Radiographic evaluation of root canal curvature in mesiobuccal canals of mandibular molars by different methods and its correlation with canal access angle in curved canals: An *in vitro* study

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**Abstract**

**Aims:** The aim of this study is to compare three different methods of measuring root canal curvature and its correlation with canal access angle (CAA) in curved mesiobuccal canals of permanent mandibular first molars.

**Materials and Methods:** Sixty human mandibular first molars were used in this study. Standardized access cavities were prepared. After endodontic access, a size 10 K-file was placed in the mesiobuccal canal extending to the apical foramen, and radiographs were taken. Radiographs of each root canal were taken in buccolingual direction with the long axis of the root perpendicular to the central X-ray beam. After that, the radiographs were scanned with a computer Scanner. The angles were measured using the Schneider method, Weine’s method, Lutein’s method, and correlated with the CAA method. The angular and linear values used in this study were plotted, and the pertinent measurements were made using the program AutoCAD R12.

**Statistical Analysis:** The resultant values were evaluated statistically using ANOVA test and Pearson correlation and multiple regression analyses (*P* = 0.001).

**Results:** Lutein’s method is as effective as the Schneider’s method, Wein’s method and CAA method in evaluating root canal curvature.

**Conclusions:** Scheider/Wein/Luiten method, together with CAA method, may be considered as a reliable guideline for preoperative assessment of canal curvature.

**Keywords:** Canal access angle method; canal curvature measurement; Luiten’s method; Schneider’s method; Wein’s method

**INTRODUCTION**

Maintaining the function and the appearance of treated natural teeth is the main purpose of endodontic therapy while treating the diseased (vital or nonvital) dental pulp. The success of root canal therapy depends on complete removal of the diseased dental pulp tissue, preparing the root canal with proper irrigation solution, and sealing them subsequently. To prohibit the bacterial ingress from the coronal portion, coronal seal must be provided.[1,2]

Not only the endodontic instruments and preparation techniques but root canal morphology and the degree of curvature also plays an important role in endodontic treatment. This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

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**How to cite this article:** Nagmode PS, Chavan KM, Rathi RS, Tambe VH, Lokhande N, Kapse BS. Radiographic evaluation of root canal curvature in mesiobuccal canals of mandibular molars by different methods and its correlation with canal access angle in curved canals: An *in vitro* study. J Conserv Dent 2019;22:425-9.
root canal preparation. According to various researches maintaining the original canal morphology during ideal root canal preparation along with flare taper shape from the coronal to the apical region and thus preserving apical foramen may be challenging due to complex root canal morphology. Hence, root curvature plays a significant role in the cleaning and shaping process.\textsuperscript{[1, 2]}

They may account for numerous procedural errors such as the loss of working length, instrument separation, ledging and zipping, canal transportation, strip perforation during instrumentation.\textsuperscript{[3]}

Various studies have been reported regarding different methods used for measurement of root canal curvature, for both \textit{in vivo} and \textit{in vitro} purposes. Among these, the most widely accepted ones used clinically are – Schneider’s method;\textsuperscript{[4]} Weine’s method,\textsuperscript{[5]} and Canal Access Angle (CAA) method. Schneider performed pioneering work on measuring canal angulation in 1971. Later, Weine and Lutein \textit{et al.} developed a different method for determining canal angulation. According to Weine, canal curvatures >30\textdegree{} results in various complications in root canal preparation.\textsuperscript{[6]} In general, curved canals causes deformation of the instrument, which leads to stresses on the instrument. Tensile stresses occur on the noncurved parts, and compressive stresses form on the curved parts of the instrument. Distortion of the instrument increases as the canal curvature increases, which ultimately leads to an increase incidence of instrument breakage.\textsuperscript{[7, 8]}

This study was intended to evaluate degree of root canal curvature by three different techniques and to correlate with CAA in curved canals. Rationale of this study is to determine more accurate technique by comparing newer methods with the most accepted Schneider’s method because it is important to evaluate the canal curvature before starting the root canal preparation and implement the appropriate instrumentation technique.

