Micro–computerized tomographic analysis of radicular and canal morphology of premolars with long oval canals

Nicola M. Grande, DDS,a Gianluca Plotino, DDS,a Raffaella Pecci,b Rossella Bedini,b Cornelis H. Pameijer, DMD, DSc, PhD,c and Francesco Somma, MD, DDS,a Rome, Italy
CATHOLIC UNIVERSITY OF SACRED HEART, ITALIAN NATIONAL INSTITUTE OF HEALTH, AND UNIVERSITY OF CONNECTICUT

Objective. The aims of this in vitro study were to measure root and canal diameters, root and canal diameter ratios, mean taper of the root canal and of each root canal section, and radicular wall thickness at different levels in premolars with long oval root canals.

Study design. Thirty human premolars, with single long oval canals were selected for this study. The specimens were analyzed with micro–computerized tomography. The cross-sections corresponding to 1, 2, 3, 4, 5, 7, 9, 11, and 13 mm from the radiologic apex were analyzed to measure the mesiodistal (MD) and buccolingual (BL) diameters of the canals and the thickness of the root and the walls. The BL/MD ratios of the canal (ΔC) and the root (ΔR) diameters were calculated, as was as the mean taper in both a BL and an MD dimension. Multiple logistic regression analyses were performed with a level of significance of \( P = .05 \).

Results. At all levels of analysis, the BL diameter was greater than the MD diameter for both the canal and the root. Generally, \( \Delta C \) and \( \Delta R \) increased coronally. Buccal and lingual wall thicknesses were greater than mesial and distal at all levels. Canal diameters at 1 mm from the apex were >0.30 mm in the shorter-oval diameter and >0.40 mm in the longer-oval diameter. In all root segments the BL taper was greater than the MD taper.

Conclusions. An oval canal anatomy was frequently present even in the most apical sections of the root canals. A high correlation was established between the shape of the root canal and the corresponding root. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;xx:xxx)

The thorough removal of debris by means of mechanical instrumentation is one of the primary objectives in endodontics and aimed at accomplishing the total elimination of remaining pulp tissue and microorganisms from the root canal system.1 Furthermore, the survival of root-filled teeth may depend on the amount of residual dentin. Many studies demonstrate a direct relationship between the loss of tooth structure and the possibility of fracture of the crown or root.2-4

A cone shape with a circular base is not the most common anatomic configuration in radicular canals, which are more oval than circular.5-9 Recently, the cross-sectional shape of a root canal has been classified as round, oval, long oval, flattened, or irregular.10 Those authors defined oval as having a maximum diameter of up to 2 times greater than the minimum diameter and long oval as having a maximum diameter of two to four times greater than the minimum diameter. Recent studies reported a high prevalence of oval and long oval root canals in human teeth, even at an apical level.8,11,12

After preparation, uninstrumented recesses may be left in many oval canals, regardless of the instrumentation technique, thus leaving a smear layer, debris and unprepared root canal walls behind.13-18 This complex anatomy must be regarded as one of the major challenges in infection control through root canal preparation, because both pulp tissue and root dentin may harbor microorganisms and toxins, thus jeopardizing the outcome of the root canal treatment.19 The use of irrigants and their activation and agitation using ultrasonic tips is of great benefit to increase cleaning of these complex anatomies and anastomoses in roots with multiple canals.20,21

It is generally recommended to maintain the original anatomic shape of the root canal, to preserve maximum dentin thickness, and at the same time to effectively enlarge the root canal, with the objective to remove its organic and inorganic contents.22,23 However, little information about the thickness of canal walls related to root canal diameters in long oval canals is available.

The aims of the present in vitro study were to measure by means of microtomographic analysis canal diameters, and root and canal diameter ratios, mean taper...
of the root canal and of each root canal section, and radicular wall thickness at different levels in premolars with long oval root canals.

MATERIAL AND METHODS

Specimen selection and preparation

Thirty human single-rooted permanent premolars not previously treated were selected from a pool of teeth freshly extracted from an adult Italian population for orthodontic reason and stored in 10% neutral buffered formalin. The teeth were thoroughly examined under a stereomicroscope at ×12 magnification (Stemi SV6; Carl Zeiss, Arese [MI], Italy), and roots with resorption, defects, fractures, or open apices were excluded from the study. The selected teeth were then placed in a 5.25% sodium hypochlorite solution for 2 h to remove the periodontal ligament, following which all remaining soft and hard aggregations were removed with a scaler.

