Scanning electron microscope study on the efficacy of root canal wall debridement of hand versus Lightspeed instrumentation

C. Bechelli[1], S. Zecchi Orlandini[2] & M. Colafranceschi[3]

1 Private endontic practice; 2 Department of Human Anatomy and Histology and 3 Institute of Pathology, University of Florence, Florence, Italy

Abstract

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Aim The aim of this *in vitro* study was to compare the efficacy of root canal wall debridement following hand versus LightSpeed™ instrumentation.

Methodology Twenty recently extracted single-rooted teeth were paired and randomly placed into two treatment groups of 10 teeth each. In group 1, a step-back instrumentation without initial coronal flaring with stainless steel Hedstroem files was used; group 2 was instrumented with Ni-Ti LightSpeed™ instruments. Both groups had the same irrigation regimen: 2.5% NaOCl and a 15% EDTA solution. The teeth were then decoronated and each root split longitudinally into two halves to be examined using the scanning electron microscope (SEM). The presence of superficial debris and smear layer was evaluated by a standardized grading system, and the resulting scores submitted to nonparametric statistics.

Results Under the conditions of this study, the removal of superficial debris was generally excellent with both canal preparation techniques. Both techniques resulted in variable presence of residual smear layer, with a canal wall covered by smear layer as the predominant characteristic. Generally, the amount of smear layer was greater in the apical than in the middle third of the root, however, this difference was statistically significant ($P < 0.005$) only in hand-instrumented teeth. The use of LightSpeed™ instruments was associated with significantly more ($P < 0.05$) smear layer presence in the middle region of the root when compared with hand instrumentation. In addition, less smear layer was present in the apical region following LightSpeed™ instrumentation than stainless steel hand files, but this difference was not statistically significant. Differences in debridement between the two halves of the same root were more evident with LightSpeed™ than manual instrumentation, however, there was no statistical significance.

Conclusions It may be inferred that the choice between hand and LightSpeed™ instrumentation should be based on factors other than the amount of root canal debridement, which does not vary significantly according to the instruments used.

Keywords: canal debridement, hand instrumentation, LightSpeed™, mechanical instrumentation, scanning electron microscopy.

Introduction

The removal of debris and smear layer from the root canal system prior to obturation with an appropriate filling is one of the primary aims of endodontic treatment (Abbott *et al.* 1991). Smear layer differs from the 'dusty' pattern of superficial debris in that it is a layer of 'muddy' material, composed of an amorphous layer of organic and inorganic debris, and sometimes bacteria (Sen *et al.* 1995), which is compacted against the dentine walls as a result of the

Correspondence: Professor Maurizio Colafranceschi, Istituto di Anatomia e Istologia Patologica, Policlinico Careggi, viale Morgagni 85, 50134 Firenze, Italy.

rasping action of endodontic instruments (Lester & Boyde 1977, Mader *et a*l. 1984). Although the thorough cleansing and shaping of the root canal system are considered as key requirements for success in root canal therapy (Smith *et al.* 1993, Knowles *et al.* 1996), there has been no agreement on how these goals might be achieved (Cameron 1995). Recently, a new generation of endodontic instruments made from nickel-titanium have been introduced (Walia *et al.* 1988), which have two to three times more elastic flexibility and appear to be more fracture resistant compared to stainless steel files (Knowles *et al.* 1996). Since most hand preparation techniques are time consuming, technically demanding, and show unpredictable outcome, attention has been directed toward mechanical methods of canal preparation. Following the introduction of an innovative rotary technique in the late 1980s, the Canal Master™ (Wildey & Senia 1989), a further improvement of the original design resulted in the marketing of the LightSpeed™ instruments in 1993 (LightSpeed™ Technology Inc, San Antonio, TX, USA). This instrument, constructed from a nickel-titanium alloy for greater flexibility and fracture resistance, is specifically designed for use with a low torque handpiece. LightSpeed™, like the Canal Master, has a short cutting blade, a smooth pilot tip, and a thin shaft. The cutting tips vary in length from 0.25 mm for size 20 instrument to 1.75 mm for size 100 instrument and have three geometric forms which optimize efficient cutting of the dentine (Glosson *et al.* 1995). LightSpeed™ instruments have been reported to remain centred within the canal system, even in the most complex canal configurations (Wildey & Senia 1994, Glosson *et al.* 1995, Knowles *et al.* 1996).

