Computed tomography evaluation of canal shaping and cleaning ability of three different instrumentation techniques; an *in vitro* study

**ABSTRACT**

*Introduction:* The purpose of the study was to assess the root canal shaping and cleaning ability of three different instrumentation techniques namely step back, crown down and hybrid, using spiral CT.

*Materials and Methods:* 90 extracted human mandibular first molar teeth was collected from the department of Oral and maxillofacial surgery, K.V.G Dental College and Hospital, Sullia, were selected for the study. Standard access cavities were made, and the teeth were sectioned into mesial and distal halves. The mesial half of the mandibular first molars were selected for the study. All the teeth were divided into groups of 15 each and instrumented using crown down, hybrid and step down techniques. They were divided into two sub groups and evaluated using spiral CT. Canal transportation and centering ability of the root canal using spiral CT was checked when instrumented using three canal preparation techniques. Kruskal Wallis and Friedman test were used to analyse the result.

*Result:* Significant canal transportation occurred with hand instruments in the apical third. Hybrid technique was found to be superior in maintaining the original root canal anatomy and less amount of debris was seen in the apical third of the group instrumented using hand instruments.

*Conclusion:* HYFLEX instruments produced cleaner and smoother and more even surface than the hand instruments. Iatrogenic errors are comparatively less in the group instrumented using hyflex rotary files. CT imaging techniques have been evaluated as noninvasive methods for the analysis of canal geometry and efficiency of shaping techniques that Nickel Titanium instruments remove less total dentine and result in less transportation especially in root canals with severe curvatures.

**Key words:** Canal transportation; centering ability; crown down; hybrid technique; hyflex files; spiral computed tomography; step-back.

**Introduction**

The aim of root canal treatment is to remove infected debris from the root canal system and filling it with a bio-compatible material. Cleaning and shaping of the root canal provide an efficient disinfection by creating reservoir for irrigants and medicaments and also provides space for root canal filling.\(^1\) Although several techniques have been developed to minimize errors that may occur during root canal instrumentation, still difficulties are faced while effectively preparing curved and flattened canals.\(^2\) Numerous modifications have been made in the field of cleaning and shaping instruments, both in terms of material aspect as well as shape aspect to address such a problem. One of such modification is hyflex files which are introduced recently and are bendable, flexible and have torsional resistance which is similar when compared with instruments made of conventional nickel-titanium (Ni-Ti).

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Their fatigue resistance is much higher, and torque during preparation is less, compared with other rotary instruments tested previously under similar conditions.\(^3\)

Crown down preparation is the most known and described technique. This technique gives good results but has limitations, such as not addressing the initial anatomy of oval or dumb bell shaped canals.\(^4\) In “the hybrid technique,” shaping files are used with a brushing action on the safe side of the canal on withdrawal. The combination of the brushing action in the coronal two-third of the canal and the use of hand files in the last few millimeters of the canal are complimentary.\(^4\) The step-back technique helped to overcome the procedural errors of the standardized technique in slight to moderately curved canals, but in more severely curved canals problems still exist and hence other techniques can be considered.\(^5\)

Different instrument geometry will produce canals with different shapes. Different approaches to root canal preparation may be essential for different cases with a variety of canal shapes and curvatures.\(^6\) The contemporary literature contains numerous assessments of cleaning and shaping, undertaken in a range of experimental models.\(^3\) In the past, methods such as scanning electron microscope, radiographic evaluation, photographic assessment, and computer manipulation for comparative analysis were used for assessment of canal instrumentation.\(^8\)

Recently, a noninvasive technology called computed tomography (CT) has been advocated for pre- and post-instrumentation evaluation of canal. CT can render cross-sectional (cut plane) and three-dimensional images that are highly accurate and quantifiable. This technique allows the measurement of the amount of root dentin removed by endodontic instruments. Several other studies have shown its use in analysis of the root canal area and parameters such as canal transportation, centering ratio, and remaining dentine thickness.\(^8\)

Hence, the purpose of this study is to compare and evaluate canal transportation and centering ability using different techniques of instrumentation.