Radiographs were made in buccolingual (BL) and mesiodistal (MD) direction to evaluate the root canal anatomy and to identify the radiographic apex. Teeth with accessory canals or a radiographically invisible main canal were excluded. Selection was based on teeth that had a single long oval root canal. If radiographs determined that at the cervical and midroot level the BL-to-MD dimensions had a ratio of ≥2, the teeth were included.8,10 Furthermore, selection was based on preliminary microtomographic analysis showing straight root canals to the apex while possessing similar root canal lengths, approximately 13 mm. A tooth with an apical foramen that was more than 0.5 mm away from the apex was excluded.

A custom-designed specimen holder for the micro–computerized tomography (MCT) was fabricated to exactly fit the specimen with the crown positioned downward and its long axis perpendicular to the floor of the specimen holder of the MCT and the X-ray source. The analysis of each sample consisted of 2 stages and required approximately 4 h to complete 1 scan: 2 h for the scanning procedure, and 2 h for the reconstruction procedure.

Tooth scanning and reconstruction

The teeth were scanned using a desktop X-ray microfocus CT scanner (SkyScan 1072; SkyScan, Aartselaar, Belgium), and the scanning procedure was completed using 10 W, 100 kV, 98 μA, a 1-mm-thick aluminium plate, and ×15 magnification with 5.9 s exposure time and 0.45° rotation step, resulting in a pixel size of 19.1 × 19.1 μm. The acquisition procedures consisted of the realization of several 2-dimensional lateral projections of the specimens during a 180° rotation around the vertical axis. The digital data were further elaborated by reconstruction software (NRecon V1.4.0; SkyScan) providing new axial cross-sections with a pixel size of 19.1 μm × 19.1 μm. The distance between each cross-section was 38.0 μm. The cross sections were collected by sample, and after cone-beam reconstruction the raw data were converted to 16-bit-grayscale picture files with a resolution of 512 × 512 pixels. Using a computer software analysis system (CT-analyzer V1.6; SkyScan), all of the files of each sample were resliced stepwise using a slice spacing factor of 2 in vertical cross-sections. These data were then stored for later use. After completion of the scanning procedure, the samples were replaced in the formalin solution.

Linear measurements

The first apical MCT cross-sectional slice in which the root appeared was recorded for each tooth as the reference point and registered as the radiographic apex. The cross-sections at 1, 2, 3, 4, 5, 7, 9, 11, and 13 mm from the radiographic apex were analyzed to measure the MD and BL diameters of the canal, the MD and BL diameters of the root, and the thickness of the buccal (B), lingual (L), mesial (M), and distal (D) walls of the roots.

All measurements were made with the use of an external program, “CTAn” (SkyScan). The BL/MD ratios of the canal (ΔC) and the root (ΔR) diameters were calculated for each specimen at various levels. Mean tapers of the root canal and of each root canal section were also calculated in both BL and MD dimensions.

Statistical analysis

Means and standard deviations of root and canal diameters were calculated for the BL and MD dimensions. Evaluation and comparison of these values were made descriptively and reported in a tabular format for the different canal levels.

A first multivariate linear regression analysis was performed to assess the influence of cross-section level (1, 2, 3, 4, 5, 7, 9, 11, or 13 mm from the apex) and ΔR (independent variables) on ΔC (dependent variable), using the backward elimination procedure described by Hosmer and Lemeshow.24

Means and standard deviations of wall thickness were calculated for each position (buccal, lingual, mesial, and distal). Effects and interactions of location (buccal, lingual, mesial, or distal) and cross-section level (1, 2, 3, 4, 5, 7, 9, 11, or 13 mm from the apex) (independent variables) on the variation of radicular wall thickness (dependent variable) were examined by subjecting the data to a second multivariate linear regression analysis.
The fit of the model was assessed using the $R^2$ values. We considered all the differences tested to be significant when the experimental F had a significance equal to $P < .05$.

The statistical analysis was performed using SPSS for Windows (release 11.0; SPSS, Oakbrook, IL).

