

An *in vitro* comparison of different techniques for glide path preparation

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ABSTRACT

Introduction: The study compared modification of canal curvature and the incidence of canal aberrations after glide path preparation using four different instrumentation techniques.

Methods: One hundred and twenty S-shaped Endo-Training-Blocks were selected, the canals coloured with ink and digital images acquired. Glide paths were prepared by a single operator with stainless steel K-files by hand (Group 1), stainless steel K-files in a reciprocating hand piece (Group 2), PathFile (Group 3) and X-Plorer files (Group 4). Pre-instrumentation and post-instrumentation images were superimposed to evaluate the parameters investigated. The images were also examined by three blinded operators for the presence of aberrations. Differences in canal curvature modification were analysed with respect to logarithmic transformed change from baseline using ANCOVA ($p<0.001$) with logarithmic transformed pre-instrumentation values as covariate. The incidence of canal aberrations was analyzed using Fisher's exact test ($p<0.05$).

Results: There was no difference between PathFiles and X-Plorer files ($p<0.001$) and both systems demonstrated significantly less modification of curvature compared with hand files and hand files in a reciprocating hand-piece ($p<0.001$). The Groups differed significantly regarding the number of aberrations ($p=0.005$). Hand files and hand files in the reciprocating hand piece did not differ statistically ($p=0.254$; 20% and 6.67%). However, hand files in reciprocating hand piece also did not differ significantly from PathFiles and X-Plorer files ($p=0.326$). There were no aberrations detected in the rotary NiTi Groups.

Conclusion: The stainless steel K-files in the reciprocating hand-piece performed better than their use by hand only. Overall, PathFiles and X-Plorer files equally demonstrated the least modification to original canal geometry. Further

research utilising the different techniques in extracted teeth is warranted.

Keywords: Glide path, reciprocation, PathFile, X-Plorer File

INTRODUCTION

A glide path has been defined as a smooth passage from the orifice to the apical foramen.¹ It is a refinement of the original canal anatomy, which allows a safer passage of mechanical shaping instruments. The preparation of a glide path has been shown to reduce separation and torsional stress of rotary nickel-titanium (NiTi) instruments even during the preparation of constricted root canals.²⁻⁴ Several techniques have been proposed for preparation of a glide path viz. stainless steel K-files manually¹; stainless steel K-files in the M4 reciprocating hand piece (Axis/SybronEndo, Coppel, Texas),⁵ and small hand files followed by rotary NiTi glide path instruments.^{6,7}

PathFile Ni-Ti rotary files (Dentsply Maillefer, Ballaigues, Switzerland), have a square cross section and a 2% taper, which makes them resistant to cyclic fatigue, ensures flexibility and improves cutting efficiency. The tip angle is 50 degrees and is non-cutting, which reduces the risk of ledge formation. PathFile No.1 (purple) has an ISO 13 tip size, PathFile No.2 (white) has an ISO 16 tip size and PathFile No.3 (yellow) has an ISO 19 tip size. The gradual increase in tip size facilitates progression of the files.⁶

The X-Plorer Ni-Ti glide path preparation system (Clinician's Choice Dental Products Inc., New Milford, USA) was recently introduced and consists of three instruments. The first X-PLORER file has an ISO 15 tip size and a 1% taper with a triangular cross section. The second file has an ISO 20 tip size with a 1% taper and the third file has an ISO 20 tip size with a 2% taper. Both these instruments have a square cross section. The files have cutting blades in the apical 10mm, reducing lateral engagement with the canal walls.^{5,11}

The M4 Safety reciprocating hand piece (SybronEndo, Coppel, Texas) is a contra angle that fits onto any E type slow speed hand piece connection. The reciprocating angle of the hand piece is 30 degrees, which replicates the watch winding, oscillating movement of hand instrumentation in an efficient manner.⁵ The technique involves negotiating a small size K-file to length before attaching the hand piece to the file. The hand piece is then moved vertically up and down, with an amplitude of 1mm to 3mm and bursts of reciprocation for approximately 15 to 30 seconds in the canal.