Generally, most studies have concluded that the canal shape was maintained by rotary nickel-titanium files, with the procedure being noticeably easier and faster than hand preparation (Esposito & Cunningham 1995, Glosson *et al.* 1995, Knowles *et al.* 1996, Barbakow & Lutz 1997, Thompson & Dummer 1997b) up to sizes not routinely attainable with stainless steel instruments (Esposito & Cunningham 1995) and, possibly, with less removal of dentine (Glosson *et al.* 1995). In the questionnaires posted by Barbakow & Lutz (1997), working lengths were claimed by 62% of the respondents to be easier to maintain by LightSpeed™ than their usual preparation techniques. Canal transportation did not appear to be a consistent problem even in canals up to 55° curvature (Glosson *et al.* 1995, Knowles *et al.* 1996).

Numerous studies have been reported on the relative effectiveness of different instrumentation techniques, based on a variety of ways of evaluating canal debridement. Outcomes of instrumentation differ according to the method of canal preparation and evaluation, each method showing advantages and disadvantages (Heard & Walton 1997). Introduction of the scanning electron microscope (SEM) has proved to be a valuable method for assessment of the ability of the endodontic procedures to remove debris from root canals, thus enabling comparison of instruments and techniques. Therefore, a number of studies about the debridement of the root canal wall have been carried out by using SEM (Mizrahi *et al.* 1975, Cameron 1995, Lloyd *et al.* 1996, Liolios *et al.* 1997). However, as far as is known, SEM studies for specifically testing the LightSpeed™ instrumentation for canal debridement have not yet been carried out.

The purpose of this *in vitro* study, in which SEM was used, was to compare the debridement of the root canal following hand versus LightSpeed™ instrumentation. Having standardized the preparation procedure for both treatment groups, the presence of superficial debris and smear layer were evaluated and graded as well in the middle and the apical regions of the root canal walls.

Materials and methods

Specimen selection

A total of 20 teeth were used in this study. Patient age-range spanned from 50 to 70 years. Only permanent anterior teeth with a single root and a single canal, recently extracted for periodontal reasons, were selected. Following extraction, the teeth were rinsed in tap water in order to remove blood and tissue debris, placed in small coded bottles containing phosphate-buffered saline solution and stored at 5°C for a few days.

Before canal instrumentation, each tooth was placed in a rigid frame simulating the mandibular bone and fixed there with wax. The use of the rubber dam contributed to simulating clinical conditions. Preoperatively, each tooth was radiographed buccolingually in order to eliminate teeth with two root canals or with canals having unusual anatomy. The teeth were then paired on the basis of the size and curvature of the root canal according to Schneider's method (Schneider 1971). Conventional endodontic access cavities were prepared using a tapered diamond bur (Intensiv, Viganello, Lugano, Switzerland) in a high-speed handpiece.

A size 08–10 K-file was then inserted into the root canal to establish the working length.

Canal instrumentation

The teeth were divided into two equal groups and each of the paired teeth was assigned randomly to the respective treatment group. Treatment groups were as follows: group 1 (10 teeth) was instrumented with stainless steel Hedstroem files (L.K.G., Switzerland); group 2 (10 teeth) was instrumented with Ni-Ti LightSpeed™ instruments.