**RESULTS**

Canal and root BL and MD diameter and B, L, M, and D thickness of dentinal walls at 1, 2, 3, 4, 5, 7, 9, 11, and 13 mm from the apex are shown in Table I. The BL/MD ratios of the canal ($\Delta C$) and the root ($\Delta R$) diameters calculated at different levels are shown in Table II.

At all levels, the BL diameter was greater than MD for both the canal and the root. The first overall regression model was statistically significant ($F = 83.117; P < .0001; R^2 = 0.454$). The independent variables considered in the model ($\Delta R$ and level of section) were significantly associated with the dependent variable ($\Delta C$). The multivariate linear regression showed that the level of section considered had the greatest positive impact on $\Delta C$ (std. $\beta = 0.471; P < .0001$). Generally, $\Delta C$ increased coronally, demonstrating an oval shape at 1 and 2 mm from the apex ($\Delta C$ of 1.4 and 1.8, respectively), a long oval shape at 3, 4, and 5 mm from the apex ($\Delta C$ of 2.2, 2.2, and 2.3, respectively), and a flattened shape in the more coronal sections ($\Delta C$ at 13 mm $= 4.3$). The $\Delta R$ had a positive effect on the outcome variable as well (std. $\beta = 0.380; P < .0001$) as $\Delta C$ and $\Delta R$ increased coronally. In a coronal direction, the differences between the MD and BL diameters were greater (Table II), in spite of the fact that at $\Delta R$ 9 mm from the apex there was a slight decrease.

The model generated by the second multivariate linear regression showed that the independent variables considered (location and level of section) were significantly associated with the dependent variable (wall thickness). Mesial, distal, buccal, and lingual location of thickness measurements were considered as single dummy variables in the model. The overall regression model was statistically significant ($F = 740.33; P < 0.0001; R^2 = 0.728$). The mesial and distal location showed collinearity, and the mesial was excluded as independent variable in the model. Buccal and lingual wall thickness was greater compared with mesial and distal at all levels (Table I). This was confirmed by the multivariate linear regression, which showed that both buccal (std. $\beta = 0.390; P < 0.0001$) and lingual (std. $\beta = 0.541; P < 0.0001$) locations had a positive correlation on wall thickness compared with mesial and distal locations. Moreover, analyzing the std. $\beta$ values it appeared that the lingual side compared with the buccal had a slightly higher influence on wall thickness. The level of section considered had the greatest positive impact on wall thickness (std. $\beta = 0.652, P < 0.0001$).

In a coronal direction, part of the root wall thickness increases. Canal diameters at 1 mm from the apex were >0.30 mm (MD 0.32 ± 0.07 mm, BL 0.45 ± 0.16 mm), and they always increased toward the coronal aspect, as did the root diameters.

Values for the mean taper of the canals are shown in Table III. The mean tapers in the MD and BL directions were subsequently 0.03 and 0.18 mm/mm. In all root

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### Table I. Mean (standard deviation) in millimetres of canal and root buccolingual (BL) and mesiodistal (MD) diameters and buccal (B), lingual (L), mesial (M), and distal (D) thickness of dentinal walls for each cut surface