**Methodology**

Forty-five extracted mandibular first molars were selected, and they were standardized to a length of 19 mm. Teeth with external resorption, malformed teeth, developmental anomalies, vertical/horizontal root fracture, calcified canals, and all canals with abrupt canal curvatures were excluded from the study. Standard access cavities were made, and the teeth were sectioned into mesial and distal halves. The mesial half of the mandibular first molars was selected for the study. Each canal was negotiated, using a No. 8 and 15 hand-held stainless steel file, until the No. 15 file was visible apically, and then the root surface was flushed with irrigant. The length of the file, from a fixed reference point coronally to the apical foramen was recorded for each canal. A digital radiograph was taken with 60 kV and 0.2 msecs exposure to determine the root canal curvature; keeping an ISO #10 K file 0.5 mm short of working length inside the root canal. Tangents were drawn and traced along the long axis of the file for the determination of angulation of canal curvature using the Schneider’s method. Teeth with 10°–20° curvature were then selected for the study.

**Evaluation of root canal curvature using Schneider’s method**

The canal curvature was determined using the angle between two straight lines by Schneider’s method. The first line begins from the orifice (point A) and is parallel to the longitudinal axis of the root canal’s coronal curvature. The separation point of the line \(L_1\) from the root canal is named point B. The second line \(L_2\) is drawn from the point of curvature apically toward point B. The acute angle formed from intersection of two lines is known as the angle of curvature.

According to this angle, the canals were categorized into three groups, namely the straight (≤10°), moderate (10°–20°), and severe (20°<) groups.

Therefore, the study sample consisted of 45 decoronated mandibular molars with root curvature of 10°–20°. Standardization of the root canal length was done. The specimens were cut to 19 mm length from the apex. All the specimens were embedded in acrylic and CT scan before
the canal preparation was carried out. All the 45 teeth were scanned by spiral CT (high performance 64 slice CT scanner Optima 660CT GE, Munich, Germany) at 120 kV and 230 mA, to determine the root canal shape before instrumentation. The samples were then randomly divided into three groups:

- **Group 1**: Crown down technique using hyflex files (15 teeth)
- **Group 2**: Hybrid technique using stainless steel hand files and hyflex files (15 teeth)
- **Group 3**: Step back technique using stainless steel hand files (15 teeth).

Root canals of samples in Group 1 were prepared using hyflex file instruments at the speed of 500 rpm after estimation of the working length. The coronal enlargement of the root canal was done with 0.08 taper and 25 size hyflex file, followed by 0.04 taper and 20 size hyflex file till the working length. Then shaping was continued in the mid root section with 20 size, 0.06 tapered file, followed by enlargement of the apical section using file with 30 size, 0.04 taper. After instrumentation with each file, the canals were abundantly irrigated with 3% sodium hypochlorite (NaOCl) before the use of the subsequent instrument.

Root canals of samples in Group 2 were prepared using “hybrid technique,” which is the combination of step back and crown down techniques. After estimation of the working length, coronal flaring and shaping of the body of the canal was done with Gates-Glidden and hand file, respectively. Hyflex files were used for preparing the root canal in crown-down technique. Hand files were used for apical finishing of the root canal.

Root canals of samples in Group 3 were prepared by using “step back technique.” Canal length was determined by lacing a file until it was visible at the apical foramen. The working length was determined 1 mm short of the canal length. The canals were prepared using precurved stainless steel K-files in quarter-turn pull motion using a step back technique. After preparation, the final apical size was standardized at size 25. Irrigation was performed after instrumentation with each instrument, using 1 ml of a 3% NaOCl solution.

