ORIGINAL RESEARCH

Assessment of Biomechanical Preparation Influence on Various Root Canal Curvatures

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Abstract

Aim: To determine the influence of biomechanical preparation on various parameters of root canal curvature.

Materials and methods: A total of 72 tooth roots with moderate (10–25°) and severe canal curvature (26–75°) were selected and embedded in autopolymerizing acrylic resin for which cone-beam computed tomography (CBCT) image analysis was performed. Schneider angle, canal access angle (CAA), and the radius of curvature were determined preoperatively using auto-computer-aided design (CAD) 2021 software. Protaper gold rotary nickel-titanium (Ni-Ti) files were used to prepare the root canals. All angular and linear values were measured in auto-CAD and compared using postoperative CBCT pictures. The difference in pre- and postoperative values was assessed using paired samples *t*-test and independent samples *t*-test.

Results: There was a statistically significant difference between the Schneider angle ($p = 0.002$), ($p < 0.001$), CAA ($p < 0.001$), ($p = 0.001$), and radius of curvature ($p = 0.01$), ($p = 0.001$) pre- and postoperatively in both moderate and severe canal curvature groups, respectively. This difference was greater in the severe curvature group (p-value = 0.027) than in the group exhibiting moderate curvature. Among the parameters tested, Schneider angle has shown maximum difference pre- and post before and after mathematical processing (BMP) compared to other parameters.

Conclusion: This approach is a new and objective way of measuring root canal geometric changes. The current findings suggest that the Schneider angle, CAA, and the radius of curvature can be used as parameters to evaluate the changes in canal geometry following biomechanical preparation.

Keywords: Biomechanical preparation, Canal access angle, Radius of curvature, Root canal curvature, Schneider angle.

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Introduction

The primary goal of endodontic therapy is to eradicate or minimize the bacterial load in the root canal, allowing the treated tooth to remain in the dental arch while restoring appropriate function and, consequently, clinical longevity.[1] Conventional endodontic therapy is divided into several phases, which include access cavity preparation, instrumentation, irrigation, and obturation.[2] While every phase of root canal treatment holds its importance, the biomechanical preparation of the root canal system requires the most substantial effort from the clinician.[3] Literature indicates that the ideal canal preparation involves maintaining the original canal morphology during biomechanical preparation while also achieving a flare taper shape from the coronal to apical region.[4]

This is frequently well achieved in straight canals; nevertheless, the complexities involved in root canal morphology pose certain challenges to accomplishing the objectives of biomechanical instrumentation. Canal systems move through multiple geometric planes and substantially curve more than the roots that house them.[5] It has been well evidenced in the literature that as the curvature increases, the complexity involved in canal preparation also increases.[6] The complex curvatures that are likely to exist along the length of the root canal if undiagnosed may lead to a number of procedural errors such as loss of working length, restricted mechanical and chemical preparation of root canal, ledge formation, lateral perforation, zipping, and instrument separation.[7,8] Curvature adds complexity to instrumentation as the cutting action of instruments along the curved canal focuses more on certain walls than others, resulting in some portions of the canal wall being left uninstrumented.[9] Regardless of the complexity involved in the geometry, the clinician is responsible for preparing the canal adequately and uneventfully to best receive the obturating material. This is well achieved with proper evaluation of canal geometry prior to actual before and after mathematical processing (BMP).

Besides the known importance of canal curvature in endodontics, not much significance has been drawn toward measuring it.[10] So far, very few methods have been introduced by some researchers for measuring root canal curvature.[11,12] Among these, Schneider proposed the most widely accepted method to describe the complexity of canal curvature.[12] Apart from Schneider's angular measurements, Schafer et al. utilized the radius of curvature to provide a more comprehensive description of the complexity of canal curvature. This approach acknowledges that two canals with the same degree of curvature, according to the Schneider method, may possess varying radii or abruptness of curvature, thereby significantly affecting canal instrumentation and instrument

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fatigue.[13,14] Besides the angular method, canal access angle (CAA) represents an effort to introduce a linear approach for calculating canal accessibility in the coronal region rather than relying on root curvature angles. This discovery is noteworthy given that the CAA of two canals with different geometries may vary, even if they share the same canal curvature as measured using the Schneider technique.[5] All these parameters were interrelated to each other, and evaluating one may not picture the whole geometry of the canal. Analyzing these three parameters could better define the geometry; henceforth, they were measured in this study. Preoperative assessment of the degree of canal geometry will guide the clinician in assessing the complexity involved during treatment, and postoperative assessment helps assess the effectiveness of the chosen method in facilitating the ease of obturation, thereby limiting the iatrogenic complications. Hence, the study was intended to evaluate the quantitative change in canal curvature and radius pre- and postinstrumentation in various curved canals, making use of three-dimensional image analysis software auto-computer-aided design (CAD). Thus, this study was a nascent attempt to evaluate the complexity involved and ascertain the geometric changes in postbiomechanical preparation.