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Several NiTi glide path systems have been investigated and compared with the use of stainless steel K-files by hand for glide path preparation.⁶⁻¹⁰ However, there are no studies comparing the performance of these instruments with other techniques of glide path preparation. Furthermore, no studies have investigated the effect on curvature when stainless steel K-files are used in a reciprocating hand piece for glide path preparation.

The aim of this *in vitro* study was to compare the performances of stainless steel K-files used manually, stainless steel K-files used mechanically in the M4 reciprocating hand piece, PathFiles and X-Plorer files with respect to percentage change in canal curvature and the occurrence of aberrations during glide path preparation. The null hypothesis was that there would be no statistical differences between the techniques investigated.

MATERIALS AND METHODS

The materials and methods were similar to those employed by Berutti *et al.*⁶ One hundred and twenty ISO 15, 0.02-tapered, S-shaped Endo Training Blocks (Dentsply Maillefer) were used. Each simulated canal was injected with India ink using a syringe. To facilitate superimposition of pre-instrumentation and post-instrumentation images, three bur landmarks were placed in each resin block using a template to ensure uniformity. Specimens were randomly assigned to four different Groups (n=30). Each specimen was mounted in a template on a microscope stage and photographed at right angles to the S-shaped canal using a Leica M165C stereo microscope at 10x magnification with a CCD camera (Leica Microsystems, Heerbrugg, Switzerland).

In Group 1, the glide paths were prepared by hand using stainless steel K-files (VDW, Munich, Germany), in a sequence from size 08, through 10 and 15 to size 20. The files were used in a quarter turn and pull motion until each file reached working length before selecting the next size.

In Group 2, the glide paths were prepared using stainless steel K-files (VDW, Munich, Germany) in the sequence of sizes 08-10-15-20 in the M4 Safety (SybronEndo) reciprocating hand piece (30 degree reciprocation) driven by the TCM III (SybronEndo) electric motor at 900 rpm at the 18:1 setting.

In Group 3, the initial glide paths were first prepared by hand, using stainless steel K-files (VDW) sizes 08 and 10 before the glide paths were enlarged using the Path-File rotary instruments nos. 1, 2 and 3.

In Group 4, the initial glide paths were first prepared by hand, using stainless steel K-files (VDW) sizes 08 and 10 before the glide paths were enlarged using the three X-Plorer files (Clinician's Choice Dental Products Inc).

All hand files were pre-curved 4mm from the tip. The rotary PathFiles and X-Plorer files were used in an endodontic hand piece (X-Smart Plus, Dentsply Maillefer) operating at 300 rpm, and at 4Ncm torque.

After glide path preparation the specimens were replaced in the photographic template and post-instrumentation images were acquired and saved as TIFF format files.

The images of pre-instrumentation and post-instrumentation blocks were used to evaluate the changes in the apical and coronal curvature as a result of glide path preparation. Rhinoceros Software (version .4.0; Robert McNeel & Associates, Seattle, WA) was used to identify and evaluate the following: (1) the mean axis of canal; (2) the reference points corresponding to the initial and end points of the two main curves of the canal; and (3) the apical and coronal radii of curvature using best fitting with circles of known radii.

The images were cropped and magnified to highlight the canal geometry. The image of each canal was used to identify its mean axis. Starting at the apex, 32 points were identified along the canal at 0.25 mm intervals, each point corresponding to the centre of the canal cross-section. These points were used as control points for the construction of a Bezier curve approximating the mean axis of the canal. A visual comparison between the canal geometry and the Bezier curve could reveal any errors in the tracing of the mean axis of the canal. The Bezier curve was analysed to evaluate the curvature, which was in general continuously variable along the axis (Figure 1a). The site of curvature change (null curvature) was taken as the flexus in the passage between the apical and the proximal curvatures of the canal and, as a consequence, as one of the reference points to be taken into consideration for quantitative curvature evaluation. The canal apex, the point of curvature change between the extremities, and the first proximal point of the canal having null curvature were selected for each canal to quantitatively evaluate the mean apical and proximal curvature by best fitting with circles of different radii (Figure 1b).

