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METHODS USED TO DETERMINE THE CURVATURE OF ROOT CANALS: A REVIEW

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ABSTRACT:

For an endodontic therapy to be successful a triad of access cavity preparation, cleaning and shaping and establishing a three-dimensional hermetic obturation is mandatory. Canal preparation is the most important part of the triad that can be very challenging due to the complexities present in the root canal system. Extreme canal curvatures of different degrees within the roots can cause problems as they lead to issues such as ledge formation, separation of instruments, canal blockage and tear-drop transportation at the apex or perforation. Anatomical variations within the complex root canal morphology are the most commonly seen cause of endodontic treatment failure. It is, therefore, essential to have a good knowledge about the internal and external morphologies of all teeth. The aim of the current paper is to review the methods used to determine the root canal curvature.

Keywords: Canal blockage, curved canals, root canal curvature, root canal morphology.

INTRODUCTION

The main aim of endodontic therapy is to manage diseased dental pulp so that the function and appearance of the treated natural tooth can be preserved. It involves the removal of diseased dental pulpal tissue, preparing the root canals and then sealing them afterward using a chemically inactive filling material. An ideal canal preparation is one in which the original canal anatomy is maintained during the preparation procedure, along with the flared tapered shape from the coronal to the apical region and thus, maintaining the apex. This, however, may not be always possible due to the convoluted root canal morphology. Common challenges that endodontists usually encounter during endodontic therapy are:

Accessing all the canals without coming across a procedural error Maintaining the adequate working length and obturating the canal to its complete working length Preparing the canals by maintaining the adequate size and complexities of canals.

Unfortunately, the root canal morphology is not always as straight and manageable as it appears on the radiographs.[1]

Root canal therapy relies on establishment and maintenance of the accurate working length. The working length maintains the apical extent of the preparation. Accuracy of this length is mandatory if damage to the root apices and periapical tissues is to be prevented during biomechanical preparation and obturation.[2]

Many curves are present along the length of the canal and the management of these curved root canals becomes very challenging for the endodontist. These curved canals may also limit the mechanical preparation of the curvature or may lead to some procedural problems affecting its prognosis. Preoperative assessment of the root canal morphology is thus necessary so that the complexity, the degree of curvature, and radius of the root canals are determined to an extent. This will significantly reduce the occurrence of the procedural errors.[1]

In the past few years, only the angle of the canal curvature was the focus for categorizing the root canal morphology and the curvature. The canal was classified as either straight (if the angle was 5° or less), moderately curved (if the angle was 10-20o), or extremely curved (if the angle was >20°). Later, it was proposed that the degree, position, and extremity of the canal curvature also play a very important role. Also, it is important to choose the correct instruments and techniques as the final outcome of the treatment in curved canals depends largely on the flexibility of the instruments used, diameter of the instrument, and technique of the instrumentation. The common challenge that a practitioner may encounter during the treatment of complex canals are:

Negotiating the root canal curvature

Enlarging the canal space by maintaining the original internal anatomy of the canal Creating a taper-shaped canal to optimize irrigation and obturation.1

DETERMINING THE ROOT CANAL CURVATURE

Curvature of the root canal system should be determined preoperatively to avoid procedural errors and subsequent treatment failure. Though there is an obvious lack of a consensus on the ideal technique to achieve this goal, it is reasonable to expect that some techniques are more suitable for clinical use and others are better restricted for research purposes. Factors such as the preference of the operator, practicality and ease of use, root canal morphology (e.g. presence of 'S-shaped' curves), as well as access to the various imaging techniques and imaging software, are likely to influence the choice of technique to measure root canal curvature.5 The following methods can be used for root canal curvature determination:

Periapical radiographs

These can be used to assess the root curvature but may lead to misinterpretation since the radiographs produce a 2D image of a 3D object and thus, curvatures that are present buccolingually may not be visible. The majority of the canals do have some curvature on the different planes and thus, it is not possible to demonstrate them solely on the basis of radiographs.(6,7)

Cone Beam Computed Tomography (CBCT)

The radius of root curvature can be found out through CBCT measured by the circumcenter using Planimp software (CDT Informatics, Cuiabá, MT, Brazil, 3Dimaging system) based on the 3 mathematical points. 2 semi-straight lines of 6 mm are drawn and the midpoint of the lines is determined. Perpendicular lines from the midpoint of each primary semi straight lines are drawn until they meet at a point that is termed the circumcenter. The distance between the circumcenter and the midpoint of each semi-straight line will actually determine the extent of the canal curvature. The smaller the radius, the greater the curvature and thus more complicated the root canal structure.

