesiodistal direction is impossible *in vivo*.

The results of this study using maxillary central incisor teeth cannot be extrapolated to all teeth.

Direction	Observer	*n*	$Score_{(radiograph)} - score_{(OPMI)}$ Mean	SD	LCL	UCL	*P*	rS
Gutta-percha								
Mesiodistal	I	30	−0.9	1.8	−1.6	−0.2	0.011	0.295
	II	30	−1.3	1.9	−2.0	−0.6	<0.001	0.233
	III	30	−0.4	2.0	−1.1	0.4	0.334	0.290
	Median	30	−1.0	1.8	−1.6	−0.3	0.007	0.320
Bucco-lingual	I	30	−1.2	1.9	−1.9	−0.5	0.002	0.210
	II	30	−1.9	1.7	−2.5	−1.2	<0.001	0.152
	III	30	−1.0	1.4	−1.5	−0.4	0.001	0.295
	Median	30	−1.5	1.7	−2.1	−0.8	<0.001	0.223
Epiphany								
Mesiodistal	I	30	−0.2	1.4	−0.7	0.3	0.440	0.423
	II	30	−0.9	1.4	−1.4	−0.3	0.002	0.161
	III	30	−0.2	1.6	−0.8	0.4	0.573	0.297
	Median	30	−0.3	1.6	−0.9	0.2	0.252	0.210
Bucco-lingual	I	30	−0.4	1.4	−0.9	0.2	0.163	0.274
	II	30	−0.9	1.3	−1.4	−0.5	<0.001	0.341
	III	30	−0.2	1.5	−0.7	0.4	0.556	0.248
	Median	30	−0.3	1.4	−0.8	0.2	0.256	0.173

Table 4 Difference (mean, SD, and 95% upper and lower confidence limits [LCL and UCL]) between scores given using radiographic and microscopic examination; *P*-value showing significant differences (*P*) between scores given using both evaluation methods, and Spearman's rank order correlation (rS)

Maxillary incisors often have straight roots. In curved canals, it is not possible to inspect the portion of the canal beyond the curvature using a microscope. However, it may be argued that in curved canals detection of remaining filling material from the orifice to the curvature may be improved when using the microscope in combination with radiographs.

Conclusions

Operating microscopes support better detection of residual filling material in retreated straight incisor teeth. Especially in the gutta-percha group, radiographic examination gave an over-optimistic impression of cleanliness compared with the visualization through the microscope. It appears important to check the cleanliness of straight root canals after reinstrumentation with the aid of an operating microscope in order to maximize removal of filling material.

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