# Extended apical enlargement with hand files versus rotary NiTi files. Part II

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***Objective.*** The objective of this study was to compare 2 preparation techniques performed under simulated clinical conditions with extended apical enlargement following determination of the optimal apical preparation size (APS).

***Study design.*** After preflaring 240 root canals, APS was evaluated as outlined in Part I. The apical portion was shaped to APS either with rotary NiTi Lightspeed instruments (LS) or NiTi hand instruments (HA) using the balanced force technique in a phantom head. After sectioning the apical area at 3 levels, every cross section was analyzed microscopically for circumferential removal of canal wall dentine. Loss of working length, instrument separation, and perforation were additionally recorded.

***Results.*** In 70% (LS) and 69% (HA) of the root canals, 2 of 3 levels demonstrated that the root canal dentin was cut circumferentially. Neither loss of working length nor perforation occurred in both groups. Four LS instruments separated.

***Conclusions.*** APS frequently results in a nearly complete apical preparation regardless of the preparation techniques. In a few cases apical enlargement to APS does not achieve complete cutting of the canal walls. There was a rather slight risk of serious procedural errors. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102:692-7)**

A primary goal of root canal treatment is to completely clean and shape the root canal system. The path of the original root canal should be maintained and the dentin on the root canal wall should be cut circumferentially so that the outline of the prepared root canal wall reflects the original outline. As stated in a recent review,[2] a challenging issue in root canal shaping is the selection of preparation sizes.

It is expected of modern engine-driven rotary root canal instruments made of nickel-titanium (NiTi) that they allow preparation of even severely curved root canals. Procedural errors such as loss of working length, instrument separation, and canal transportation documented as straightening of the root canal, zip or elbow formation, strip perforation, and excessive weakening of the root were reported to be rather infrequent when root canals of extracted teeth were shaped with rotary NiTi instruments.[3-5] Although the number of clinical studies using rotary NiTi is limited so far, Lightspeed and ProFile instruments were recently reported to be successfully used to a minimum apical size #40 (Lightspeed) or #35 (ProFile).[6] This was in line with the results of Ramirez-Salomon et al.,[7] who demonstrated a low fracture rate when using Lightspeed instruments in curved root canals apically instrumented to at least size #45.

In Part I of the present study the guidelines for the apical enlargement were already presented.[1] The concept provides for an individual apical preparation size that is determined by sizing the smallest most apical canal diameter. Part II was initiated to check whether this concept can be achieved using NiTi instruments under simulated clinical conditions. For this purpose, 2 instrumentation techniques using either NiTi hand files or rotary Lightspeed instruments were compared. The hypothesis was that the Lightspeed instruments allowed wide apical preparation sizes due to their special design resulting in complete circumferential cutting of canal wall dentin without procedural incidents and that they were superior to the NiTi hand files. To limit the impact of the tooth anatomy as one ever-present risk factor[2] a large number of canals of one tooth type should be subjected to apical gauging and root canal preparation.

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Received for publication Nov 17, 2005; returned for revision Nov 17, 2005; accepted for publication Nov 17, 2005.
1079-2104/$ - see front matter

doi:10.1016/j.tripleo.2005.11.014

## MATERIALS AND METHODS

### Tooth selection

Included in the study were intact extracted maxillary and mandibular human molars with fully formed roots and without any visible signs of external resorption. None of these teeth experienced prior root canal treatment. Eighty molars with a total of 246 root canals were selected. Six root canals that could not be negotiated to the apical foramen had to be excluded. The second mesio-buccal canal of upper molars was excluded. The teeth were stored in 0.1% chlorhexidine.

### Preparation of the teeth

Caries and restorations were removed when present. The cusps of the molars were levelled to exactly define the occlusal reference point. Preoperative radiographs were taken to estimate the root canal length and to register the extent of root canal curvature. The teeth were accessed and the pulp removed. The root canals were negotiated with a size #06 hand file and irrigated with 1% sodium hypochlorite. The reference length of the root canal ($l_{ref}$) was measured by inserting a #06 hand file into the root canal until the file tip was just visible at the apical foramen. The distance between the tip of the file and the occlusal reference plane was defined as $l_{ref}$.