**MATERIALS AND METHODS**

In this study, extracted human mandibular first molars with closed apices were used. After extraction, all the molars were stored in distilled water. Standardized access cavity preparations done using a high-speed air turbine handpiece (Pana Air, NSK, Nakanishi Inc., Japan) and ISO standardized diamond points and burs (\textit{Mani Inc.} Round [no. 4] and Endo z.) After endodontic access, a size 10 K-file was placed in the mesiobuccal canal extending to the apical foramen. A soft wax 2 cm × 2 cm attached to the lingual aspect of crown and root as close as possible to the sensor. Paralleling radiographic technique using Radio Visio Graphy (RVG) is used for taking radiographic images in a mesiodistal direction. The long axis of roots is kept parallel to the long axis of the film. The digitalized image of a mandibular molar is taken in which an instrument is stressed due to the deformation by curvature in mesiobuccal canal during canal preparation. AutoCAD 02 – Autodesk software is used for the evaluation of linear and angular entities or variables.

For measuring Schneider angle [Figure 1a] point A denotes the canal orifice and point B apical foramen and point where canal curvature begins is marked as point C.

In the coronal third, a line is drawn parallel to the long axis of the canal and the second line is drawn by joining point (B) at the apical foramen and the point where first-line left long axis of the canal. The intersection of these lines is the Schneider angle.

Weine angle is the intersection of the line formed drawn from point A at canal orifice to the coronal portion of the curve, and a second line is drawn from point B at the apex to the apical portion of the curve.

In the CAA technique, A line is drawn from point A at the canal orifice and point B at the apical foramen, (AB) and line drawn parallel to the long axis of the canal from the coronal part (AC) (used in the Schneider method), intersection of these lines is defined as the CAA.

For measuring Lutein’s technique, Luiten \textit{et al.} modified Schneider’s technique by using two lines drawn by the identification of four geometric points. Center of canal orifice is marked as Point A and then point 2 mm below the orifices in the long axis of the canal is marked as point B.

![Figure 1: (a) Schneider angle; BCE Figure (b) Wein’s angle; BFE (c) Lutein’s angle; BGH (d) canal access angle; BAE (e) canal access angle method](image-url)
joining point, A and point B, a first primary line is drawn and a second primary line is drawn by joining point C which is at a point 1 mm coronal to the apical foramen and Point D at the apical foramen. The angle formed by the intersection of these two is measured as in the Schneider method.

The angular and linear values used in this study were plotted in a PC environment using the program FreeHand (The FreeHand MX (11.0.2), Adobe), and the pertinent measurements were made using the program AutoCAD R12 (Autodesk, Inc., San Rafael, CA). The resultant values were evaluated statistically using Pearson correlation and multiple regression analyses.

RESULTS

The mean curvature angle values measured using Schneider, Weine, and Luiten methods are 31.56 (6.71), 47.91 (11.50), and 53.26 (9.17), respectively. The largest and smallest average curvature angles measured using Schneider, Weine, and LA methods are 7.98° to 35.45°, 11.70° to 56.79°, and 0.35° to 46.25°, respectively. ANOVA showed that there were significant differences between the curvature angles measured using each technique (P < 0.001). The Pearson correlation analysis found a significant positive correlation between angles S and W (r = 0.45) and angles W and Lutein (r = 0.902), and a positive correlation between angles S and Lutein (r = 0.574).

All the above angles were then correlated to CAA and also two linear parameters, i.e., curvature height (x) and curvature distance (y). The results of this investigation are summarized in Table 1. The curvature starting distance corresponded to the coronal third in 67% of the roots and to the medium third in the remaining 33%.

Furthermore, the CAA was significantly smaller than the Schneider curvature angle (P < 0.001).

The Pearson correlation analysis revealed the following [Table 2]:
1. A positive correlation (r = 0.171) between the CAA and curvature height (x), and
2. a negative correlation (r = –0.116) between the CAA and curvature distance (y)

3. A positive correlation (r = 0.465) between the CAA and Schneider angle (P = 0.001).

The multiple regression analysis indicated that the values of x and y influence the CAA, i.e., change in the CAA depends on the values of x and y.

DISCUSSION

Appropriate knowledge of root canal morphology is important for successful endodontic treatment. The morphological variations in root canals such as long, narrow, or curved canals are most prone to endodontic mishaps, which can cause serious problems during root canal therapy. Various stages in endodontic therapy affected by curved canals are access cavity preparation, biomechanical efficacy of endodontic irrigants, and obturation.