Materials and Methods

The manuscript for this laboratory study adheres to the guidelines outlined in the Preferred Reporting Items for Laboratory Studies in Endodontology 2021. The present *in vitro* study was conducted in the Department of Pediatric Dentistry in collaboration with the Department of Oral Medicine and Radiology and CAD/computer-aided manufacturing (CAM) Institute, Eluru, Andhra Pradesh, India.

The ethical protocol was verified and approved by the Institutional Ethics Committee. A total of 200 freshly extracted permanent human teeth were collected from the tooth bank in accordance with the guidelines of the Centers for Disease Control. From this sample, teeth with twisted and fused roots, those exhibiting internal and external resorption, endodontically treated teeth, roots with incompletely formed apices, and roots with obliterated canals were excluded based on the collected sample. Out of 200 teeth, 175 teeth that fulfilled the study objectives were debrided of debris and preserved in distilled water containing 0.05% thymol. Later, all the specimens were de-coronated using a carbide disk mounted on a slow-speed handpiece under water coolant. For each tooth, an access cavity was prepared using an Endo Access bur (Dentsply, United States of America). After locating the root canal orifices, #10 K-file (Mani Incorporated Japan) was used for the negotiation of the canal. While doing so, roots from calcified and nonnegotiable canals were discarded. Finally, 130 roots were considered in the study to measure the Schneider angle.

All the specimens were embedded in autopolymerizing acrylic resin (Dental Products of India—root repair cold cure) using a plastic mold. To ensure standardization for tomographic imaging, all the specimens were arranged parallel to the long axis of the acrylic mold. Preoperative images were captured using CBCT (Care stream CS 9300) featuring a field of view of 10 × 5, tube current of 4 mA, tube voltage of 85 kV, and exposure time of 20 seconds.

Parameters Assessed in the Study to Evaluate the Canal Geometry

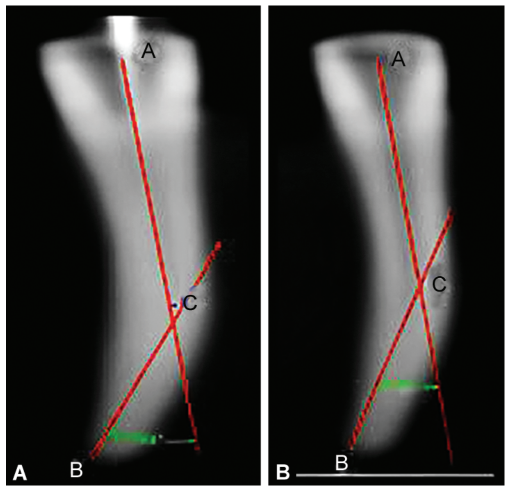
For each sample, Schneider angle, CAA, and radius of curvature were determined using auto-CAD software.

The Schneider method initiates with a line drawn parallel to the long axis of the canal (AC), followed by a second line (BC) from the apical foramen to intersect point C, where the first line departs from the canal's long axis. The angle formed between these lines is designated as the Schneider angle (Fig. 1A). Roots displaying straight canal morphology were excluded based on the Schneider angle. Consequently, the remaining sample of 72 roots, exhibiting various degrees of curvature, was divided into two groups.

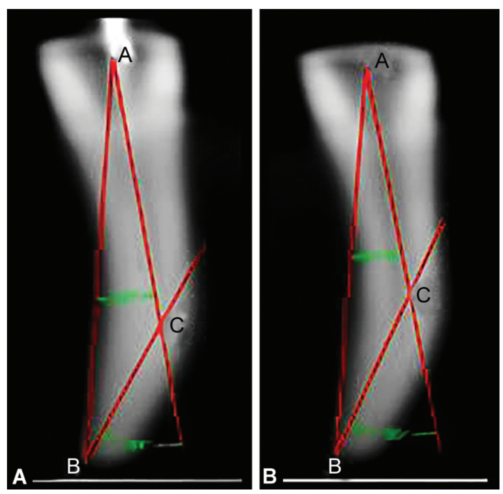
Group I (n = 21) = moderate curvature (10–25°), and group II (n = 51) = severe curvature (26–70°).