The change in radius of curvature from baseline (pre-instrumentation) and after instrumentation was expressed as a percentage using the formula: $\{(\text{post-instrumentation radius} - \text{pre-instrumentation radius}) / \text{pre-instrumentation radius} \} \times 100$. The lower the percentage, the less the change to initial canal anatomy, whilst a higher percentage meant a greater change. This constituted the quantitative assessment.

Using the bur marks as indices, the photographs after preparation were superimposed onto the pre-instrumentation photographs before glide path preparation using Adobe Photoshop Digital Software (Adobe Systems Inc,

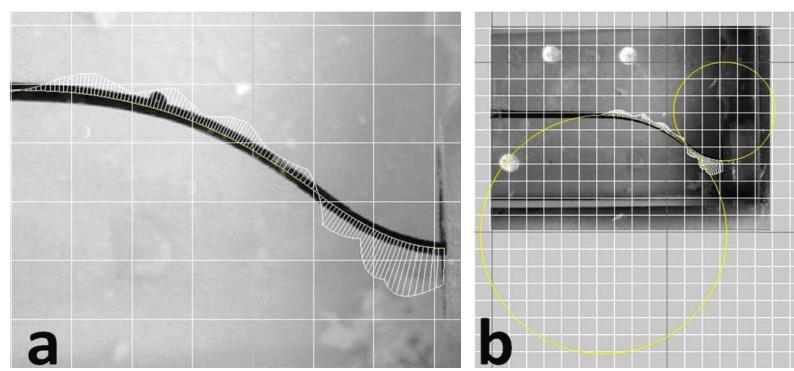


Figure 1: (a) The curvature analysis (white) of the Bezier curve showing the end points of the curve and the point of curvature change of the apical and coronal curves; (b) Determining the mean radius of apical and coronal curvature using best-fit circle circumferences (yellow) after evaluating the endpoints of the curves (white).

San Jose, CA) (Figure 2). The paired images were imported into a Microsoft Office PowerPoint presentation (Microsoft Corporation, Redmond, WA).

Three calibrated, blinded examiners independently assessed the canals after glide path preparation for aberrations in canal anatomy (ledging, zipping and elbows) and for any deviation from the original following the approach described by Thompson and Dummer.¹² This constituted the qualitative assessment.

Statistical analyses were performed with StataCorp.2009 (Stata: Release 11.) software package (Statistical Software. College Station, TX: Statacorp LP). The Shapiro-Wilk test for normality of change from baseline was significant both for apical ($p<0.001$) and for coronal ($p<0.001$) radii overall. After logarithmic transformation for change from baseline, the Shapiro-Wilk test for normality was not significant for any of the prepared (post- instrumentation) Groups, both for apical and coronal curvature change.

Prepared Groups were then compared with respect to logarithmic transformed change from baseline using analysis of covariance (ANCOVA) with logarithmic transformed pre-instrumentation values as covariate. As confirmation, an ANCOVA for ranks was also performed. The point and interval estimates for both apical and coronal radii employed the geometric mean and its 95% confidence interval. After establishing preparation differences, both for change from baseline (pre-instrumentation) for apical and coronal curves, specific differences were tested using Fisher's LSD for pairwise comparisons.

Post-instrumentation Groups were compared with respect to the presence of aberrations using Fisher's exact test. Testing was done at the 0.05 level of significance.

RESULTS

Change to Curvature

The results relating to change in curvature are summarized in Table 1. The geometric mean and 95% confidence intervals for coronal and apical curves are shown in Tables 2 and 3 respectively. The ANCOVA test showed that Group 1 (Hand K-files) and Group 2 (M4 hand piece) differed significantly from the other Groups ($p<0.001$). Group 3 (PathFiles) and Group 4 (X-Plorer files) did not differ significantly from each other and were also superior to the other Groups ($p <0.001$).

Canal Aberrations

There were no differences in the assessments of the images by the three calibrated blinded examiners. There was a higher incidence of ledges (3), elbows (2) and apical zips(1) for Group 1 compared with all the other Groups. The only other Group that showed evidence of ledge formation was Group 2 (2 ledges).

