Morphological Changes of The Root Apex In Anterior Teeth With Periapical Periodontitis: An In-Vivo Study

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Research Article

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Morphological Changes of the Root Apex in Anterior Teeth with Periapical Periodontitis: an in-vivo study

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Abstract

Introduction

The aim was to analyze the morphological changes of root apex in anterior teeth with periapical periodontitis.

Methods

32 untreated anterior teeth with periapical periodontitis were enrolled, compared with the healthy contralateral teeth. Cone-beam computed tomography was used to measure diameter of the apical constriction. 3D reconstruction technique was used to reconstruct the teeth, analysis the constriction forms, and measure the distances of constriction to apical foramen and anatomical apex respectively.

Results

The difference value between buccolingual and mesiodistal diameter was (0.06±0.09) mm in periapical periodontitis and (0.04±0.04) mm in healthy teeth ($p<0.05$). The mean distances between apical constriction and anatomical apex were (0.97±0.25) mm and (1.59±0.48) mm in periapical periodontitis and healthy teeth. The mean distances of apical constriction to apical foramen were (0.39±0.12) mm and (0.70±0.18) mm in periapical periodontitis and healthy teeth. The most common form of apical construction was flaring (65.6%) in periapical periodontitis.

Conclusions

The anterior teeth with periapical periodontitis had shorter distances of apical constriction to anatomical apex and apical foramen, bigger disparities between the diameters of buccolingual and mesiodistal, and higher proportion of flaring apical construction.

Keywords

periapical periodontitis; anterior teeth; Cone-beam computed tomography; 3D reconstruction; root apex morphology

1 INTRODUCTION

Periapical periodontitis (AP), also known as periapical lesion, is one of the most common dental diseases in clinical work. It could cause periapical tissues destruction, hard tissue resorption, and local inflammation. The main clinical symptoms were swelling, pain, tenderness and sinus tract formation. Increased inflammation may promote more obvious bone resorption and the formation of radicular cysts (1). If an apical lesion developed into a cyst, root canal therapy might not be sufficient. Sometimes, apicectomy or even extraction of the affected teeth could be required(2). On the other hand, recent studies have found that AP was associated with cardiovascular diseases, diabetes mellitus and coronary heart disease(3, 4). Numerous epidemiological studies have investigated the incidence of AP, ranged from 27% to 64%(5-7).

It is well known that endodontic therapy is the basic treatment for periapical diseases nowadays. The successful rate was ranging from 50%–97%(8-10). It is found that apical morphology was a significant factor related to the clinic curative effect of root canal treatment(11). With scanning electron microscopy (SEM), external apical root resorptions areas with irregular surface and different depths were found around the apical foramen of teeth associated with chronic periapical periodontitis(12). Root resorptions could destroy the apical root structure in different degrees, and lead to various configurations(13).

In recent years, researches achieved a better understanding of influences of AP on the morphology at the root apex. These studies focused on ultrastructure of apical surfaces using scanning electron microscopy(12) or micro-computed tomography (micro-CT)(14, 15). Both of them provide high resolution owing to the high energy parameters and smaller voxel sizes, but require high radiation doses and long scanning time, which makes them limited to laboratory studies. Although there have been some in-depth studies, this area as a whole is still lack of systematic.

Cone-beam computed tomography (CBCT) scanning is a noninvasive method, which could be directly used on patients. Accordingly, by the use of cone-beam computed tomography, the present study aimed to analysis the morphological changes of root apex in anterior tooth with periapical periodontitis in a Chinese subpopulation, in order to provide a new insight into root canal therapy with periapical periodontitis.

2 MATERIALS AND METHODS

2.1 Sample selection:

Patients visited Nanjing Stomatological Hospital, Medical school of Nanjing University between January 2018 and February 2019 and underwent CBCT for reasons independent of the present study, including orthodontic treatment or implants unrelated to the present study. CBCTs were also performed independent of this study. The inclusion criteria were: adult patients; anterior teeth with periapical lesion (radiographically by CBCT images) and the contralateral homonymous teeth without periapical lesion; single root canal; without root canal treatment, post, or crowns; no calcified root canals; a fully formed apex. Through case history inquiry, the patients with the history of developmental disorders, systemic disease, malignancy, orthodontic treatment and trauma were excluded. Only high-resolution images were included to ensure analytic accuracy.

Finally, the study consisted of 32 patients (18 females and 14 males), with a mean ± SD age of 38.0 ±11.5 years. The patients enrolled were Chinese born in China. All patient-related materials and data were stored anonymously and only made available to the study investigators. Written informed consent was obtained from all the participants in the study, which was approved by the Ethics Committee of Nanjing Stomatological Hospital, Medical school of Nanjing University (NO: JX-2020NL-013).