Root canals of the samples of all three groups were subjected to spiral CT under identical conditions as in the preinstrumentation samples after canal preparation and the images were recorded and archived for further evaluation. The preinstrumented sections made were 1 mm thick, apical to the canal orifice. Three sections from each tooth with the identification number of the tooth and its level were archived onto a magnetic, optical disc. The first two sections were 3 mm coronal to the apical end of the root (apical level) and 3 mm apical to the orifice (coronal level), respectively. A further section (mid-root level) was recorded at a level dividing the distance between the sections into two equal lengths. Images were then transferred to the computer (GE Centricity DICOM Viewer) [Figures 2-4]. The shortest distance from the root canal to the outer surface of mesial and distal wall was measured in the pre- and post-instrumentation slices. Canal transportation and centering ability were calculated based on the formula put forth by Gambill et al.[9]

**Evaluation of canal transportation [Figure 5]**

- **X1**: Shortest distance from the edge of un-instrumented canal to the periphery of the root on mesial wall
- **Y1**: Shortest distance from outside of the root to the periphery of the un-instrumented root canal on the distal wall
- **X2**: Shortest distance from outside of the root to the periphery of the instrumented root canal on mesial wall
- **Y2**: Shortest distance from outside of the root to the periphery of the instrumented root canal on the distal wall.
Transportation results give an indication of how much material was removed with respect to the ideal preparation (where no transportation occurs). Centering ability indicates how well a technique removed dentin equally over the prepared area.

The formula to measure transportation is:

\[(X_1 - X_2) - (Y_1 - Y_2)\].

While assessing the transportation, a value other than “0” indicates that some transportation has occurred.

**Evaluation of centering ability**

Centering ability was calculated for each section using the following ratio:

\[(X_1 - X_2)/(Y_1 - Y_2)\] or \[(Y_1 - Y_2)/(X_1 - X_2)\].

While calculating the centering ratio by the formula using pre- and post-instrumentation values, the smallest value has to be the numerator always.

A value of “1” indicates perfect centering.

**Results**

Comparison of the canal transportation in the coronal region between the three groups shows that the canal transportation is highest in the Group 1 with median of 0.04 and is statistically significant with \(P\) value of 0.0018 and Kruskal–Wallis statistic of 12.64 [Table 1].

Comparing the canal transportation in the middle region between the three groups it is found that the canal transportation is highest in the Group 3 with median of 0.03 and is statistically significant with \(P\) value of 0.001 and Kruskal–Wallis statistic of 28.9 [Table 2].

Comparing the canal transportation in the apical region between the three groups, it is found that the canal transportation is highest in the Group 1 with median of 0.02 and is statistically significant with \(P\) value of 0.0001 and Kruskal–Wallis statistic of 33.16 [Table 3].

Comparing the canal centering ability in the coronal region between the three groups it is found that the centering ability is highest in the Group 1 with median of 1.8 and is statistically significant with \(P\) value of 0.0269 and Kruskal–Wallis statistic of 7.23 [Table 4].
The comparison of the centering ability is not significant in the middle third [Table 5].

Comparing the canal centering ability in the apical region between the three groups it is found that the centering ability is highest in the Group 1 with median of 1.5 and is statistically significant with $P$ value of 0.5584 and Kruskal–Wallis statistic of 1.165 [Table 6].

**Discussion**

The mechanical preparation of root canals plays a significant role in endodontic therapy. The process involves the removal of pulp cavity content and the consequent reduction of microorganism counts, especially in nonvital teeth with periapical lesion. With proper instrumentation, the root canal is enlarged and smoothed to fittingly receive the filling. The endodontic cube enables comparison of the pre- and post-instrumentation features providing an excellent method of assessment for the influence of canal instrumentation.\[10\]

In the study, Kuttlers endodontic cube has been used for the adaptation of the specimens in the acrylic blocks. As tooth and root canal anatomy are equally important during canal preparation, the appropriate use of the endodontic instruments and their close contact with canal walls for pulp extirpation and cleaning purposes is likewise crucial to the treatment.\[11\]