<table>
<thead>
<tr>
<th>Distance from the apex</th>
<th>Canal BL (mm)</th>
<th>Canal MD (mm)</th>
<th>Root BL (mm)</th>
<th>Root MD (mm)</th>
<th>Root B (mm)</th>
<th>Root L (mm)</th>
<th>Root M (mm)</th>
<th>Root D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm</td>
<td>0.45 (0.16)</td>
<td>0.32 (0.16)</td>
<td>2.41 (0.40)</td>
<td>1.71 (0.45)</td>
<td>0.85 (0.29)</td>
<td>1.05 (0.33)</td>
<td>0.69 (0.26)</td>
<td>0.69 (0.18)</td>
</tr>
<tr>
<td>2 mm</td>
<td>0.60 (0.27)</td>
<td>0.32 (0.11)</td>
<td>3.17 (0.52)</td>
<td>2.10 (0.41)</td>
<td>1.16 (0.27)</td>
<td>1.38 (0.33)</td>
<td>0.94 (0.21)</td>
<td>0.88 (0.18)</td>
</tr>
<tr>
<td>3 mm</td>
<td>0.76 (0.42)</td>
<td>0.35 (0.13)</td>
<td>3.85 (0.55)</td>
<td>2.48 (0.46)</td>
<td>1.46 (0.25)</td>
<td>1.63 (0.30)</td>
<td>1.07 (0.22)</td>
<td>1.04 (0.25)</td>
</tr>
<tr>
<td>4 mm</td>
<td>0.90 (0.43)</td>
<td>0.41 (0.12)</td>
<td>4.36 (0.56)</td>
<td>2.68 (0.48)</td>
<td>1.64 (0.25)</td>
<td>1.81 (0.23)</td>
<td>1.14 (0.26)</td>
<td>1.12 (0.25)</td>
</tr>
<tr>
<td>5 mm</td>
<td>1.03 (0.49)</td>
<td>0.47 (0.14)</td>
<td>4.78 (0.57)</td>
<td>2.87 (0.47)</td>
<td>1.80 (0.26)</td>
<td>1.96 (0.22)</td>
<td>1.20 (0.24)</td>
<td>1.21 (0.24)</td>
</tr>
<tr>
<td>6 mm</td>
<td>1.18 (0.63)</td>
<td>0.53 (0.18)</td>
<td>5.26 (0.71)</td>
<td>3.12 (0.48)</td>
<td>2.01 (0.23)</td>
<td>2.23 (0.23)</td>
<td>1.28 (0.26)</td>
<td>1.31 (0.22)</td>
</tr>
<tr>
<td>7 mm</td>
<td>1.38 (0.83)</td>
<td>0.58 (0.21)</td>
<td>6.34 (0.66)</td>
<td>3.38 (0.39)</td>
<td>2.11 (0.25)</td>
<td>2.31 (0.27)</td>
<td>1.38 (0.23)</td>
<td>1.44 (0.19)</td>
</tr>
<tr>
<td>8 mm</td>
<td>1.55 (0.66)</td>
<td>0.64 (0.22)</td>
<td>6.85 (0.56)</td>
<td>3.82 (0.39)</td>
<td>2.17 (0.26)</td>
<td>2.37 (0.26)</td>
<td>1.58 (0.22)</td>
<td>1.62 (0.16)</td>
</tr>
<tr>
<td>9 mm</td>
<td>1.71 (0.52)</td>
<td>0.67 (0.24)</td>
<td>7.11 (0.49)</td>
<td>4.26 (0.38)</td>
<td>2.17 (0.24)</td>
<td>2.32 (0.32)</td>
<td>1.79 (0.19)</td>
<td>1.82 (0.16)</td>
</tr>
</tbody>
</table>

### Table II. Buccolingual mesiodistal ratios of the canal ($\Delta C$) and root ($\Delta R$) diameters at different distances from the apex (levels)

<table>
<thead>
<tr>
<th>Level</th>
<th>$\Delta C$</th>
<th>$\Delta R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>2 mm</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td>3 mm</td>
<td>2.2</td>
<td>1.6</td>
</tr>
<tr>
<td>4 mm</td>
<td>2.2</td>
<td>1.7</td>
</tr>
<tr>
<td>5 mm</td>
<td>2.2</td>
<td>1.7</td>
</tr>
<tr>
<td>6 mm</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>7 mm</td>
<td>2.7</td>
<td>1.8</td>
</tr>
<tr>
<td>8 mm</td>
<td>3.7</td>
<td>1.9</td>
</tr>
<tr>
<td>9 mm</td>
<td>3.8</td>
<td>1.8</td>
</tr>
<tr>
<td>11 mm</td>
<td>4.3</td>
<td>1.7</td>
</tr>
<tr>
<td>13 mm</td>
<td>4.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>
using a spatial resolution of 38 μm. It appears that this method is a very useful tool to study the external and internal anatomy of teeth and surrounding tissues. It overcomes the shortcomings of previously reported techniques that are complicated and time consuming and that can introduce artefacts and distortion of the internal anatomy of the tooth. It appears that this nondestructive method is more accurate than other methods for the morphologic study of teeth (i.e., clearing, serial cross-sections, radiographic examination). Unfortunately, MCT is expensive and time consuming, and for that reason only 30 teeth were examined in the present study. Micro-computerized tomography represents the “gold standard” technique when pretreatment and post-treatment comparisons (i.e., root canal shaping) are being made. Micro-computerized tomography was used here because it is as accurate if not more than other methods that are more complicated and time consuming and may introduce artefacts. When making serial cross-sections using histologic techniques, it is difficult to section precisely the area of interest and correlate the many sections that are produced. With the use of MCT, the cross-sections can be made at a precise distance from the apex.