2.2 Image Acquisition

All CBCT images were obtained by a NewTom VG scanner (QR srl, Verona, Italy). The voxel size was set 0.125 mm and operated according to the manufacturer's instructions. All CBCT exposures were performed by an experienced licensed radiologist with the minimum exposure necessary for adequate image quality, following strictly the as low as reasonably achievable protocol.

The images were exported in Digital Imaging and Communications in Medicine (DICOM) data format. Then the data were imported into 3D Slicer 4.8.1 (https://www.slicer.org/), a free open-source software for medical image processing(16), analyzed using a 13.9-inch HUAWEI Mate Book X Pro 2020 (HUAWEI Corporation, Shenzhen, China) screen with a resolution of 3000*2000 pixels in a darkroom.

2.3 Two-dimensional (axial slices) measurement

The apical construction was defined to be the apical cross sections having the smallest area(17). According to Schell's methods(18) of determining the location of apical constriction, CBCT analysis of serial cross sections, perpendicular to the canal axis, were analyzed from both buccolingual (BL) and mesiodistal (MD) aspects. The root canal measurements included BL and MD diameters from the apex. CBCT images were carefully examined from the pulp chamber to the apical apex by continuously scrolling the toolbar on axial view to evaluate the topography of the apical constriction. By rolling the middle axis of the mouse, the grayscale value was continuously changed, until the best display was obtained. On the axial view, the diameters of BL and MD were measured (Figure 1), and the difference value of diameter between BL and MD was calculated. According to the diameter of BL and MD, two operators determine the location of the apical constriction individually, until a consensus was reached.

2.4 3D reconstruction and Measurement

Each structure including root and canal was assigned a label. By using the "Editor" module of 3D Slicer software tools, the contour of tooth image (root canal and root) was segmented semi-automatically or manually slice by slice, with a mouse. The segmentations were mainly performed on axial slices. In addition, some adjustments were then performed on sagittal and coronal views. By using the image processing tool in the software, the brightness and contrast were adjusted to achieve optimum visualization. Then the anatomical structures (roots and canals) were reconstructed using the "Merge And Build" module of 3D Slicer. Similarly, the optimal reconstruction was ensured by adjusting the opacity of the images.

In this study, according to the topography of the apical constriction of Schell(18), the parallel form was recognized when the minor diameter of the canal extended steadily for a long distance (>2.5 mm) and only widened for a short distance (0.1 mm) at the foramen. When the canal walls widened apically and coronally from the narrowest zone, it was considered to be traditional. In the flaring form, the canal walls constantly diverged towards the apex. Three forms of constriction morphologies were observed in the buccal-lingual views and the mesiodistal views of the 3D models (Figure 2).

Horizontal red lines in Figure 2 were portrayed in the apical region (approximately 1-3 mm) where a constriction might be present. The apical morphology between the red lines was examined and categorized by evaluators in the longitudinal view of reconstructed teeth. The constriction forms were subdivided into traditional, parallel and flaring.

In the 3D model of teeth, the distances from apical constriction to foramen (AC-AF) and to anatomical apex (AC-AA) of each canal were recorded. On 3D views, the distance of AC-AF and AC-AA were measured directly (Figure 3).

2.5 Radiologic evaluation

To check for the inter- and intra-observer reliabilities, manual segmentations were performed twice for each of 10 teeth which were not included in this study by two independent examiners, with a 1-week interval between the assessments. The inter-examiner agreement value was 0.854. The intra-examiner agreement values were 0.878 and 0.889 respectively for the first and second assessments.

2.6 Statistical analysis

Results from the evaluators were collected and analyzed. Percentages and frequencies were used to describe categorical variables. Quantitative data from measurements were presented as mean and standard deviation. Comparisons were made between periapical periodontitis teeth and healthy teeth data (AC-AA, AC-AF) through paired *t* tests with a significance level of 5%. Differences in constriction forms were analyzed by Fisher exact test or Chi square test according to gender. Statistical Package for Social Sciences 25.0 (IBM Co, New York, NY) was used for statistical analysis. The significance level was set at $p < 0.05$.