The procedures used for each instrumentation group were standardized. Following the preparation of three canals, the instruments were replaced. Both groups had the same irrigation regimen: the irrigants used during instrumentation were 2.5% NaOCl solution at a temperature of 40–45°C and a 15% EDTA solution (RC-Prep, Medical Products Laboratories, Philadelphia, PA, USA). Copious irrigation was performed between each instrument, using a hypodermic 2.5-mL plastic syringe, delivering the irrigating solutions via a 23-gauge needle inserted deeply into the canal.

Group 1 In hand-prepared specimens, a step-back instrumentation without initial coronal flaring was used. Each file was passively placed to working length then filed circumferentially until loose. Shaping of the canals was accomplished by using a step-back technique in 1.0 mm increments. The apical patency was established by periodic passage of a size 10/15 H-file through the apical opening. Coronal flaring was then performed with Hedstroem files and size 050, 070, 090 and 110 Gates Glidden drills (Maillefer, Ballaigues, Switzerland). The apical matrix was a size 25–35 H-file.

Group 2 An electrically-powered handpiece was used to drive the rotary instruments at a constant speed of 750 r.p.m. Beginning with size 20, the LightSpeed™ instruments were advanced slowly to the working length with a gentle apical pressure and then removed whilst maintaining continuous rotation. The teeth were instrumented to an apical preparation varying from 30 to 40. LightSpeed™ instruments were available in half-sizes; therefore, step-back was performed in 0.5 mm increments to ensure 1.0 mm step-back of sizes 50, 55, and 60. After preparation was complete, a size 20 LightSpeed™ instrument was passed 1 mm through the apex to remove any dentinal plug and to ensure patency of the foramen.

Final irrigation was carried out with 3 mL of saline solution in both groups. All canals were dried with paper points.

SEM examination

The crowns were removed at the amelo-cemental junction using a tungsten carbide fissure bur in a high-speed handpiece. To facilitate fracture into two halves, all roots were grooved longitudinally on the buccal and lingual surfaces with a small round diamond bur, avoiding penetration into the cavity. Finally, the roots were split with a small chisel into two halves and placed in coded containers containing a 2.5% glutaraldehyde aqueous solution in phosphate buffer until analysis with the SEM.

Each root section was then dehydrated in graded concentration of alcohol, critical point dried in CO_2, mounted on an aluminium stub, sputter-coated with 10% gold-palladium, and observed with a scanning electron microscope (Stereoscan 100, Cambridge, England, UK). A representative series of photomicrographs was taken at different magnifications.

Specimen grading

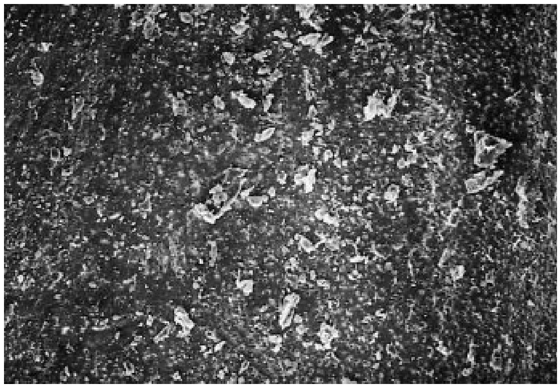
Specimens were coded for blind evaluation, the two examiners (S.Z. & M.C.) being unaware of the treatment applied.

Superficial debris and smear layer were independently subjected to a standardized semiquantitative evaluation in four grades, according to the classification of Gutmann *et al.* (1994). This latter classification was modified with regard to the higher magnification used in this study (x200 vs. x100) for the evaluation of the superficial debris. Criteria for the scoring were the following:

Score of the superficial debris (Fig. 1): (a) score 1, little or no superficial debris covering up to 25% of the specimen; (b) score 2, little to moderate debris covering between 25 and 50% of the specimen; (c) score 3, moderate to heavy debris covering between 50 and 75% of the specimen; and (d) score 4, heavy amounts of aggregated or scattered debris over 75% of the specimen.