Using teeth with straight root canals reduced the possibility of artificial measurements due to root canal curvatures. Therefore, teeth that did not show a straight root canal 1 mm from the apex after a preliminary 3D microtomographic reconstruction were excluded from the study. All mandibular and maxillary premolars were included in a single group, because criteria of specimen selection were based on the ratio of long to short root canal diameter. This feature, determining the presence of a single long oval root canal, may be encountered in both mandibular and maxillary first and second premolars. The selection of teeth with a long oval cross-sectional shape for this study was to strictly focus on root canal anatomy, in particular the difference in root and canal dimensions in MD and BL directions.

Many studies have demonstrated that widely accepted endodontic cleaning and shaping techniques are inadequate. This can be attributed to the fact that root canal diameter is larger than the instrument used. This has been confirmed in the present study. Furthermore, the results of the present study show that in the apical third, root canals have a minimum diameter >0.30 mm and a maximum diameter >0.45 mm, even at a distance 1 mm from the apex. These results confirm those of the morphometric anatomic studies on root canal dimension that also reported a high prevalence of oval canals in the apical third. Wu et al. measured canal diameters at 1, 2, and 5 mm from the apex. They reported median values of BL canal diameter at 1 mm from the apex of 0.37 mm in single canal maxillary premolars and 0.35 mm in mandibular premolars and median values of MD canal diameter at 1 mm from the apex of 0.26 mm and 0.28 mm, respectively. The mean results obtained in the present study at the same level were slightly greater for the BL dimension (0.45 ± 0.16 mm), whereas they were similar for the MD dimension (0.32 ± 0.16 mm). These differences may be explained by the fact that Wu et al. reported the median values, with a high range between minimum and maximum measurements of canal diameter. Furthermore, the reported mean values of BL and MD canal diameter at 2 and 5 mm from the apex were similar to those obtained in the present investigation, taking into consideration the median values and the range between minimum and maximum canal diameter. Root canal maximum diameters obtained in the present study were similar to those described by Kerekes and Tronstad for mandibular premolars at 1, 2, and 3 mm from the root apex, although those obtained by the same authors at 5 mm from the root apex were greater.

One of the primary goals of root canal treatment is to completely clean and shape the root canal system by cutting the dentin on the root canal wall circumferen-

### Table III. Mean taper of the root canal and of each root canal section in buccolingual (BL) and the mesiodistal (MD) dimension

<table>
<thead>
<tr>
<th>Level</th>
<th>Canal BL</th>
<th>Canal MD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 mm</td>
<td>0.15</td>
<td>0.00</td>
</tr>
<tr>
<td>2-3 mm</td>
<td>0.16</td>
<td>0.03</td>
</tr>
<tr>
<td>3-4 mm</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>4-5 mm</td>
<td>0.13</td>
<td>0.06</td>
</tr>
<tr>
<td>5-7 mm</td>
<td>0.18</td>
<td>0.06</td>
</tr>
<tr>
<td>7-9 mm</td>
<td>0.27</td>
<td>0.05</td>
</tr>
<tr>
<td>9-11 mm</td>
<td>0.19</td>
<td>0.06</td>
</tr>
<tr>
<td>11-13 mm</td>
<td>0.16</td>
<td>0.03</td>
</tr>
<tr>
<td>Mean</td>
<td>0.18</td>
<td>0.03</td>
</tr>
</tbody>
</table>
tially. Although in the coronal and middle thirds of the root canal the objective is to remove the inner layer of dentin so that the outline of the prepared root canal wall reflects the original outline, the apical few millimeters the objective must be to enlarge the canal to a suitable size permitting adequate debridement. It should also obtain a circular shape that permits manipulation and control over filling materials and instruments, so that the tightest seal can be achieved with current root canal filling techniques. These objectives are more difficult to achieved in complex anatomic spaces such as oval canals, in which the apical portion should be enlarged to at least the maximum canal diameter, which normally is the BL diameter. However, this will also increase the diameter of the canal in the MD direction, thereby reducing wall thickness. The results of the present study show that a circular preparation would require instruments of a size that may perforate or significantly weaken the root. Nevertheless, larger apical shaping, as has been frequently demonstrated, promotes cleaner apical preparations and a reduction in bacteria count.