According to this method, curvature can be divided as:
Small radius ($r < 4$ mm): Severe curvature
Intermediary radius ($r > 4$ and $r < 8$ mm): Moderate curve
Large radius ($r > 8$ mm): Mild radius.8

Schneider's method

Using this method, a mid-point is marked on the file at the level of the canal orifice. A straight line is drawn parallel to the image and that point is labelled as point A. Another second point B is marked where the flare starts to vary. A third point C is marked at the apical foramen and the angle formed by the intersection of these lines is measured. If the angle is less than 5°, the canal is straight; if the angle is 5-20°, the canal is moderately curved; and if the angle is greater than 20°, the canal is classified as a severely curved canal.[9,10]

Lutein method

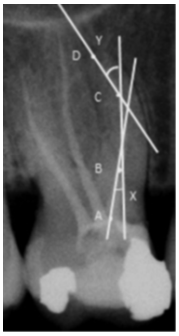
Lutein et al. modified Schneider's method by using two lines drawn by the recognition of 4 geometric points. Point A is first marked at the centre of the canal orifices and then point B is marked 2 mm under the orifices in the long axis of the canal. A first primary line is drawn joining point A and point B and then point C is marked 1 mm coronal to the apical foramen. Point D is marked at the apical foramen then a second primary line is drawn merging these two lines. The angle formed by convergence of the two lines is measured as in the Schneider method.[11]

Cunningham's and Senia's method

This approach is different as it focuses on multiple root curvatures, that is, S-shaped canals, and the angle is measured differently at the coronal and apical ends. Point A is first drawn at the middle of the orifices and then Point B is marked where the deviation or curve of the canal starts and a line is drawn merging these two lines. Point C is then marked where the canal again deviates and point C is joined with point B. Point D is finally marked at the apical area and joined with point C. The angle formed by the intersection of lines through points A and B and then points B and C is named angle X while the angle formed by the junction of lines through points B and C and points C and D is named angle Y.[12]

Weine's method

Weine described a different method for the determination of root canal curvature similar to Schneider's method but showed the differences in the angles according to curvature of the canal. In this method, a straight line is drawn from the canal orifices to the point of curvature and a second line is drawn from the apex for the apical curvature and the angle is measured at the point between the two lines.[13]



Diagrammatic representation of Cunningham's and Senia's method

Several authors conducted various studies on the determination and management of root canal curvature:

Southard et al 1987:

50 root canals in extracted human molar teeth were assigned to two curvature groups, unidirectional and S curve and canals were biomechanically prepared with straight Unitek K files to a file size #45 using the technique of Roane. The position in the root canal of a series of instruments from file #20 to #45 was compared with the original position in the canal of a #10 or #15 file by means of a method utilizing drawings and projected radiographs. His study suggests that effective instrumentation of curved root canals may be achieved with straight instruments of fairly large size without major deviation from the original canal position.[14]

Hankins & Eldeeb 1996

The step-back (SB), balanced-force (BF), and Canal Master (CM) instrumentation techniques were compared in 53 mesial canals of mandibular molars using two instrument types: Flex-R and CM. The BF technique was significantly faster than either SB or CM. The remaining mesial-distal root structure at all levels was similar among groups.[15]

Harlan et al 1996:

The Flex-R file was compared with the Onyx nickel titanium file in respect to canal center movement and final canal area after balanced-force instrumentation. Results showed no significant changes in canal center movement or post-instrumentation area when Flex-R or Onyx files were used at the apical section. Coronally, the Flex-R files demonstrated greater movement of the canal center.[16]

Pettiette 1996:

The purpose of his study was to compare the effect of the type of instrument used by students on the extent of straightening and on the incidence of other endodontic procedural errors. Nickel-titanium 0.02 taper hand files were compared with traditional stainless-steel 0.02 taper K-files. By superimposing tracings from the preoperative on top of the postoperative radiographs, the degree of deviation of the apical third of the root canal filling from the original canal was measured. The presence of other errors, such as strip perforation and instrument breakage, was found by analyzing the radiographs. In curved canals instrumented by stainless-steel K-files, the average deviation of the apical third of the canals was 14.44 degrees. The deviation was significantly reduced when nickel-titanium hand files were used to an average of 4.39 degrees. The incidence of other procedural errors was also greatly reduced by the use of nickel-titanium hand files.17

Willershause 2006:

Aim of the study was to determine the position of the root canal curvature and measure the distance from the CEJ to the first curvature using in vitro methods. The results showed that a more number of maxillary premolars had a curvature with a median value of 8 mm apically from the CEJ. Their findings suggest that such measurements can be used to consider during endodontic treatment and post insertion.[18]

Fuentes 2015:

Aim of the study was to describe the degree and orientation of root curvature in mandibular premolars and to identify the radicular third in which the curvature begins, using digital panoramic radiographs and linear morphometry. They also aimed to identify the prevalence of excessive root curvatures or dilacerations A statistically significant association was found between tooth type and orientation of the curvature and between the tooth third in which the curvature begins and the orientation of the curvature. In respect to mandibular premolars, 72.09% have root curvatures. Most curvatures begin at the apical third. The prevalence of dilacerations was 0% to 30.27%. From the results it is believed that knowledge of the anatomy of the tooth root is required before performing dental procedures. [19]

Fuentes 2018:

Aim of the study was to describe the degree of curvature in distal roots in the permanent mandibular molars. 412 teeth and roots were analysed, finding a dilaceration prevalence of 0.73%. 84.72% of the roots presented some type of curvature. The middle third had the highest percentage of curvatures and the greatest average of angular curvature, whereas the cervical third was the straightest. The analysis of curvature by root third offers to the clinician a better idea of the directional change of the roots and does not limit it to just the presence of curves. The report of the angular degree of the curvatures, informs to the clinicians about the likelihood of finding complexities when treating root canals. [20]

Backman 1992:

The ability of 2 instrumentation techniques to negotiate and enlarge small curved canals was compared radiographically. The Progressive Enlargement technique and Balanced Force technique were both capable of instrumenting small curved canals to their respective largest apical preparation sizes. However, at sizes equivalent to the largest apical preparation sizes used in the PE technique, the BF technique produced significantly less deviation from the center of the main canal. [21]

Kyomen 1994:

In a laboratory study, the apical force necessary to cause files of sizes #10 to #70 to bend and conform to an average canal curvature was determined. These measurements were then related to the apical forces applied to teeth when using the Balanced Force technique in a simulated clinical setting. It was then put forward that the apically directed force necessary to prevent coronal movement of the file and to effect dentinal shearing during counter clockwise rotation placed the file in compression, flexing it to conform to the curvature of the canal. This explanation was similar to the experimental data for the files used in this study up to size #60 for an average canal curvature and for average instrumentation forces.[22]

Thompson 1995:

Aim of the paper is to describe an in vitro method which provides clear and accurate details of root canal shape. The method uses the technique of contact microradiography to produce high resolution, two-dimensional, real-size images of canals in a longitudinal plane. Specimens can be accurately rotated through 90° allowing images to be produced in a bucco-lingual and mesio-distal direction. The method is simple, relatively quick and can process large numbers of teeth without the need for complicated and expensive mounting blocks or film holders. The technique can be used to produce pre- and post-operative images of canal shape which can be superimposed to outline the dentine removed during canal preparation. The method is thus good for the evaluation of the shaping ability of endodontic instruments and preparation techniques.[23]

Nagy 1995:

The aim was to give a mathematical data of root canal forms with the help of differentiated geometrical pattern analysis and computer graphics. Classification of root canal morphology on the grounds of Schneider's angle is different from the classification of geometrical pattern analysis. 4th-degree function approximation as a new method for the explanation of the shape of root canal curvatures seems to be exact and reliably repeatable. This type of classification of root canals is fit for standardizing test specimens, including natural human teeth used for testing root forms: I (straight), J (apical curve), C (entirely curved), or S (multicurved).24

