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ORIGINAL ARTICLE

Tooth anatomy risk factors influencing root canal working length accessibility

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The aim of this study was to analyze the specific influence of root canal anatomy on the accessibility of working length during root canal therapy. Four hundred seventy-six root canal therapy cases (amounting to a total of 1 005 root canals) were examined. The anatomy risk factors assessed in each case included: tooth type (tooth location), root canal curvature, and root canal calcification, as well as endodontic retreatment. The investigation examined the correlation between each of these anatomic factors and the working length, with statistical analysis consisting of Chi-square tests and multiple logistic regression analysis. In an independent factor analysis, tooth type (tooth location), root canal curvature, canal calcification, and endodontic retreatment were determined to be the primary risk factors. In a multiple-factor regression model, root curvature and canal calcification were found to most significantly influence root canal working length accessibility ($P<0.05$). Root canal anatomy increases the difficulty of root canal preparation. Appropriate consideration of tooth anatomy will assist in accurate determination of preparation difficulty before instrumentation. This study alerts clinical therapists to anatomical factors influencing the working length accessibility, and allows for a direct estimate of success rate given in situ measurements of tooth factors during the root canal treatment procedure.

***Keywords*:** root canal anatomy; root canal preparation; root canal treatment; working length

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Introduction

Endodontic disease is associated with multiple-bacterial infection, where root canal therapy serves as a significantly effective treatment method [1-2]. Although successful therapy depends on many factors, one of the most important steps in any root canal treatment is canal preparation [3]. Canal preparation determines the degree of control over the complete elimination of root canal contents, which is crucial to debridement infection [4-5]. A number of studies have indicated that the ability of the dental instrument to access the full root canal length (called the working length accessibility) significantly affects the success of the root canal treatment. Negishi reported that inaccessibility of the apical anatomy significantly impairs the success of root canal treatment [6]. Consistently, researchers [7] showed that an instrument that reaches to the apical constriction gives the best prognosis. These results suggest that establishing and maintaining adequate working lengths is critical for root canal treatment.

Unfortunately, canal preparation is adversely affected by the highly variable nature of root canal anatomy [8-9]. Many problems that occur during root canal preparation, such as missed canals, perforation of the pulp floor, or canal transportation, result from poor knowledge of the

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root canal anatomy. A clear understanding of pulp anatomy and the variations that occur in instrumentation is essential if working length accessibility is to be achieved [10]. However, the influence of the anatomy risk factors relating to working length accessibility have not yet been investigated. In addition, the degree to which working length accessibility is affected by anatomy risk factors has not been elucidated.

The aim of this study was to analyze the specific influence of root canal anatomy on the accessibility of working length during root canal therapy. We assessed the effect of anatomy factors on working length accessibility using a statistical analysis.

Materials and Methods

Cases selection and classification

476 cases with a total of 1 005 root canal therapies (RCT) were consecutively selected from the Conservative Dentistry Department, West China Stomatology hospital, between August 2007 and February 2008. Information associated with each case, including the tooth type (tooth position), root canal curvature, canal calcification and the previous endodontic treatment history, were recorded. All patients were fully informed and gave their consent to participation in the study. The experimental procedure was approved by the Ethical Committee Board of West China School of Stomatology, Sichuan University.

During the RCT procedure, radiographs (TROPHY Radiology S.A. Paris, France) were taken to observe the tooth anatomy of the patient. Radiographs, in TIFF format were analyzed with Image-Pro Plus 5.0 software (Media Cybernetics Company, America).

The cases were further classified in terms of tooth location (type), root canal curvature, canal calcification, and root canal history (Table 1) [11]. The measure of root canal curvature was determined by the Schneider's method [12]. Root canal calcification was classified into three grades. If the degree of calcification shown in the radiographs was not clear, instrumentation was used as follows: (i) #15 K file could reach the root canal constriction easily; (ii) #10 K file could just reach the root canal constriction; (iii) #10 K file or #8 K file could reach the root canal constriction under some measures, or the instrument could not reach.