The results of the present study demonstrated that premolar root canals become more oval toward the coronal aspect, because the level of section considered had a positive impact on ΔC (std. β = 0.471; P < .0001). This is underscored by the fact that the taper in the MD direction is much lower than in the BL direction. This, too, has been confirmed by earlier investigations. The data of Table III show that the mean BL taper was greater than in the MD: 0.18 and 0.03 mm/mm, respectively. These values demonstrate that the mean MD taper matches the taper commonly found in NiTi rotary systems (.06), whereas the taper in the BL direction differs, especially for the middle and coronal portion of the root canal. This implies that, if one is to obtain a circumferential root canal preparation, instruments should be used with a lateral brushing action, thus optimizing the efficacy while preserving maximum dentin thickness and enhancing cleaning of buccal and lingual recesses. Furthermore, a recent study has shown that nickel-titanium rotary instruments can be safely used in a brushing motion.

Because there is an appreciable loss of dentin during root canal preparation and post space preparation, attention must be directed to roots with a minimum diameter. The measurements reported here of the narrowest MD root canal width are in accordance with those of an earlier study that reported measurements at cervical, middle, and apical levels. They are also similar or slightly larger than those reported by Kerekes and Tronstad at 1, 2, 3, and 5 mm from the root apex. Furthermore, a mostly mesiodistally flat root shape has also been reported.

The results of the present study demonstrated that at all levels the mesial and distal wall thickness was less than the buccal and lingual. This was confirmed by the multivariate linear regression (buccal location: std. β = 0.390; P < .0001; lingual location: std. β = 0.541; P < .0001). In many sections, the dentin was very thin. This observation is in accordance with Pilo et al., and Pilo and Tamse, and Bellucci and Perrini who reported wall thickness values in MD and BL direction corresponding to those reported in the present investigation. It was demonstrated that the mesial and distal wall thickness was similar according to the collinearity of the statistical model. This is in agreement with Pilo et al., Pilo and Tamse, and Bellucci and Perrini; however, the lingual wall thickness was slightly greater than the buccal, also in accordance with Bellucci and Perrini. In contrast, Pilo et al. and Pilo and Tamse observed a similarity in buccal and lingual thickness, which justified the grouping of these measurements. Regardless of the fact that for part of the root the wall thickness increases toward the coronal aspect (level of section: std. β = 0.652; P < 0.0001), it is preferable, when preparing a post space in teeth with noncircular anatomy, to use an instrument that can maintain the original anatomy of the root canal, thus removing as little dentin as possible. It is not recommended to adapt the shape of the canal to the post, which requires the unnecessary sacrifice of sound dentin, but rather to follow the anatomy of the radicular canal by designing flattened posts in an MD direction, thus preserving maximum dentin thickness. The dentin should be removed from the buccal and lingual walls where the thickness is greater. This also reduces the risk of weakening or perforating a root. Furthermore, it has been reported that radiographic evaluation of the residual dentin thickness during preparation of the post space can be misleading, owing to the inaccuracy of radiographic interpretation. Overestimation may lead to overpreparation of the canal or to root perforation.

CONCLUSIONS

Within the limitations of the study, the results from this MCT analysis confirm the frequent presence of an oval canal, including in the last few apical millimeters of the root canals. The results also demonstrated that canals at 1 mm from the apex are larger than the smallest diameter of 0.30 mm and greater than the largest diameter of 0.40 mm. The data confirm the suggestion to reconsider the preparation diameters when cleaning the apical third of oval root canals. Furthermore, a high correlation could be established between the shape of the root canal and the corresponding root.
REFERENCES
44. Rollison S, Barnett F, Stevens R. Efficacy of bacterial removal from instrumented root canals in vitro related to instrumentation...