In the subsequent phase, the CAA was determined. Initially, a straight line connecting the canal orifice (A) and apex (B) points was drawn. The angle formed by the intersection of this line (AB) and another line parallel to the long axis of the canal from the coronal part (AC) was measured (Fig. 1B). The radius of curvature was then computed based on the measured length of the chord BC. This line, extending from points B to C, represents a chord of a hypothetical circle defining the curved section of the canal. The curved segment between points B and C illustrates the arc of this theoretical circle, with its radius determined by its circumference (Fig. 2). The radius was calculated using the following formula:

$$R = BC / (2 \sin S)$$



Figs 1A and B: Pre- and postoperative image representing Schneider angle



Figs 2A and B: Pre- and postoperative image CAA

Procedure

Coronal enlargement was achieved using an SX ProTaper Gold orifice enlarger instrument from Dentsply (New York, United States of America). Subsequently, biomechanical preparation was performed using S1, S2, and F1 ProTaper Gold rotary nickel-titanium (Ni-Ti) files, also from Dentsply (New York, United States of America). The crown-down technique was employed with ethylenediaminetetraacetic acid, serving as a lubricating gel. Following each file sequence, the prepared root canals were irrigated with 2 mL of 5.25% sodium hypochlorite solution (Vishal Dentocare India), followed by a final rinse with saline (Claris Life Science India). The postoperative CBCT images were taken with the same parameters as those of the preoperative scan. All the scanned images were analyzed using auto-CAD software to determine any change in measured parameters.

Statistical Analysis

Statistical analysis of the data was done using Statistical Package for the Social Sciences version 20 software (IBM Corp., Armonk, New York, United States of America). Descriptive statistics, paired samples *t*-tests, and independent samples *t*-tests were employed for data analysis. Data presentation was accomplished using bar charts.

Results

The biomechanical preparation resulted in a reduction of root canal curvature in both groups. A significant difference was observed between pre- and postinstrumentation with respect to Schneider angle ($t = 3.63, p = 0.002$), ($t = 6.54, p < 0.001$); CAA ($t = 4.95, p < 0.001$), ($t = 3.37$, $p = 0.001$); and radius of curvature ($t = -2.82$, $p = 0.01$), ($t = -3.64, p = 0.001$); for group I and II, respectively (Tables 1 and 2). When intergroup comparison of the selected parameters was made between the two groups, there was no statistically significant difference between CAA ($t = -0.46$, $p = 0.645$) and radius of curvature ($t = -1.88$, $p = 0.063$). However, the changes obtained with respect to Schneider angle were more in group II, and the difference was statistically significant ($t = -2.26, p = 0.027$) (Table 3).

Discussion

The sophisticated internal tooth anatomy and complex root canal system often go beyond simple perception. Knowledge of root canal anatomy is an indispensable prerequisite that helps to assess the arduous root canal sections[15] and plays a most demanding role for the clinician. The primary goal of biomechanical preparation is to prepare the canal in all three dimensions of the canal space, thus creating a favorable environment without altering the original geometry. One aspect of canal configuration that has laid out to have a crucial impact on instrumentation is canal curvature.[16]

These curved canals may, in like manner, curb the biomechanical preparation of the root canal and also provoke some procedural errors in determining the long-term prognosis of the tooth.[2] Thus, the preoperative evaluation of canal geometry helps the clinician reach the proposed mechanical, biological, and clinical objectives

Table 1: Pre- and postoperative variations in measured parameters in group I

Parameter	*Time point*	*n*	*Mean*	*SD*	*SE*	*t*	*p-value*
S angle	Pre	21	15.62	6.095	1.33	3.63	0.002*
	Post	21	13.57	5.87	1.28		
CAA	Pre	21	5.57	1.98	0.434	4.95	<0.001*
	Post	21	4.29	1.55	0.339		
Radius	Pre	21	8.49	4.47	0.97	–2.82	0.01*
	Post	21	10.26	5.95	1.29		

Paired samples *t*-test; $p \leq 0.05$ considered statistically significant; *, denotes statistical significance