Score of the smear layer (Fig. 2): (a) score 1, little or no smear layer; covering less than 25% of the specimen; tubules visible and patent; (b) score 2, little

a



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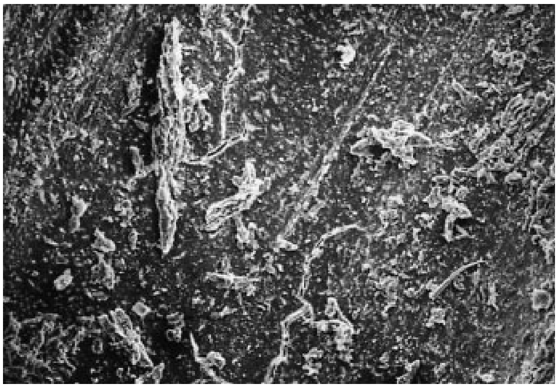

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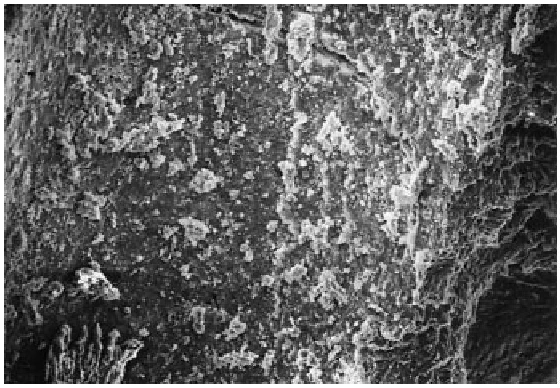

d

Figure 1 Standardized gradations of superficial debris used for specimen evaluation. (a) = score 1; (b) = score 2; (c) = score 3; (d) = score 4. Original magnification x200.

to moderate or patchy amounts of smear layer; covering between 25 and 50% of the specimen; many tubules visible and patent; (c) score 3, moderate amounts of scattered or aggregated smear layer; covering between 50% and 75% of the specimen; minimal to no tubule visibility or patency; and (d) score 4, heavy smear layering covering over 75% of the specimen; no tubule orifices visible or patent.

Evaluation

Scoring was performed in the middle and apical third of each longitudinal half of the root. For superficial debris, 6–8 microscopic fields at x200 were randomly assessed in each third of each half-root, whereas 12 fields at x780 were, respectively, examined for the smear layer. Both these magnifications were chosen because they allowed sufficient detail whilst still maintaining the microscopic field as large as possible. Consequently, the smear layer was evaluated in 48 fields and the debris in 24–32 fields in the middle-apical region of the root of each instrumented tooth. Each field was graded from 1 to 4 according to the scoring system, and the mean value was calculated for each region of each half of the root.

A preliminary series of four teeth, not included in this study, served for training and calibration of the procedure, both for operator and observers. Four photomicrographs, taken as representative of the four-grade scoring system for both superficial debris and smear layer, served as visual reference standards throughout the evaluation. Each examiner assigned his score independently from the other, and in case of disagreement the evaluation was discussed until agreement was achieved.

The data on the score levels were recorded directly onto coding sheets and transferred to a desktop computer. The statistical analyses were carried out by means of nonparametric tests (Mann–Whitney test between the groups and Wilcoxon signed-ranks test