With respect to the number of aberrations, Group 1 was statistically different from Group 3 and Group 4 ($p=0.005$).

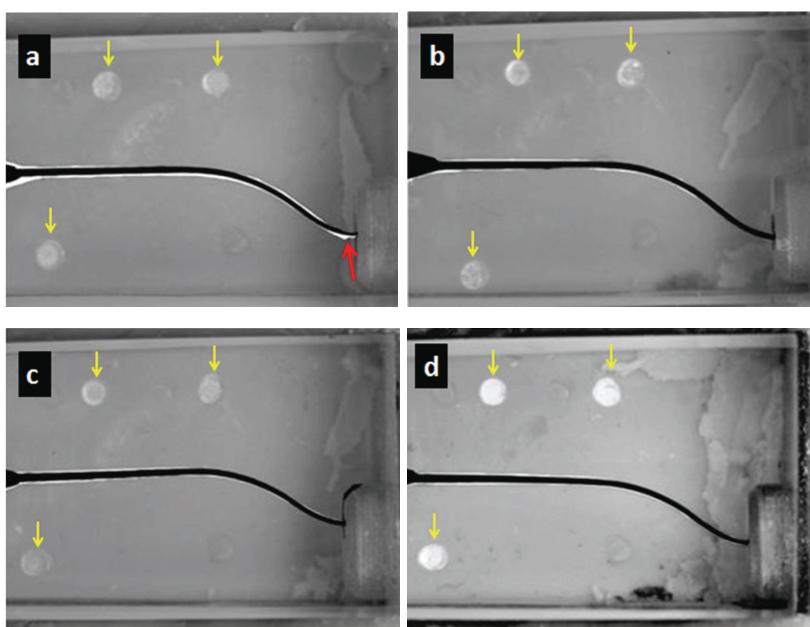


Figure 2: Representative super-imposed pre-instrumentation and post-instrumentation images using the bur landmarks (yellow arrows) on the plastic blocks. **(a)** Group 1: Hand K-files Group, showing the presence of a ledge (red arrow). **(b)** Group 2: Hand K-files in the M4 Safety reciprocating hand piece - no visible canal aberration. **(c)** Group 3: Hand K-files and PathFiles - no visible canal aberration. **(d)** Group 4: Hand K-files and X-Plorer files - no visible canal aberration.

Group 1 and Group 2 did not differ statistically ($p=0.254$; 20% and 6.67%), and neither did Group 2 differ significantly from Group 3 and Group 4 ($p=0.326$). There was no significant difference between Group 3 and Group 4.

DISCUSSION

Simulated canals have been widely used to investigate instrumentation techniques and the shaping ability of endodontic instruments.^{6,13} They were used in this study to standardize experimental conditions.¹⁴ S-shaped simulated canals were selected because of the inherent difficulty in shaping a canal with more than one curvature along its length without causing aberrations.^{6,7,15,16} This model also serves to highlight any differences in the performance of instruments.^{13,17}

The first part of the study used a quantitative analysis through observation of changes between pre-instrumentation and post- instrumentation curvatures. The stainless steel K-files in the M4 safety reciprocating hand piece performed better in maintaining the canal curvature compared with their use by hand only. The improved performance of the stainless steel K-files in the reciprocating hand piece could be attributed to the smaller arc of reciprocation of the hand piece (30 degrees) compared with the quarter turn-and-pull motion employed during hand filing (90 degrees).