Table 2: Pre- and postoperative variations in measured parameters in group II

Parameter	*Time point*	*n*	*Mean*	*SD*	*SE*	*t*	*p-value*
S angle	Pre	51	46	18.56	2.59	6.54	<0.001*
	Post	51	41.25	18.61	2.607		
CAA	Pre	51	17.57	7.46	1.045	3.37	0.001*
	Post	51	15.92	7.618	1.067		
Radius	Pre	51	3.49	1.43	0.2	–3.64	0.001*
	Post	51	4.28	2.25	0.31		

Paired samples *t*-test; $p \leq 0.05$ considered statistically significant; *, denotes statistical significance

Table 3: Comparison of changes in measured parameters between groups I and II

Parameter	*Curvature*	*n*	*Mean*	*SD*	*SE*	*t*	*P-value*
S angle change	Moderate	21	2.05	2.578	0.563	–2.26	0.027*
	Severe	51	4.75	5.180	0.725		
CAA change	Moderate	21	1.29	1.189	0.260	–0.46	0.645
	Severe	51	1.65	3.486	0.488		
Radius change	Moderate	21	-1.774	2.87	0.628	–1.88	0.063
	Severe	51	-0.787	1.54	0.21		

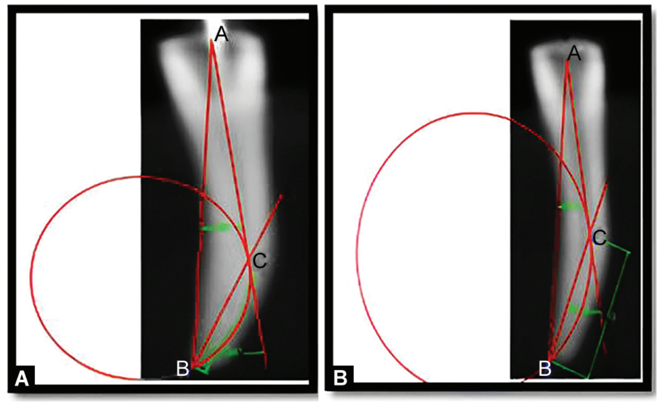
Independent samples *t*-test; $p \leq 0.05$ considered statistically significant; *, denotes statistical significance of endodontic therapy, such as straight-line access, hydraulics of obturation, and the form and function of teeth in the arch.[17] The parameters selected were radius of curvature, Schneider angle, and CAA. The Schneider angle was selected as it was a more accurate, simple, and reliable method among all the available curvature measurement techniques.[2,18] According to the literature, the combination of measuring the angle of curvature using the Schneider method along with the radius of the curve is considered a superior method for describing canal curvature. CAA has been additionally added to the study; when Schneider measures the apical curvature, the CAA measures the coronal accessibility, and these three parameters utilize common points yet measure different aspects of canal geometry.[19]

For biomechanical preparation, the standard protocol of rotary instrumentation has been followed because the introduction of Ni-Ti files into dentistry claimed to reduce the aforementioned procedural errors if not eliminated. With improved flexibility as well as superior resistance to torsion, Ni-Ti rotary files were claimed to have a greater advantage when preparing curved canals in terms of preparing the canal in its original axis, maintaining the original canal anatomy, and a more centered canal preparation, causing less transportation.[20] Several studies reported the better shaping ability of Ni-Ti rotary files compared to the stainless steel files when used in curved canals,[21–23] thus incorporated in the study.

Amid the selected method, the preoperative assessment of canal geometry will help the clinician improve the success of root canal treatment and prevent endodontic mishaps. Thereafter, postoperative assessment will help us evaluate the change in canal geometry and come to a conclusion on the effectiveness of the chosen method in facilitating the ease of obturation. The present study was intended to address the pre to postoperative change in the canal curvature quantitatively to reveal the change in geometry of the canal under *in vitro* conditions.

Very few studies attempted to measure the pre- and postoperative changes in canal geometry and were limited to measuring the Schneider angle alone.[11,16] This has been evidenced in many studies that Schneider angle alone may not describe the complete geometry of the canal.[4,18] Hence, in the current study, Schneider angle, along with CAA and radius of curvature, were compared before and after instrumentation.