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**Table 1: Kruskal–Wallis test: Canal transportation in coronal third**

| Group | Number of values | Minimum | 25% percentile | Median | 75% percentile | Maximum | Kruskal–Wallis statistic | $P$ |
|-------|------------------|---------|----------------|--------|----------------|---------|--------------------------|-----|
| Group 1 – Canal transportation coronal third | 15 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 12.64 | 0.0018 |
| Group 2 – Canal transportation coronal third | 15 | 0.03 | 0.03 | 0.03 | 0.04 | 0.05 | |
| Group 3 – Canal transportation coronal third | 15 | 0.02 | 0.02 | 0.03 | 0.04 | 0.1 | |

**Dunn’s multiple comparison test**

| Comparison | Difference in rank sum | $P$ | Summary |
|------------|------------------------|-----|---------|
| Group 1 – Canal transportation coronal third versus Group 2 – Canal transportation coronal third | 14.27 | <0.01 | ** |
| Group 1 – Canal transportation coronal third versus Group 3 – Canal transportation coronal third | 13.73 | <0.01 | ** |
| Group 2 – Canal transportation coronal third versus Group 3 – Canal transportation coronal third | −0.5333 | >0.05 | NS |

**Table 2: Kruskal–Wallis test: Canal transportation in the middle third**

| Group | Number of values | Minimum | 25% percentile | Median | 75% percentile | Maximum | Kruskal–Wallis statistic | $P$ |
|-------|------------------|---------|----------------|--------|----------------|---------|--------------------------|-----|
| Group 1 – Canal transportation middle third | 15 | 0.01 | 0.02 | 0.03 | 0.03 | 0.03 | 28.9 | <0.0001 |
| Group 2 – Canal transportation middle third | 15 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | |
| Group 3 – Canal transportation middle third | 15 | 0.03 | 0.04 | 0.05 | 0.01 | 0.2 | |

**Dunn’s multiple comparison test**

| Comparison | Difference in rank sum | $P$ | Summary |
|------------|------------------------|-----|---------|
| Group 1 – Canal transportation middle third versus Group 2 – Canal transportation middle third | 6.6 | >0.05 | NS |
| Group 1 – Canal transportation middle third versus Group 3 – Canal transportation middle third | −17.4 | <0.001 | *** |
| Group 2 – Canal transportation middle third versus Group 3 – Canal transportation middle third | −24 | <0.001 | *** |

**NS** - Not significant, (***) statistically significant at $P$ (< or =) 0.05
Canal centering ability and the canal transportation caused by an instrument, are valuable means of studying the ability of an instrument to preserve the normal anatomy of the root canal. Numerous studies have tested and compared various instruments, instrumentation systems, motion of instrumentation, and importance of glide path for their canal centering ability\textsuperscript{12} and canal transportation\textsuperscript{13} potential.

Tambe et al.\textsuperscript{14} compared rotary ProTaper one shape and wave one system and found that wave one caused
significantly lesser transportation of root canal. On the other hand, Naseri et al.\(^1\) compared wave one primary system used with full rotation versus reciprocation movement and found no significant difference in canal transportation and centering ability. Agarwal et al.\(^2\) compared centering ability and canal transportation with one shape and wave one single file system with multistep ProTaper rotary file system and found that the multistep system had significantly higher transportation and low centering ability at 4 mm from apex.

The role of creating a glide path for the preservation of original canal anatomy has also been illustrated. Elnaghy and Elsaka\(^3\) compared ProTaper next with and without glide path and found significantly lesser transportation at 3 and 5 mm when the glide path was made using ProGlider. Whereas Paleker and van der Vyver\(^4\) compared the same between K file, ProGlider and G file after glide path enlargement and found significantly less centered preparation with K file at 1 mm from the apex and 7 mm from the apex, ProGlider created more centered preparation K file. Therefore, K file exhibited more canal transportation at 1 mm from the apex.