The two NiTi rotary systems that were used for glide path preparation performed significantly better than the above-mentioned Groups. No significant differences between the PathFile and X-Plorer file systems were observed, even though their design characteristics differ. Therefore, under the present study conditions, it might be assumed that these instruments have more fidelity in adhering to the original canal anatomy, as shown in Figure 2. The findings of the present study were in agreement with previous studies which showed that NiTi glide path instruments caused less modification to canal curvature when compared with the effects of stainless steel hand instruments.^{6,7,9} Since the flexibility of an endodontic file may influence its ability to

Table 1: Coronal and apical curves: Descriptive statistics of the radii of curvature (mm) and their change (%) after glide path preparation

| Group | Group 1: Hand K-Files (control) | | | Group 2: Hand K-files in M4 Safety reciprocating hand piece | | | Group 3: Hand K-files and PathFiles | | | Group 4: Hand K-files and X-Plorer files | | |
|----------------|---------------------------------|--------|--------|---|-------|--------|-------------------------------------|--------|-------|--|--------|-------|
| | Pre | Post | %Ch | Pre | Post | %Ch | Pre | Post | % Ch | Pre | Post | % Ch |
| Coronal | | | | | | | | | | | | |
| Mean | 74.26 | 87.04 | 17.28 | 77.7 | 85.49 | 10.11 | 76.63 | 81.33 | 6.16 | 73.27 | 77.5 | 5.81 |
| SD | 3.94 | 6.29 | 7.37 | 4.84 | 6.15 | 5.93 | 4.24 | 4.88 | 3.66 | 5.16 | 5.67 | 3.62 |
| Median | 74.41 | 87.94 | 17.01 | 78.6 | 84.49 | 8.42 | 76.77 | 80.75 | 5.64 | 73.06 | 77.4 | 5 |
| Minimum | 66.24 | 73.95 | 4.38 | 68.44 | 76.02 | 2.53 | 67.81 | 69.11 | 1.67 | 61.57 | 65.13 | 0.43 |
| Maximum | 81.74 | 98.23 | 30.3 | 88.37 | 97.2 | 22.97 | 85.62 | 95.08 | 14.84 | 84.32 | 89.11 | 13.5 |
| | 72.79- | 84.69- | 14.53- | 75.9- | 83.2- | 7.9- | 75.05- | 79.51- | 4.8- | 71.34- | 75.38- | 4.46- |
| 95% CI | 75.74 | 89.39 | 20.04 | 79.51 | 87.79 | 12.32 | 78.22 | 83.15 | 7.53 | 75.2 | 79.62 | 7.16 |
| Apical | | | | | | | | | | | | |
| Mean | 36.86 | 54.06 | 47.05 | 37.78 | 44.44 | 17.77 | 37.56 | 40.33 | 7.31 | 38.08 | 40.99 | 7.72 |
| SD | 3.23 | 9.91 | 26.34 | 3.71 | 5.2 | 8.92 | 3.5 | 4.41 | 4.43 | 4.09 | 4.48 | 3.71 |
| Median | 36.86 | 55.66 | 50.02 | 37.9 | 43.83 | 16.4 | 37.27 | 40.76 | 6.57 | 37.75 | 40.15 | 7.49 |
| Minimum | 30.81 | 40.2 | 13.01 | 30.16 | 36.63 | 2.84 | 30.52 | 32.61 | 1.79 | 31.06 | 34.66 | 2.21 |
| Maximum | 43.14 | 74.24 | 97.73 | 46.97 | 57.64 | 36.85 | 45.05 | 50.42 | 18.46 | 45.35 | 53.42 | 17.79 |
| | 35.66- | 50.36- | 37.22- | 36.39- | 42.5- | 14.44- | 36.25- | 38.69- | 5.65- | 36.55- | 39.32- | 6.33- |
| 95% CI | 38.07 | 57.76 | 56.89 | 39.16 | 46.38 | 21.1 | 38.87 | 41.98 | 8.96 | 39.6 | 42.66 | 9.1 |

Pre: Pre-instrumentation; **Post:** Post-instrumentation; **%Ch:** Percentage change from pre-instrumentation $\{(Post-Pre)/Pre\} \times 100$;
SD: Standard deviation; **CI:** Confidence interval

shape curved canals¹⁸ the difference in curvature modification is probably due to the higher flexibility of NiTi files compared with stainless steel files. However Alves *et al.* (2012) and D'Amario *et al.* (2013) found no difference between stainless steel K-files and NiTi rotary files during glide path preparation.^{19,20} This disparity is possibly due to the previous studies having been completed on extracted teeth, whilst resin blocks were used in the present study. These are softer than dentine and offer less resistance to the cutting forces of slightly stiffer stainless steel instruments.^{14,21}