By comparing pre- and postinstrumentation radiographic images outlining the longitudinal root canal axis, it was possible to evaluate the most relevant parameters of root canal geometry. The findings of the present study validated a significant change in Schneider angle for groups I and II before and after biomechanical preparation. These outcomes are most probably attributed to the fact that the lines joining the point of intersection AB and BC edge nearer, leading to a decrease in the angle (Fig. 1). The increased taper and flexibility of Ni-Ti files made the canal geometry more favorable with biomechanical preparation, though there is no abnormal straightening of the canals observed. A significant decrease in CAA was observed pre- to post-instrumentation in both groups. The decrease in CAA can be attributed to the slight uncurving of the root canal in the coronal region, which positioned the line AC further straight and AB more toward AC (Fig. 2). The results of the present study were in accordance with the results obtained by Malur and Chandra[18] where significant decrease in Schneider and CAA were noted from pre to post instrumentation.[18] conversely radius of curvature significantly increased with biomechanical preparation. The slight uncurving of the canal well elucidates why the radius of curvature increased after biomechanical preparation. The radius (R) is directly proportional to line BC and inversely proportional to Schneider angle according to the following formula used in the study.[19]



Figs 3A and B: Pre- and postoperative image representing radius of curvature

$$R = BC / (2 \sin S)$$

The length of the chord BC increased postoperatively due to uncurving of the canal, leading to increased radius of curvature (Fig. 3). When the selected parameters were compared between moderate and severe curvature there is no statistically significant difference between CAA and radius of curvature which indicates that irrespective of canal curvature, biomechanical preparation has led to favorable changes postoperatively. However; the changes obtained with respect to Schneider angle were more in group II compared to group I. This can be ascribed to the likelihood that a higher degree of curvature resulted in a nonuniform distribution of stress on the instrument, thereby increasing transportation values. These results were aligned with the study conducted by Faraj,[24] wherein biomechanical preparation decreased the Schneider angle in both moderate and severe curvature groups, albeit without statistical significance. Notably, a greater deviation was observed in teeth with severe curvature compared to the moderate group.[24] The lack of statistical significance may be attributed to methodological differences across studies.

The Schneider angle stresses the overall length of the canal, so any change in the apical curve deflections in severely curved canals could very well appreciated. As the distance from the file tip to its point of attachment to the rotary device increases, more deflection of the tip of the file is seen, so the changes could be more noticed in the apical region. The CAA alone as a sole parameter concentrates on the coronal region where file deflection will usually be less noticed, and so will the changes. The radius of curvature defines the path taken by the canal, which has the same portal of entry and exit. The path does not get altered much, but it will be maintained uniformly in either of the groups, which were well defined in the results obtained. These results were compatible with the results obtained by Christodoulou et al.[10] where the canal preparation led to a decrease of the root canal curvature by 30.23% on an average in all the groups and comparatively to a greater extent of change in the severe curvature group.[10] Another noteworthy discovery was the minimal alteration observed in the moderate curvature group, which could be attributed to the instrument's effective centralization capacity within the canal. Protaper gold rotary Ni-Ti files were selected for this study since clear evidence exists in the literature supporting their efficiency in the preparation of different root canal morphology.[25,26] The results of the present study also confirmed the ability of the Protaper Ni-Ti rotary file system in maintaining the original root canal curvature and that none of the examined samples surpassed the crucial level of canal straightening.

Limitations

As the teeth were collected randomly without prior evaluation of root canal geometry, an equal distribution of the sample size was not achieved. Most of the collected teeth roots were included in the severe curvature group. An equal distribution of samples would have elicited better results.

Till now, many authors have given various methods to evaluate canal geometry. The limited resources, in the form of time and finance, forced us to limit our evaluation to the selected parameters. If all other proposed methods of canal geometry were also evaluated, one can come out with a method that better assists the clinician in preoperative assessment so that endodontic mishaps can be limited.

Conclusion

Within the limitations of the study, the following conclusions can be drawn:

- There was a considerable amount of change in root canal geometry when the changes in root canal curvature were evaluated before and after biomechanical preparation.
- Schneider angle, CAA, and radius of curvature changed favorably following biomechanical preparation with the rotary endodontic file system.
- The degree of change in canal curvature was greater in severely curved canals than in moderately curved canals when the Schneider angle was evaluated.
- This study was an inaugural attempt to better evaluate the root canal geometry prior to the biomechanical preparation, which reflects directly on a more efficacious canal preparation that limits iatrogenic errors and enhances the treatment outcome.

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