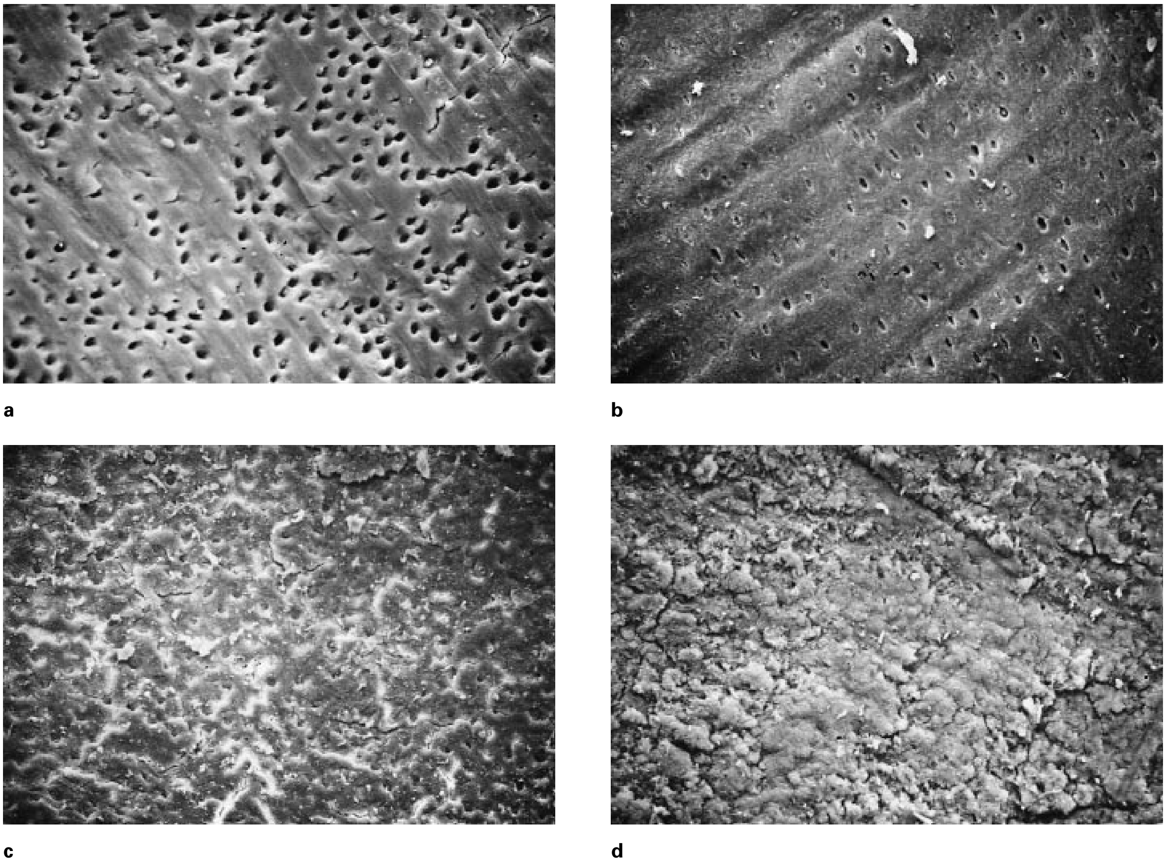

Figure 2 Standardized gradations of smear layer used for specimen evaluation. (a) = score 1; (b) = score 2; (c) = score 3; (d) = score 4. Original magnification x780.

within the groups). The aim was to assess whether there were any significant differences between the two techniques in the score of debris or smear layer either overall or at the different regions of the canals or between the two halves of the same root. A probability value equal to or less than 0.05 was considered to indicate significance.

Results

Superficial debris

In both the hand and LightSpeed^{TM} instrumentation groups, superficial debris was minimal at x200 magnification. Generally, the removal of superficial debris appeared more effective in the middle than in the apical part of the root, but this was not statistically significant by the Wilcoxon test. The small differences observed between the scores of manual and Lightspeed^{TM} instrumentation were not significant using the Mann–Whitney test (Tables 1, 2).