The second part of the study comprised a qualitative observation of any canal aberrations. The use of stainless steel K-files by hand resulted in the highest number of canal aberrations compared with those seen when stainless steel K-files were used in the M4 reciprocating hand piece ($p=0.254$). The ledges created with stainless steel K-files by hand were located between the apical curvature and the foramen, while the ledges created with hand K-files in the M4 safety reciprocating hand piece were located between the coronal and apical curves. This difference in position of ledges could be due to keeping the M4 safety hand piece stationary for a prolonged period at a particular position along the length of the canal or repeatedly taking it to a particular length with the vertical amplitude of motion. In contrast, with hand instrumentation there is a better tactile sense of the first curve, but beyond the first curve and as the tapered file progresses around the second curve, there is considerable lateral engagement of the instrument along the canal walls. This increased lateral engagement of the file reduces the tactile sense of the file tip which is a possible reason that the ledges occurred closer to the foramen in this Group and may also explain the zipping of the apex and elbow formation as the file was withdrawn in the pulling motion. Coronal flaring may also reduce this risk with hand instrumentation, as it would result in less lateral engagement of the instrument in the coronal portion of the canal and better tactile sense of the file tip. The higher

Table 2: Geometric means and 95% confidence interval for change to coronal radii by prepared Groups.

| Prepared Group | Geometric Mean | 95% Confidence interval |
|--|----------------|-------------------------|
| Group 1: Hand K-files | 15.51 | 12.83 - 18.74 |
| Group 2: Hand K-files in M4 Safety reciprocating hand piece | 8.52 | 6.78 - 10.70 |
| Group 3: Hand K-files and Pathfiles | 5.13 | 4.04 – 6.51 |
| Group 4: Hand K-files and X-Plorer files | 4.58 | 3.41 – 6.14 |

Table 3: Geometric means and 95% confidence interval for change to apical radii by prepared Groups.

| Prepared Group | Geometric Mean | 95% Confidence interval |
|--|----------------|-------------------------|
| Group 1: Hand K-files | 39.46 | 31.2 - 49.92 |
| Group 2: Hand K-files in M4 Safety reciprocating hand piece | 15.24 | 12.11 - 19.19 |
| Group 3: Hand K-files and Pathfiles | 6.10 | 4.82 - 7.72 |
| Group 4: Hand K-files and X-Plorer files | 6.84 | 5.65 - 8.3 |

incidence of aberrations with stainless steel K-files could also be attributed to the stiffness of these instruments. Camps and Pertot (1994) found that the bending moment of K Flexo-files (Dentsply/Maillefer) was less than half of stainless steel K-files (Kerr Company, Romulus, MI, USA) of the same size.²² The higher incidence of aberrations with stainless steel K-files by hand may be attributed to the quarter turn and pull, filing motion employed during glide path preparation. Furthermore no irrigants were used during preparation of the canals. The kinematics of both hand file methods employed under these dry conditions

could have resulted in debris accumulation between the blades and canal walls, which would contribute to the occurrence of aberrations. It must be noted that in the clinical situation, irrigation of the canals is mandatory during instrumentation.

Our findings using plastic blocks as experimental models, are in agreement with those of other authors^{6,7} who have suggested the use of small stainless steel files followed by NiTi glide path preparation instruments. In this way the mechanical properties of both these alloys are utilized for safer subsequent root canal shaping.

In conclusion, within the limits of this study, there were no differences between PathFiles and X-Plorer files for glide path preparation. Both rotary Ni-Ti systems performed better than stainless steel K-files in the reciprocating hand piece which in turn performed better than stainless steel K-files used by hand. The null hypothesis was therefore rejected. Caution should be exercised when extrapolating the results in plastic blocks to the clinical situation. It may be advisable to use flexible hand files when employing plastic blocks as experimental models. Further research is warranted to compare the different methods of glide path preparation in extracted teeth.

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