This study evaluated the canal transportation at the apical, middle and the coronal thirds when instrumented with stainless steel K-file, rotary hyflex file and hybrid technique using both. In this investigation, there was no clinically significant occurrence of canal transportation at the coronal and middle thirds but significantly higher for apical third. This is in accordance with the study conducted by Nagaraja and Sreenivasa Murthy et al.\(^5\) in which maxillary first molars were evaluated for canal transportation.

In this study, it was found that in the apical third hyflex files produced a lesser amount of canal transportation than stainless steel hand files in the apical third.

This can be justified based on the type of instruments and instrumentation technique employed, i.e., hand or rotary instrumentation. Ni-Ti instruments have got excellent shape memory, and superelasticity and hence showed less canal transportation when compared with stainless steel instruments. At the coronal levels hyflex files produced more of canal transportation this may be attributed to the shape of the instrument, i.e., increased taper coronally along with cutting edges. Moore et al.\(^6\) found similar results in his study in which there was less amount of canal transportation in the hybrid technique using ProTaper files.

The second parameter was the centering ability. In the coronal thirds centering ability was highest for Group 2 in which root canal was prepared using hybrid technique and lowest for Group 3 in which manual technique with K-file was used. This result may be compared with the findings of Kumar et al.\(^7\) who concluded that rotary instrumentation with hyflex and twisted file system showed better centering of canal than hand K file alone. The reason may be use of Gates-Glidden drills at the coronal portion of the canals.\(^8\) Centering ability was higher in middle and apical thirds in the group instrumented with hyflex rotary files. This may be attributed to the fact that hyflex rotary instruments are bendable and flexible and have similar torsional resistance like conventional Ni-Ti instruments.\(^9\)

**Table 6: Kruskal-Wallis test: Centering ability of the apical third**

| Group 1 – Centering ability apical third | Number of values | Minimum | 25% percentile | Median | 75% percentile | Maximum | Kruskal-Wallis statistic | P |
|----------------------------------------|-----------------|---------|----------------|--------|---------------|---------|-------------------------|---|
| Group 1 – Centering ability apical third | 15              | 1.2     | 1.5            | 1.5    | 1.5           | 2       | 1.165                   | 0.5584 |
| Group 2 – Centering ability apical third | 15              | 1.2     | 1.5            | 1.5    | 1.5           | 2       | 1.652                   | 0.2604 |
| Group 3 – Centering ability apical third | 15              | 1.1     | 1.1            | 1.3    | 2.2           | 3       | 1.165                   | 0.0584 |

**Dunn’s multiple comparison test**

| Group 1 – Centering ability apical third versus | Difference in rank sum | P | Summary |
| Group 2 – Centering ability apical third      | −1.8                   | >0.05 | NS      |
| Group 1 – Centering ability apical third versus | 3                      | >0.05 | NS      |
| Group 3 – Centering ability apical third      | 4.8                    | >0.05 | NS      |

NS - Not significant

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**Conclusion**

Evaluating the root canal shaping and cleaning ability of three different instrumentation techniques namely step back, crown down, and hybrid using spiral CT and scanning electron microscope it can be concluded that.

- Canal transportation was highest with the crown down technique with hyflex files in the coronal third compared to middle and apical thirds, whereas canal transportation...
was seen to be more in step back technique with K-files at middle and apical thirds which was statistically significant
- Comparing the centering ability between the three groups, it can be concluded that hybrid technique produced more centered root canal preparations in the coronal third. In the apical third more centering was seen in crown down and hybrid technique. The canal centering was least in hand instrumentation. This result was not statistically significant in the middle thirds
- It can, therefore, be concluded that the crown down technique with hyflex files and hybrid technique with a combination of hyflex and K files creates less canal transportation and have superior centering ability when compared with step back technique with K-files, which is desirable for optimal outcome of root canal treatment.

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Conflicts of interest
There are no conflicts of interest.

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