Smear layer

Few surfaces showed smear layer to be absent and dentinal tubules completely patent (Fig. 3). Occasional openings of dentinal tubules were infrequently observed in the apical region and the canal wall was usually covered with a thick smear layer ('bark tree' pattern) which, at the margins of the fractured wall, slightly penetrated the dentinal tubules. In the middle region the treatment produced a similar surface, although generally smoother and more even. A characteristic surface morphology of the residual smear layer was not identified in relation to the instrumentation procedure. Smear layer removal was more effective in the middle than the apical level of the root for both instrumentation procedures, however, this was statistically significant ($P = 0.005$ by Wilcoxon test) only in the group of hand-prepared teeth (Tables 3, 4).

mongst the groups, the Mann–Whitney test displayed statistically significant differences at the middle level of

Table 1 Scores of superficial debris in hand-instrumented teeth in the middle and apical thirds of the root canal

	Middle		Apical	
Specimen	Score	SD	Score	SD
1H	1.21	0.41	1.17	0.39
2H	1.07	0.28	1.08	0.28
3H	1.45	0.52	2.00	0.39
4H	1.14	0.36	1.57	0.51
5H	2.00	0.42	2.00	0.55
6H	1.00	0	1.25	0.45
7H	1.33	0.49	1.50	0.55
8H	1.41	0.51	1.00	0
9H	1.25	0.45	1.67	0.48
10H	1.08	0.29	1.00	0
Mean score	1.30		1.44	NS

[a] Wilcoxon test for matched pairs was used.
[b] SD, standard deviation; NS, not significant.

Table 2 Scores of superficial debris in LightSpeed™ instrumented teeth in the middle and apical thirds of the root canal

	Middle		Apical	
Specimen	Score	SD	Score	SD
1L	1.19	0.40	1.08	0.28
2L	1.00	0	1.21	0.42
3L	1.23	0.44	1.71	0.49
4L	1.17	0.41	1.57	0.53
5L	1.33	0.51	1.25	0.46
6L	1.00	0	1.00	0
7L	1.07	0.25	1.07	0.26
8L	1.33	0.65	1.23	0.44
9L	1.17	0.39	1.00	0
10L	1.00	0	1.17	0.39
Mean score	1.15		1.25	NS

[a] Wilcoxon test for matched pairs was used.
[b] SD, standard deviation; NS, not significant.

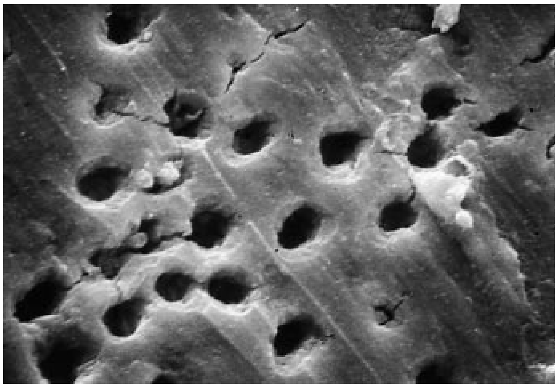

Figure 3 Mid-root section, showing a dentinal surface with minimal smearing. Hand-prepared specimen. Original magnification x2960.

the root ($P < 0.05$), the hand-prepared teeth showing the lower score (2.39 hand vs. 2.86 LightSpeed™ instrumentation) (Tables 3, 4; Figure 4). Smear layer removal at the apical third, although slightly more effective with LightSpeed™ instrumentation (score 3.04 vs. hand 3.23), did not differ significantly according to the same statistical test (Tables 3, 4; Figure 5).

Since some dentinal surfaces were heavily smeared whilst others were untouched in the same root, irrespective of the treatment, a comparison was made for the mean differences of debridement in the two halves of the root between hand and LightSpeed™ instrumentation (Table 5). Statistically significant differences for smear layer debridement between the two parts of the root were more evident with the use of LightSpeed™ instruments than with manual instrumentation. In this respect, however, a statistically significant

Table 3 Scores of smear layer in hand-instrumented teeth in the middle and apical thirds of the root canals

	Middle		Apical	
Specimen	Score	SD	Score	SD
1H	2.52	0.75	3.25	0.61
2H	1.79	0.66	2.67	0.48
3H	2.92	0.41	3.25	0.44
4H	2.37	0.49	3.04	0.36
5H	2.46	0.51	3.04	0.20
6H	2.04	0.69	3.87	0.34
7H	2.58	0.50	3.62	0.57
8H	2.79	0.51	3.46	0.51
9H	1.83	0.38	3.17	0.38
10H	2.62	0.65	3.00	0.42
Mean score	2.39		3.23	$P = 0.005$

[a] Wilcoxon test for matched pairs was used.
[b] SD, standard deviation.