Table 1 Case-classification criteria for risk factors

Factor	Case-classification criteria
Tooth type (position)	1 anterior tooth
	2 premolar
	3 molar
Canal calcification	1 canal(s) visible and not reduced in size
	2 canal(s) and chamber visible but reduced in size; pulp stones
	3 indistinct canal path; canal(s) not visible
Canal curvature	1 short or no curvature($\leq$10°)
	2 moderate curvature(10°–30°)
	3 extreme curvature ($\geq$30°)
	or S-shaped curve
Endodontic treatment history	1 no previous treatment
	2 previous access without complications
	3 previous access with complications (*e.g*., perforation, non-negotiated canal, ledge, separated instrument); previous surgical or nonsurgical endodontic treatment completed

According to international normalization classification-AAE [11].

Root canal preparation

In all selected cases (1 005 root canals) the same method, instruments and materials were used for treatment. The root canals were prepared by stainless-steel hand K files using the step-back technique. The canal was cleaned and shaped to a size of at least three ISO sizes larger than the master apical file (#25). In some difficult cases, if the smaller #10 or #8 instruments could not reach the root apex before enlarging the root canal, it was prepared as far as possible. During preparation, root canals were irrigated with 2.5% NaClO with every change of instrument. With re-treatment of previously root canal-filled teeth, the root canal fillings were softened with chloroform and removed with H files.

Teeth were subsequently prepared following the above-mentioned method.

Evaluation of Working Length Accessibility

Working length accessibility was affirmed if after preparation, a Root ZX electronic apex locator (J. Morita Corp., Kyoto, Japan) indicated that the master apical #25 K file could reach the root canal constriction. The K file was confirmed to a point 0.5–1.0 mm short of the root apex *via* the X-ray radiographs.

Working length inaccessibility was affirmed if instruments could not reach the root canal constriction as indicated by electronic apex locator after the preparation. In addition the K file was confirmed to exist at a point short of the root apex (>1.0 mm) using X-ray radiographs.

In the evaluation of preparation, all radiographs were analyzed separately by two independent observers. In cases of disagreement, the opinion of a third specialist was taken as final. The weighted kappa for inter-observer agreement with the consultant was larger than 0.86.

Statistical Analysis

The working length accessibility was used as the dependent variable. Remaining variables were used as predictors. Logistic regression analysis was also used to determine significant association between the anatomy factors and results of the root canal preparation. All independent variables were initially analyzed using the Chi-square test to screen for significant factors. All significant variables were then combined into a multiple logistic regression model to determine the effect of the group of variables on the root canal preparation. A P value of <0.05 was used as the cutoff value for all analyses. Statistics were computed by using SPSS 13.0 software (SPSS 13.0, SPSS Inc., Chicago, USA).

Results

Single factor analysis

Table 2 summarizes statistical results of the Chi-square test, which indicated that the anatomy factors of: (i) tooth type (tooth position), (ii) root canal calcification and (iii) curvature were statistically significant variables contributing to the root canal work length accessibility. When difficulty in classification increased, the success rate of working length accessibility decreased. Previous endodontic treatment also significantly influenced working length accessibility (Table 3).

Table 2 Statistical outcome in each risk and difficulty factor

Variables	Total root canal number	Success root canal number	Success rate /%	χ^2	P test
Tooth type					
Anterior tooth	137	128	93.43		
Premolar	168	148	88.10	8.406	0.015
Molar	700	591	84.43		
Root calcification					
1	819	757	92.43		
2	149	106	71.14	232.876	<0.001
3	37	4	10.81		
Root curvature					
1	513	478	93.18		
2	369	295	79.95	43.190	<0.001
3	123	94	76.42		

Table 3 Previous endodontic treatment history

Treatment history	Total root canals number	Success root canal number	Success rate /%	χ^2	P
1	695	627	90.22		
2	216	168	77.78	29.712	<0.001
3	94	72	76.60		

Multiple factors analysis

The results of logistic regression model screening for anatomy risk factors are listed in Table 4. In the multiple-factor model, two factors were shown to have the most significant impact on root canal preparation results: (i) root canal curvature and (ii) calcification with $P<0.05$. Tooth type or location was less closely related with the working length accessibility ($P>0.05$).