To improve the clinical success of endodontic treatments and allow easier comparison between various investigations on curved root canals, a thorough knowledge of root canal morphology is essential; canal curvature should also be precisely measured and described.

The common causes of endodontic treatment failure in cases of atypical canal anatomies are due to procedural errors such as ledge formation, fractured instruments, blockage of the canal, and bending while preparing the canal. Consequently, an equivalent force acts on the instrument in the dentine. The stress acting on a canal instrument is highest in the curvature zone. This resultant stress due to the contact between the file and the surface of the canal is enough to break the file.

Pruett et al. reported that a sharp canal curvature increases the stress on canal instruments. Nickel-titanium endodontic instruments were introduced in curved canals because of its superelasticity and flexibility. Despite this increased flexibility, many investigators have reported unexpected fractures. They also found that the tapers of files were significant in that as diameter increased, fracture time decreased. Sattapan et al. demonstrated that torque delivered to the endodontic instrument was dependent on tip size, taper, and canal size. Larger tapers and smaller canals generated more torque on the instrument.

Most studies on curved root canals have only used the Schneider angle. Only a few studies have compared the Schneider angle in combination with other canal curvature measuring methods. No previous study has measured root canal curvature using Schneider, Weine, Luiten methods, and correlated these methods with CAA method. In this study, we have measured root canal curvatures using Weine and Luiten’s method and compared
In the present study, we measured the root canal curvature using computerized software (AutoCAD) on radiographic images taken using RVG. However, all root canals have curvatures in the mesiodistal direction, which cannot be seen in routine radiography or buccolingual view. In our study, the largest curvature angles (53.26° ± 9.17°) were obtained by Schneider’s method, whereas the smallest (31.56° ± 6.17°) by Lutein’s method. The Schneider technique and Weins’s technique mainly emphasizes the canal curvature in the coronal region, whereas the Weine technique considered the apical region. The Schneider method appears to underestimate canal curvature. It provides an acceptable estimate of gradual root curvatures, but it does not take into consideration canals with acute deviations near the apex. The Lutein technique allows for a more accurate measurement of the true canal curvature regardless of the location of the curve relative to its deviation from the main axis of the canal.

While preparing mild to severe curved canals instrument tends to bind in the apical third of canal where most of the curvatures lie. As a result, there is increase in the torsion and flexural fatigue of instrument which ultimately results in instrument fracture.18 Thus, it is important to evaluate the canal curvature before starting the root canal preparation and implement the appropriate instrumentation technique. All the methods used in present study for evaluating canal curvature are easy, reproducible and efficient, which allows a more accurate planning of root canal instrumentation and minimizes the impact of anatomical difficulties and limitations of endodontic instruments.

The results of this study show that the Lutein’s method is as effective as the Schneider’s method, Weins’s method and CAA method in evaluating root canal curvature with respect to its influence on the operation and effectiveness of the new root canal instruments.

CONCLUSIONS

It can be concluded that the preoperative assessment of canal curvature is necessary to avoid procedural errors during root canal treatment. Schneider/Wein/Luiten method together with CAA method may be considered as reliable guideline.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Table 2: Correlation among various techniques in determining the curvature angles in curved root canals

| Method           | Schneider’s technique (r, P) | Weine’s technique (r, P) | Lutein’s technique (r, P) | CAA technique (r, P) |
|------------------|----------------------------|-------------------------|--------------------------|---------------------|
| Schneider’s      | -                          | 0.45, <0.001 (HS)       | 0.574, <0.001 (HS)       | 0.465, <0.001 (HS)  |
| Weine’s          | 0.45, <0.001 (HS)          | -                       | 0.902, <0.001 (HS)       | 0.188, 0.149 (NS)   |
| Lutein’s         | 0.574, <0.001 (HS)         | 0.902, <0.001 (HS)      | -                        | 0.218, 0.094 (NS)   |
| CAA              | 0.465, <0.001 (HS)         | 0.188, 0.149 (NS)       | 0.216, 0.094 (NS)        | -                   |

HS: Highly significant, NS: Not significant, CAA: Canal access angle
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