The root canals were instrumented applying a hybrid concept.[8] Flaring of the coronal and middle third of the root canals was done with rotary 0.06-mm/mm tapered NiTi instruments (HERO 642, MicroMega, Besançon, France) using a crown-down approach to eliminate all interferences cervical of the apical region. The sequence of instruments was as follows:

- Mesio-buccal, mesio-lingual, and disto-buccal canals: Gates-Glidden burs size #2 to #3 for the cervical third followed by 0.06 mm/mm tapered HERO #20 for the middle third.
- Distal and palatal canals: Gates-Glidden burs #2 to #4 for the cervical thirds followed by a 0.06-mm/mm tapered HERO size #20 and size #30 for the middle third.

The HERO instruments were used in a circumferential fashion in oval canals. The root canals were intermittently irrigated with 1% sodium hypochlorite. The apical thirds (about 4 mm in length) were left unprepared.

After preflaring was completed, instruments (SI) specifically designed to individually gauge the apical canal diameter were available as described in Part I.[1] In brief, the SI was inserted passively into the root canal until the working length was reached. Care was taken to avoid any force during sizing. The largest SI with which some resistance had to be overcome to reach the most apical region was recorded within the range of 1 mm. The diameter of SI ($d_{SI}$) was the basis for calculating the minimum apical preparation size (APS) as outlined in detail in Part I.[1]

- For distal/palatal canals: $APS = d_{SI} + 0.40$ mm
- For mesio-buccal/mesiolingual/disto-buccal canals: $APS = d_{SI} + 0.30$ mm

### Apical preparation

The 80 molars were assigned to 2 groups after having balanced them with regard to the parameters "APS" and "root canal curvature" measured on the basis of the Schneider angle. Each group consisted of 40 teeth with 120 root canals. Apical enlargements were done using the engine-driven rotary Lightspeed instruments in group LS (Lightspeed instrumentation group). NiTi hand files were applied using the balanced-force technique in group HA (hand instrumentation group).

The root canal preparations were performed under simulated clinical conditions. For this purpose the embedded tooth was integrated in a dental model. This model and an opposite model with antagonists were mounted into the phantom head with an inter-occlusal distance of approximately 3 cm in the molar region. All root canals were prepared by one dentist (T.B.) with 4 years of endodontic experience, but without having used any of the shaping techniques routinely. During an initial training phase the 2 techniques were first (theoretically) explained by an experienced user of LS instruments and then practiced on 40 root canals of extracted teeth.

*Hand instrumentation (HA).* The apical portion was prepared using exclusively NiTi handfiles with a 0.02-mm/mm taper (NiTiflex, Dentsply-Maillefer, Ballaigues, Switzerland). Starting with a file size #8 or #10, the canal was shaped to working length ($WL = l_{ref} - 1$mm) using the balanced-force technique.[9] The instrument was inserted into the canal with slight apical pressure and simultaneous 90° to 120° clockwise rotation. Dentine cutting was then achieved by rotating the instrument up to 180° counterclockwise with simultaneous (stronger) apical pressure. Afterward the file was removed from the root canal and before inserting it again the dentine shavings were removed. If necessary, these working sequences were repeated until WL was easily reached. The preparation continued with the next instrument in the sequence until APS was reached with master apical file. Half-size files were additionally used for narrow or severely curved canals. The apical preparation was completed by stepping back in 1-mm steps. The root canal was irrigated with 1 mL NaOCl (1%) after every second instrument.

*Lightspeed instrumentation (LS).* The LS instruments were run by a cordless battery-operated hand-

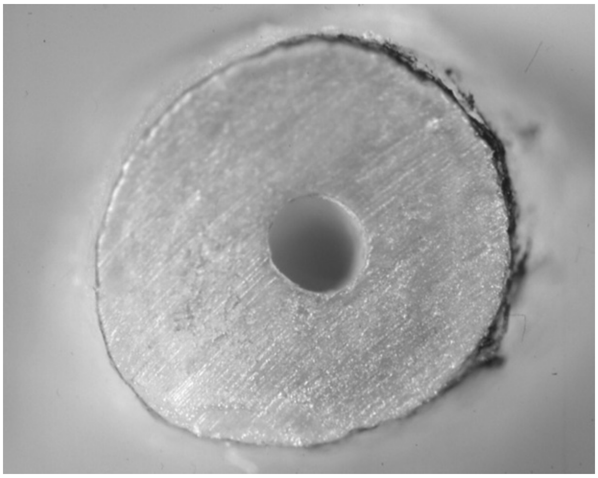

Fig. 1. Cross-section showing a root canal that was circumferentially cut by rotary Lightspeed instruments.