Table 4 Logistic regression analyses

Variables	Coefficient	Standard error	Wald value	*P* value	OR
Location	0.357	0.194	3.390	0.066	1.429
Curvature	0.677	0.150	20.238	0.000	1.967
Calcification	1.924	0.169	129.740	0.000	6.847
Constant	-6.653	0.638	108.622	0.000	0.001

Discussion

In this study, single and multi-factor models were utilized to determine anatomical factors influencing the working length accessibility. It was determined that the success rate in teeth with complex anatomy is lower than in cases with simple and normal anatomy, indicating an effect of tooth position/type. In multi-factor analysis canal curvature and calcification were found to significantly increase the difficulty of achieving working length accessibility.

Root canal instrumentation includes both cleaning and shaping of the canal. Cleaning is the significant reduction of tissue as well as micro-organisms and their by-products from the pulp system. Ideally, instrumentation should terminate at a suitable location, making working length accessibility among the most important factors for the successful root canal preparation [7, 13]. A large number of studies have demonstrated that familiarity with root canal anatomy increases the success rate of root canal preparation [14-15]. Representative root canal anatomy features and their relation to successful root-canal preparation were chosen as parameters in our study.

Accurate determination of working length during a root canal preparation is a challenge. Post-preparation radiographs were generally taken to determine whether or not instruments reached the apical constriction [16]. Unfortunately, the physiological apical foramen is not a constant feature, and can only be detected in histological sections. Electronic apex locators can be recommended to complement and assist radiographic methods of working length determination [17]. In clinical practice, they can determine a position within 0.5 mm of the foramen in >90% of occasions [18]. Therefore, working length was measured from post-preparation radiographs and electronic apex locators in order to verify weather root canals were prepared effectively.

Our study demonstrated that the posterior teeth, due to complex morphology, significantly influenced the working length accessibility compared to the canal morphology of anterior teeth (success rate of 93.43% versus 84.43%) in a single-factor model. Canal-shaping of human teeth has many difficulties, because each root canal has its own individual form. The anatomy of posterior teeth is more complex than that of anterior teeth, which maybe only a single-canal. In addition, the posterior teeth location in behind the dental arch increases the difficulty of maneuvering and preparation.

Both root canal calcification and curvature are conclusive risk factors in root canal preparation (Table 2). When the degree of curvature increased, the success rate of working length accessibility significantly decreased. It is challenging to achieve optimum cleaning and shaping in curved canals due to the degree of curvature and the radius of curvature [19-20]. The further from the apex the curvature begins, the more irregular the shape of the prepared canal. The root canal calcification also had significant effects on the preparation outcome [21]. However, not many reports have analyzed the influence of root canal calcification associated with working length accessibility. Calcification could result in morphological irregularities and obstructions of the canal, thereby making the achievement of adequate working length difficult.

We found that root canal retreatment had a significant impact on working length accessibility. Removing filling materials from the root canals is one of the major differences between primary endodontic preparation and retreatment. The treatment history was not a direct anatomy factor, however may result in changes to the root canal morphology which influence the root canal

preparation. There is a possibility of ledging and perforation occurring during the retreatment procedure. In addition, retreatment may be associated with difficulties in the elimination of the particular microflora in such cases. Therefore, there is increased difficulty in obtaining adequate working length during endodontic retreatment. This study showed a markedly lower incidence of success in retreated teeth [15, 22].

Based on the above discussed data, an indicator for the success rate of root canal therapy can be calculated given measurements of the significant anatomy factors. Multiple factor analysis identified only two significant variables (root canal curvature and calcification ($P< 0.05$)). In our study, these two factors were divided into three levels and the difficulty of working length accessibility for each level was investigated. As the extent of canal calcification increased one level of intensity, the difficultly in reaching the root canal constriction increased 7 times. Increasing root curvature by one level of intensity resulted in 2 times decrease in the chance of reaching the canal constriction (Table 4). This is one of the few studies to evaluate the influence of several variables on working length accessibility using multiple regression analysis.

In clinical treatment, preoperative radiographs are taken to comprehend root canal anatomy status. From tooth radiographs, root canal curvature, calcification and treatment history can be determined. Based on the conclusions of this study, once the information is obtained, the difficulty of the preparation will be known, and the prognosis can be anticipated.

Conclusions

This is one of the few studies to evaluate the effect of canal calcification and to determine the influence of several variables on working length accessibility using multiple regression analysis. This study alerts clinical therapists to anatomical factors influencing the working length accessibility, and allows for a direct estimate of success rate given in situ measurements of tooth factors during the root canal procedure.

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