3 RESULTS

In this retrospective study, a total of 64 teeth in 32 patients were analyzed. According to the diameter of BL and MD, the apical constriction was located in each tooth. The mean BL diameter of apical constrictions were (0.32±0.10) mm and (0.28±0.08) mm in anterior teeth with periapical lesions and healthy teeth (p <0.05). The mean MD diameters of apical constriction were (0.26±0.06) mm and (0.24±0.07) mm in anterior teeth with periapical lesions and healthy teeth (p >0.05). The difference value between BL and MD diameter was (0.06±0.09) mm in teeth with periapical periodontitis and (0.04±0.04) mm in healthy teeth. Difference in the disparity between the diameters of BL and MD was statistically significant between AP and healthy teeth (p <0.05) (Table 1).

By the longitudinal perspective view of 3D reconstructed teeth, the constriction forms of apical areas were analyzed (Table 2). The constriction forms in order of frequency were flaring (65.6%), parallel (28.1%), traditional (6.3%) in anterior teeth with periapical periodontitis, while the constriction forms in healthy teeth were parallel (75.0%), traditional (25.0%). Significant differences were not found between sexes (p >0.05) (Table 2). In teeth with periapical periodontitis, there were 9 cases with the parallel constriction, 2 cases with the traditional constriction, and 21 cases with the flaring constriction. In healthy teeth, there were 24 cases with the parallel constriction, 8 cases with the traditional constriction. The distributions of the constriction forms in periapical lesions and healthy teeth were shown in Figure 4(c). Among the three constriction forms, the flaring constrictions were only found in the teeth with periapical periodontitis.

Measurements of distances between AC to AA and AF were depicted in Table 3 and Figure 4. The distances between AC and AA were (0.97±0.25) mm in anterior teeth with periapical lesions (Table 3). Among them, there were 23 cases (71.9%) with the distance between 0.5-1.0 mm, 7 cases (21.9%) with the distance between 1.0-1.5 mm, and 2 cases (6.3%) with the distance of 1.5-2.5 mm (Figure 4(a)). The distances between AC and AA were (1.59±0.48) mm in healthy teeth (Table 3). Among them, there were 18 cases (56.3%) with the distance between 1.0-1.5 mm, 9 cases (28.1%) with the distance between 1.5-2.0 mm, and 5 cases (15.6%) with the distance over 2.0 mm (Figure 4(a)).

The distances between AC and AF were (0.39±0.12) mm in anterior teeth with periapical lesions (Table 3). Among them, there were 26 cases (81.3%) with the distance under 0.5 mm, 6 cases (18.8%) with the distance between 0.5-1.0 mm (Figure 4(b)). The distances between AC and AF were (0.70±0.18) mm in healthy teeth (Table 3). Among them, there were 3 cases (9.4%) with the distance under 0.5 mm, 26 cases (81.3%) with the distance between 0.5-1.0 mm, and 3 cases (9.4%) with the distance of 1.0-1.5 mm (Figure 4(b)). The distances of AC-AA and AC-AF differed significantly in anterior teeth with or without periapical lesions ($p < 0.05$).

4 DISCUSSION

The present study provided a detailed anatomical description of morphological changes of the root apex in anterior teeth with periapical periodontitis based on a retrospective analysis of CBCT images. Numerous methods could be used to evaluate morphology of root apex, such as intraoral periapical radiograph(19), longitudinal cutting(20), stereomicroscope(21), micro-computed tomography(14, 18, 22-26) and CBCT(27). Among these methods, CBCT and periapical radiography meet both non-invasive requirements and in-vivo conditions. Various studies have shown that CBCT is much more reliable than periapical radiography in diagnosing complex root canal morphology, because it could provide three-dimensional images of three-dimensional objects(28). Moreover, CBCT has been proved to be more sensitive and accurate to identify apical periodontitis than the two-dimensional imaging technique(29, 30). In the accuracy of detection of the root canal configuration, CBCT imaging has been showed no difference with the gold standard (micro-CT)(31).

In our study, an apical constriction was found in all the root canals examined. The results were similar to the researches of Schell(18) and Dummer(32). However in the studies of Meder-Cowherd(26), Marceliano-Alves(24) and Wu(33), apical constriction was not identified in every root. The reason may be that two different longitudinal sections (buccal/lingual or mesial/distal view) of the same canal showed different topographical canal outlines, so longitudinal section could not show the narrowest part of the canal(25). In many canals, the narrowest part only could be detected by analyzing the cross-sectional areas along the path of the root canal.

It is usually considered that the ideal apical end point of root canal therapy was the apical constriction(17). The size of the root canal instruments was classified by the size of the apical constriction, which was determined by the minimal area of root canal. In most canals, the instrument size was determined by the maximum diameter. In the present study, the disparity between BL and MD diameter was larger in the teeth with periapical periodontitis ($p < 0.05$) (Table 3). Because of the difference, the instrument size that would fit the apical constrictions of teeth with chronic periapical periodontitis may be larger than teeth without apical lesions.