piece without torque control (Taskal, NSK, Tokyo, Japan) at a constant speed of about 1000 rpm. Apical preparation began with a LS instrument size #20 to working length and was continued up to APS using every half size. The apical third of the root canal was prepared by stepping back 1 mm, 2 mm, 3 mm, and 4 mm from WL with sequentially larger LS instruments. After every second LS instrument the root canal was irrigated with 1 mL NaOCl (1%). Root canal preparation was completed by recapitulation with the master apical rotary to WL.

The LS instruments and NiTi hand files were discarded after preparation of 10 canals.

### Sectioning and microscopic analysis

The roots were carefully sectioned at $l_{ref} - 1$ mm, $l_{ref} - 2$ mm and $l_{ref} - 3$ mm by a rotating diamond disc positioned perpendicular to the root canal, and prepared for microscopic analysis. Each cross-section was rinsed with saline and then stained with a fuchsin solution to highlight the contours of the root canal. All cross-sections were examined under the light microscope at ×14.4 magnification (Makroskop, Leica, Benzheim, Germany) and photographed. The slides were independently analyzed by two examiners (R.W., T.B.). One examiner (R.W.) was blinded, whereas the seconded one knew the code of the cross-sections. The criterion was whether the inner layer of dentin wall was circumferentially cut by the instrument or not. A preparation was considered "complete" when the contours of the root canal wall appeared sharp, rounded, and even without irregularities (Fig. 1). When anastomoses were visible between 2 root canals, e.g., in the mesial root of a lower molar, these canal segments were excluded from the analysis. In case of an incomplete preparation, the portion of the canal wall that had been cut was measured, related to the total length of the canal wall, and expressed in percent. In addition, the width of the canal wall was measured to the nearest of 0.1 mm. When apical preparation resulted in a canal wall thickness of less than 0.5 mm (i.e., ≤ 0.4 mm when measured to the nearest mm) at any site, cross-sections were categorized as "weakened canal wall" and the instrumentation as "overprepared."

### Statistical analysis

For comparison, the following parameters were recorded for the 3 groups:

- Complete circumferential apical preparation (CAP)
- Loss of WL
- Incidence of fractured instruments
- Apical perforation

The interexaminer agreement was evaluated for CAP by calculation of the kappa (κ) coefficient for every section level. A joint decision was taken in cases with a different evaluation. The percentage of cross-sections with CAP was calculated along with the corresponding 95% confidence interval in relation to section level and root canal. Overlapping confidence intervals indicate that there is a statistically significant difference.

## RESULTS

Both groups were balanced with regard to the variables "root canal curvature" and "APS." The mean diameter of the master apical file or master apical rotary used to reach APS varied between 0.45 mm and 0.48 mm for the mesio-buccal, disto-buccal, and mesio-lingual canals and between 0.62 mm and 0.67 mm for the distal and palatal canals, respectively (Table I). As 4 LS instruments separated in the LS group, a total of 116 root canals were finally sectioned and analyzed. No attempt was made to remove or bypass the LS cutting heads, all of which fractured in the apical part of the root canal. In the HA group, preparations could be completed without any instrument separation. Neither loss of working length nor perforation were noted in both groups.

The kappa values for CAP ranged from 0.62 to 0.88 indicating "good" to "very good" agreement between the 2 evaluators. The percentage of cross-sections with CAP depended on the sectioning level (Table II). CAP was recorded in 70% to 78% of the cross-sections at the 2-mm and 3-mm levels in both groups compared to 45% (LS) and 57% (HA) at the most apical level. The overlapping 95% confidence intervals indicated that there were no significant differences between the test groups with regard to CAP. Table III shows the per-