Table 4 Scores of smear layer in LightSpeed™ instrumented teeth in the middle and apical thirds of the root canals

	Middle		Apical	
Specimen	Score	SD	Score	SD
1L	2.94	0.65	3.04	0.62
2L	2.12	0.74	2.75	0.44
3L	2.67	1.09	3.08	0.51
4L	2.33	0.49	2.50	0.52
5L	2.75	0.62	3.17	0.39
6L	2.83	0.64	3.08	0.41
7L	2.83	0.87	3.00	0.51
8L	3.29	0.62	3.92	0.28
9L	3.87	0.34	3.12	0.80
10L	2.92	0.50	2.79	0.66
Mean score	2.86		3.04	NS

[a] Wilcoxon test for matched pairs was used.
[b] SD, standard deviation; NS, not significant.

Table 5 Mean differences in the smear layer score between the root halves at the middle or apical third of the root

Instrumentation	Middle third	Apical third	
Hand	0.18	0.21	NS
LightSpeed™	0.55	0.44	NS
	$P < 0.05$	NS	

[a] Statistical tests: Mann–Whitney test between the groups and Wilcoxon test within the groups were used.
[b] Mann–Whitney test: $P < 0.05$; NS, not significant.

difference between the two canal preparation techniques was reached in the middle region only.

Discussion

The main advantage of SEM is that it allows evaluation of both halves of the canal wall along their entire length. However, only the surface can be examined, and the depth of debris cannot be determined precisely. Preparation of the specimen may also induce artefacts (Heard & Walton 1997). Moreover, there are practical limitations for grading the root canal surface when a scoring system is used. In fact, magnification is a compromise between the need to observe large areas of the root internal surface, yet still maintaining the possibility of identifying specific structures. This

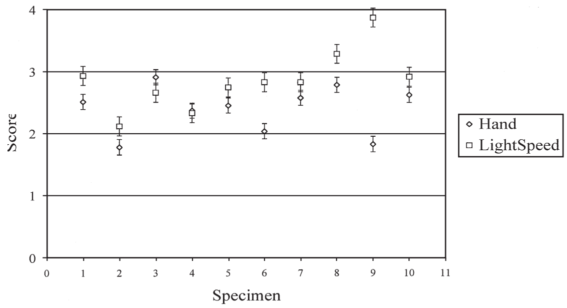

Figure 4 Hand versus LightSpeed™ instrumentation. Mean scores of the smear layer in paired teeth at the middle third of the root. The standard deviation is shown for each specimen.

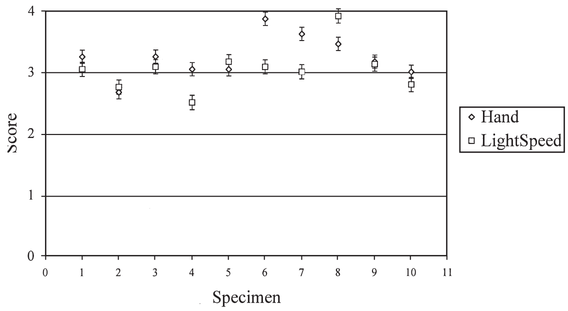

Figure 5 Hand versus LightSpeed™ instrumentation. Mean scores of the smear layer in paired teeth at the apical third of the root. The standard deviation is shown for each specimen.

considered, it is estimated that a sufficiently representative view of the debridement of the root canal was achieved in the present study.