Pruett 1997

Cyclic fatigue of nickel-titanium, engine-driven instruments was studied by ascertaining the effect of canal curvature and operating speed on the breakage of Lightspeed instruments. A new method of canal curvature evaluation that addressed both angle and abruptness of curvature. Results indicate that, for nickel-titanium, engine-driven rotary instruments, the radius of curvature, angle of curvature, and instrument size are more significant than operating speed for predicting separation.25

Lopes 1997:

The purpose of his investigation was to determine the occurrence of apical transportation after root canal instrumentation using only K-Flexofiles or K-Flexofiles intercalated with K-Flexofile Golden Mediums. For this purpose, the degree (Schneider's method) and the radius of the curvature was determined before and after instrumentation. The results showed that there was no statistically significant difference between the techniques.26

Dobo-Nagy 2000:

The objective of the present study was to determine the 3D root canal axis mathematically. The root canal axis that is described by the 3D function forms a basis for determination of curvature values and torsion values in each of the axis points. Evaluating these values may also yield a new type of classification.[27]

Schafer 2002:

Canal curvatures of 700 permanent human teeth were determined by measuring the angle and the radius of the curvatures and the length of the curved part of the canal. The greatest angle of all the teeth was 75 degrees with a radius of 2 mm. To define the canal curvature mathematically and unambiguously, the angle, the radius, and the length of the curve should be given.[28]

Iqbal 2003:

A new radiographic technique was used to compare apical transportation in four Ni-Ti rotary instrumentation sequences. The results indicate that the operational sequence of ProFiles or preinstrumentation with GT files has no effect on degree of transportation and loss of WL.29

Gunday 2005:

In the first part of his study the Schneider (S), Weine (W), and Long-Axis (LA) techniques are used for comparing the measurement of canal curvature. In the second part of this study the term "canal access angle" (CAA) was introduced and it was defined by examining the morphology of canal curvature. Canal length, curvature distance (y), curvature height (x), Schneider angle, and the newly defined CAA were evaluated statistically. The results indicated that the CAA is a more effective way of evaluating the root canal curvature.30

Sonntag 2006:

The aim of his paper is to present a new method based on numeric calculus to provide data on any type of root canal curvature at any point of the long axis of the canal. Twenty severely curved, simulated root canals were prepared with rotary FlexMaster® and

Profile® instruments in the crown-down technique and manually in the step-back technique. The inner and outer curvatures were registered in a system of coordinates before and after preparation in increments of 0.5 mm. The method offers a means of determining curvatures precisely without random specification of reference points. The method is also capable of registering only minor changes in curvature in the two-dimensional long axis of the canal.[31]

Peters 2000:

Aim of his study was to evaluate the potential and accuracy of a three-dimensional, non-destructive technique for detailing root canal geometry by means of high-resolution tomography. Root canal geometry was accurately assessed by this innovative technique; therefore, variables and indices presented may serve as a basis for further analyses of root canal anatomy in experimental endodontology.[32]

Bergmans 2001

Aim of the paper was to present an objective methodology for quantitative evaluation of root canal instrumentation using microcomputer tomography, together with developed software based on a constructed mathematical model. This methodology is a new and objective way for quantitative evaluation of root canal instrumentation using microcomputer tomography and dedicated software.[33]

Lee 2006:

The purpose of the study was to measure the three-dimensional (3D) canal curvature in maxillary first molars using micro-computed tomography (microCT) and mathematical modeling. This study has measured the 3D curvature of root canals in maxillary first molars and reinforced the value of microCT with mathematical modeling.[34]

Estrela 2008

The article describes and discusses a method to determine root curvature radius by CBCT. The higher accuracy of CBCT images to identify anatomic and pathologic alterations compared to panoramic and periapical radiographs has been shown to reduce the incidence of false-negative results. The CBCT-aided method for determination of root curvature radius presented is easy to perform, reproducible and allows a more reliable and predictable endodontic planning, which reflects directly on a more efficacious preparation of curved root canals.[35]

Eaton 2015:

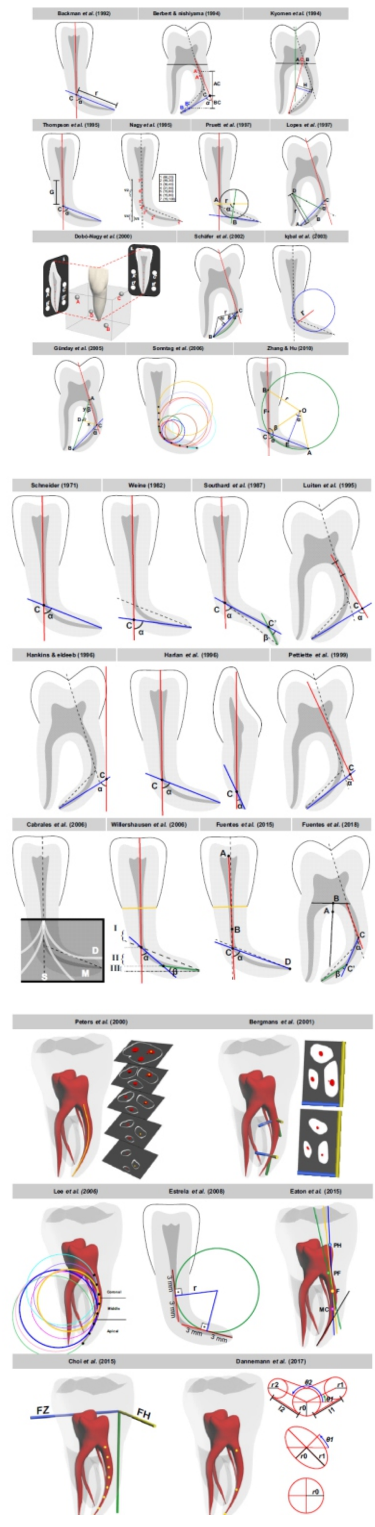
The study investigated the influence of anatomic root canal system landmarks on access outline forms of mandibular molars and correlated these to the theoretical distance of orifice relocation and changes in canal primary curvature. The use of different landmarks to establish access outline designs affected the primary angle of curvature in relatively calcified mandibular molars.[36]

Choi 2015

The study evaluated the prevalence of distolingual roots in mandibular molars among Koreans, the root canal system associated with distolingual roots, and the concurrent appearance of a distolingual root in the mandibular first molar and a C-shaped canal in the mandibular second molar. The canal curvature of distolingual roots was found to be very complex, with a different direction in each portion. No correlation was found between the presence of a distolingual root in the mandibular first molar and the presence of a C-shaped canal in the mandibular second molar.37

Dannemann 2017

The study aimed to design and realize a method for analyzing the geometric characteristics of human root canals. 2 extracted human molars were radiographed in the occlusal direction using micro-computed tomographic imaging. The 3D geometry of the root canals, calculated by a self-implemented image evaluation algorithm, was described by 3 different mathematical models: the elliptical model, the 1-circle model, and the 3-circle model. The different applied mathematical models obtained similar geometric properties depending on the parametric model used. Considering more complex root canals, the differences of the results increase because of the different adaptability and the better approximation of the geometry. With the presented approach, it is possible to estimate and compare the geometry of natural root canals. Therefore, the deviation of the canal can be assessed, which is important for the choice of taper of root canal instruments. Root canals with a nearly elliptical cross-section are reasonably approximated by the elliptical model, whereas the 3-circle model obtains a good agreement for curved shapes.[38]



CONCLUSION

Root canal treatment can be very challenging for an endodontist due to complex anatomy and the presence of severe root curvatures that causes hindrance during ideal preparation of the canal. The curvature may vary from gradual curvature of the entire canal, sharp curvature of the canal near the apex, or a gradual curvature of the canal with a straight apical ending. S-shaped canals (double curvature) may also occur and success in negotiating these canals depends on the size and construction of the canal, degree of curvature, size and flexibility of the instrument, along with the skills of the operator. Therefore, preoperative assessment of the horizontal and vertical variations of the canals should be done and a proper instrumental technique is very necessary to avoid procedural errors. Moreover, hand instrumentation is a time-tested, easy, and economic method for root canal treatment but care must be taken during their use to avoid problems like ledge formation, creation of zip, transportation, and instrument breakage. In severely curved canals, the use of rotary NiTi files after making a glide path with hand stainless steel files is recommended.

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