**Table I.** Mean apical preparation size (APS) dependent on the type of root canal

| | *Lower molar* | | | | | *Upper molar* | | |
|---|---|---|---|---|---|---|---|---|
| *APS* | *dis* | *mb* | *ml* | *db* | *dl* | *pal* | *mb* | *db* |
| n | 34 | 39 | 39 | 7 | 7 | 36 | 37 | 36 |
| mean [ISO] | 61.6 | 46.8 | 45.0 | 55.0 | 54.3 | 67.2 | 48.2 | 48.3 |
| 10th percentile | 52.5 | 42.5 | 40.0 | 52.5 | 50.0 | 59.3 | 44.5 | 44.3 |
| 90th percentile | 75.0 | 55.0 | 50.0 | 60.0 | 60.0 | 76.5 | 55.0 | 55.0 |

*n,* number of treated root canals; *db,* distobuccal; *dl,* distolingual; *dis,* distal; *mb,* mesiobuccal; *ml,* mesiolingual; *pal,* palatal.

**Table II.** Percentage of root sections demonstrating complete apical preparation (CAP) at different section levels (95% confidence interval)

| *CAP* | *LS group, %* | *HA group, %* |
|---|---|---|
| 1-mm level | 45 (36; 54) | 57 (49; 66) |
| 2-mm level | 70 (61; 78) | 73 (65; 81) |
| 3-mm level | 78 (70; 85) | 72 (64; 80) |

*LS,* Lightspeed instrumentation; *HA,* hand instrumentation.

**Table III.** Percentage of root canals demonstrating complete apical preparation (CAP) at the 3 evaluated levels or at least at 2 levels or 1 single level (95% confidence interval)

| *CAP* | *LS group, %* | *HA group, %* |
|---|---|---|
| At all levels | 35 (27; 44) | 44 (37; 53) |
| At 2 or 3 levels | 70 (62; 79) | 69 (61; 78) |
| At 1, 2, or 3 levels | 86 (80; 92) | 88 (83; 94) |

*LS,* Lightspeed instrumentation; *HA,* hand instrumentation.

centage of root canals associated with 3 cross-sections with CAP or less in each group. In the cross-sections without CAP the canal walls have been cut to at least 66% (1-mm level) or 75% (2-mm level and 3-mm level). Weakened canal walls were observed in 10.0% (1-mm level), 7.6% (2-mm level), and 6.8% (3-mm level).

## DISCUSSION

An essential prerequisite for transferring the results of root canal preparation techniques to daily practice is the simulation of clinical conditions under which root canal treatment is performed. So far there are only a few experimental studies available comparing actual rotary instruments in clinical situations that render the instrumentation of curved root canals more difficult.[3,10]

Other important variables having an impact on the evaluated parameter are "root canal curvature" and "the smallest canal diameter" gauged at the most apical region as it is suggested that both parameters have an impact on the instrumentation results. In this study an attempt was made to balance the test groups with respect to these variables. The fact that root canal anatomy of molars is variable in nature and presents a risk factor per se was considered by a large sample size of 120 per group. Half of the root canals were severely curved with an angle of 20° or more. Even when the radius of the curvature was not measured, only a few canals showed an acute curve. The "smallest" most apical canal diameter ranged between 0.125 mm and 0.20 mm in about two thirds of the cases.

Analyzing root canal contours after root canal instrumentation requires cross-sections that are perpendicular to a tangent, which meets a defined point of the curvature as done in the present study. In case the cutting plane is chosen only vertical to the axis of the root or the embedded tooth, then in the curved part a round root canal appears oval in the cross-section. In those cases the extent of the geometric distortion depends in the end on the actual root canal curvature. By contrast, the Bramante technique,[11] which would allow the evaluation of the cross-sections before and after canal preparation, was not applied as reassembling the apical portion following sectioning at 3 levels with a small distance of 1 mm would alter the apical root canal anatomy and influence the preparation results. A noninvasive technique such as micro-computed tomography would overcome these shortcomings and allow 3-dimensional visualization of the apical area.[6] However, this method is time consuming and expensive, particularly when analyzing such a high number of root canals.

A cross-section was categorized "CAP" when the contours of the root canal wall were sharp, rounded, and even without visible irregularities. Although the authors are aware that this method is a rather rough measure, it is to be expected that a rotary instrument or a file used in a rotating action left a sharp and even contour in the canal wall like a drill. Experimental studies assessing cross-sections of shaped root canals confirmed this observation.[3-5,10,12] Undoubtedly, the method applied in this study did not provide reliable data with regard to the amount of root dentin removed.