It should be emphasized, as with most *in vitro* studies, that a degree of caution should be exercised in the interpretation of the findings and their extrapolation clinically (Thompson & Dummer 1997a). Many variables were encountered in the clinical and experimental techniques used in the literature, i.e. freshly extracted or saline- or formalin-stored teeth, instrumentation following decoronation or through a clinical access cavity, different irrigating solutions and/or procedures. This makes every comparison impossible, and could account for the apparent conflict in results (Cameron 1995). Furthermore, an unavoidable bias of this kind of experimentation is its single-blind design. In the present study, differences were encountered between hand and LightSpeed™ preparation in the evaluation of the apical size in paired teeth. This was due to the greater flexibility and short cutting blade of the LightSpeed™ instrument which operates in the apical area approaching the actual size of the apex, without transportation.

Under the conditions of this study, neither the hand nor the LightSpeed™ preparation technique achieved total root-canal debridement. However, the removal of superficial debris was generally excellent, and the differences between the two experimental groups were not statistically significant. Similarly, in the experimental studies by Shoha & Glickman (1996) and by Hinrichs *et al.* (1997), there were no statistical differences with respect to the total extruded debris amongst different types of handpiece-driven Ni-Ti instruments (LightSpeed™ included) and stainless steel K-files or Flex-R instruments.

Regarding smear layer, the predominant pattern was a canal wall still covered by smear layer with both techniques of instrumentation. Looking at different regions of the canal, residual smear layer was more evident in the apical than in the middle third of the root. Only in hand instrumented teeth, however, this difference was highly significant ($P = 0.005$).

The use of LightSpeed™ instruments compared with hand instrumentation was associated with a lesser degree of smear layer removal in the middle region of the root, and this difference was statistically significant ($P < 0.05$). Conversely, LightSpeed™ instrumentation appeared slightly more effective in reducing smear layer in the apical region, but this difference was not significant.

Morphology and thickness of the remaining smear layer seemed to vary in different parts of the single root, irrespective of the technique used. The differences in debridement between the two halves of the root were more marked in the LightSpeed™ group, however, the difference between the two procedures reached the significance level only at the middle third of the root. Manual instrumentation appeared superior to mechanical instrumentation for the debridement of large, straight canals but, again, this difference did not reach statistical significance.

It was not possible to determine whether this incomplete debridement occurred because of the nature of the experimental model. Mastering any new endodontic technique is undoubtedly related to the individual's learning curve (Barbakow & Lutz 1997), however, our results cannot be explained by operator inexperience, since she had been practising hand instrumentation as well as LightSpeed™ instruments for a significant period prior to this study. Indeed, incomplete debridement appears to be a common problem of SEM investigations (Heard & Walton 1997), which have generally concluded that all hand and mechanical instrumentation and irrigation methods leave debris, both organic and inorganic, within the canal (Cunningham *et al.* 1982). Present findings are in agreement with these observations, demonstrating that untouched dentinal surfaces are usually left and the aim to provide the optimum cleanliness of the root canal is a theoretical one. Indeed, smear layer removal still remains a controversial issue (Liolios *et al.* 1997), and, since many other bio-mechanical factors may affect the outcome of root canal treatment, further studies are needed to establish the clinical importance of its absence or presence (Sen *et al.* 1995). Moreover, an irregular secondary dentine is associated with the physiological ageing of the root (Wakabayashi *et al.* 1993) so that surface morphology, especially in the apical region, is far from smooth, which is generally advocated in endodontics to be typical of the normal or well-debrided canal wall.

The suggestion is advanced that the choice between manual and rotary instrumentation should be based on factors other than the amount of root canal wall debridement, which does not vary significantly according to the instruments used. In this respect, irrigating solutions and procedures appear more critical than instrumentation techniques. More important factors to be considered are the speed and ease of use, canal shaping ability, reduced apex transportation, and the reliability of instruments under mechanical stress.

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