Root canal preparations were carried out by a dentist with limited experience in using rotary instruments. Consequently, the results reflect the potential of the applied instrumentation techniques when applied by a novice after attending a continuing education course and practicing on extracted teeth.

Within these limitations it was demonstrated that under simulation of the clinical situation moderately and severely curved root canals could be prepared apically to individually determined sizes exceeding size #45. Loss of working length and apical perforation were not observed in both groups, disproving our hypothesis initially stated. Surprisingly, apical preparation by hand files was completed without instrument fracture whereas 4 LS instruments (3.4%) separated between the shaft and the cutting head, 2 of them in canals with an acute curve (78°). A more experienced clinician and the use of a torque-controlled motor might help to avoid these mishaps. Nevertheless, the fracture rate was in line with that reported in other investigations, ranging from 0% to 10% in severely curved canals prepared with apical sizes of #40 or #45.[4,7,10,12] Also, the present results underlined the potential of the balanced-force technique in combination with NiTi hand files.[13] It appears that for curved root canals, Lightspeed instruments are far more suitable than rotary NiTi instruments with a long cutting edge and a taper greater than 0.02 mm/mm for extended apical enlargement due to their unique flexibility, which is size-dependent, and their short cutting head.[14]

The APS, to which the canals were shaped, ranged from size #40 to #55 for most of the "more difficult" canals and from size #52.5 to #80 for the distal and palatal canals of molars. This is well in agreement with the results of Part I of the study.[1] When considering the parameter CAP, there were differences between the most apical level and the 2-mm and 3-mm levels regardless of the instrumentation technique. At the 1-mm level, the lower incidence of CAP might be due to the tip design of the instruments used. The noncutting pilot tip of both instrument types was likely to be responsible for apical areas being incompletely cut at the 1-mm level, which represented the apical endpoint of the preparation. This might be avoided by using Lightspeed instruments to the radiographic apex instead of protruding them 1 mm short of it, especially when considering that LS instruments beginning with size #32.5 have a long noncutting tip of 1.25 mm. By contrast, CAP was registered in 70% to 80% at the 2-mm and 3-mm levels as a result of the wide APS and the step-back technique. Hence, the percentage of root canals with 2 or 3 cross-sections with CAP amounted to approximately 70% in both groups. The manufacturer of the Lightspeed instruments advocates a technique of doing a defined number of pecks with the Lightspeed instruments. As there are no studies related to this issue, the question if comparable preparation results may be achieved remains unanswered for the moment. Also, this technique is recommended for shaping the entire length of the root canal and is not focused on the apical area of the root canal.

When calculating an approximate average value for every single root canal, the master apical instrument reached more than 80% of the canal wall at the 1-mm level (LS 82% and HA 87%) and more than 90% at the 2-mm (LS 93% and HA 93%) and 3-mm (LS 94% and HA 93%) levels. This calculation considers not only the cross-sections with CAP but also the cross-sections without CAP. In the latter specimens, the dentin walls were cut to 66% (1-mm level) and 75% (2-mm and 3-mm levels) or more (data not shown). From other investigations[2,10,15] it became evident that root canals were shaped circumferentially to 60% to 80% or less of the canal outlines. This might be explained by the apical preparation sizes of ISO #40 or #45 being lower on average than those in the present study.

Apical shaping with rotating instruments having a large diameter, however, may weaken the root structure. Although no apical perforation occurred, "over-prepared" root canals were recorded in 7% to 10%. This was particularly true for canals with an oval or flat cross-section in the most apical part. Also, from a microbiological point of view there are no valid data on the amount of dentine that should be removed in cases with root canal wall infection to promote apical healing or prevent the formation of an apical lesion.

## CONCLUSIONS

Both preparation techniques allow a wide apical preparation with a rather slight risk of procedural errors in molars. The individually determined APS frequently results in complete apical preparation in the majority of the cross-sections. However, in a few cases even a wide apical enlargement does not ascertain complete cutting of canal walls.

Acknowledgment

The authors thank Carmen Buckley for correcting and editing the manuscript.

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