In the present study, the most common form of the constriction was flaring (65.6%) in teeth with periapical periodontitis, while the most common form was parallel (75.0%) in healthy teeth (Table 2). Dummer(32) inspected longitudinal sections and found that the most frequent form of the constriction was the traditional form (46.0%). Meder(26) found that the most frequent form of the constriction in teeth was the parallel form (35.0%). This discrepancy may due to the differences in tooth forms. Dummer studied central incisor, lateral incisors, canines and premolars. In Meder's research, they studied palatal roots of maxillary molars. While in our study, the samples were anterior teeth including central incisors, lateral incisor and canines. What's more, the instruments used to detect the constriction were different. Dummer used the microscopic and Meder used micro-CT, while we made use of CBCT in the present study.

In our study, the distances of AC-AF and AC-AA were different from some researches. In Wolf's study(15), the mean distances between AC and AA were 0.82mm (MB), 0.81mm (DB) and 1.02mm (P) in maxillary first molars, 0.54mm (MB), 0.43mm (DB) and 0.63mm (P) in maxillary second molars. In Mousavi's study under microscopic, the mean distance between AC and AF was 0.85 ± 0.33 mm in incisors, and the mean distance between AC and AA was 1.23 ± 0.39 mm in incisors(34). By the use of microscopic Kutter and Dummer found that the narrowest part of the canal was 0.59 mm to AF(17) or 0.89 mm to AA on average (32). Several reasons may account for the differences. First, the methods were different. Our study was a three-dimensional reconstruction analysis, while other researchers mentioned above conducted only two-dimensional analysis. Second, the samples in the studies mentioned above were extracted teeth. In contrast, the samples in this study were in vivo, which would represent the actual situation better. Third, the ethnic population in this study was different from that in other studies mentioned above. Mousavi studied the Iranian population, while the studies of Wolf and other researches did not account for it. These reasons may result in different distances of AC-AF and AC-AA. In canals without apical lesions, the apical limit for root canal instrumentation and filling is determined by the apical constriction and the apical foramen.

In summary, the present retrospective study provided evidences to support that the teeth with periapical periodontitis had shorter distances of AC-AA and AC-AF, bigger disparities between the diameters of BL and MD, and higher proportion of flaring apical construction. These data may help clinicians to understand the morphological changes of the root apex in anterior teeth with periapical periodontitis and provide references for clinical treatment.

5 Conclusions

The anterior teeth with periapical periodontitis had shorter distances of apical constriction to anatomical apex and apical foramen, bigger disparities between the diameters of buccolingual and mesiodistal, and higher proportion of flaring apical construction.

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The authors deny any conflicts of interest related to this study.

Consents were obtained from all the patients whose CBCT images were used in this study.

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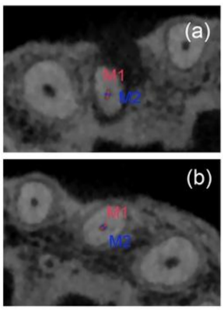

Figure 1: The measurement of apical constriction diameters in CBCT images. Horizontal plane at the apical constriction level of the root canal with AP (a) and without AP (b) were measured respectively. The diameter was determined by drawing a line between the two most distant pixels of the root canal walls. M1 represented the diameter of BL (red line), while M2 represented the diameter of MD (blue line).

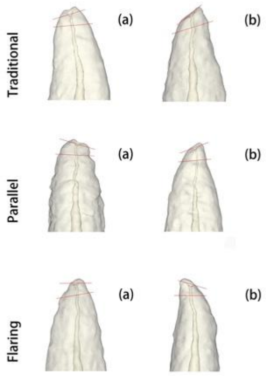

Figure 2: The longitudinal perspective view of reconstructed teeth.
Figure (a) and (b) were the buccolingual views and the mesiodistal views respectively. Horizontal red lines were portrayed in the apical region.

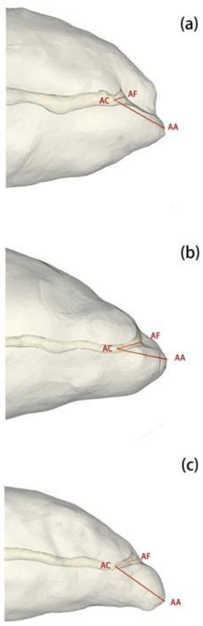

Figure 3: Measurements of different apical constriction forms.
Figure (a) showed the measurement of traditional form, while Figure (b) and (c) were parallel and flaring forms respectively.

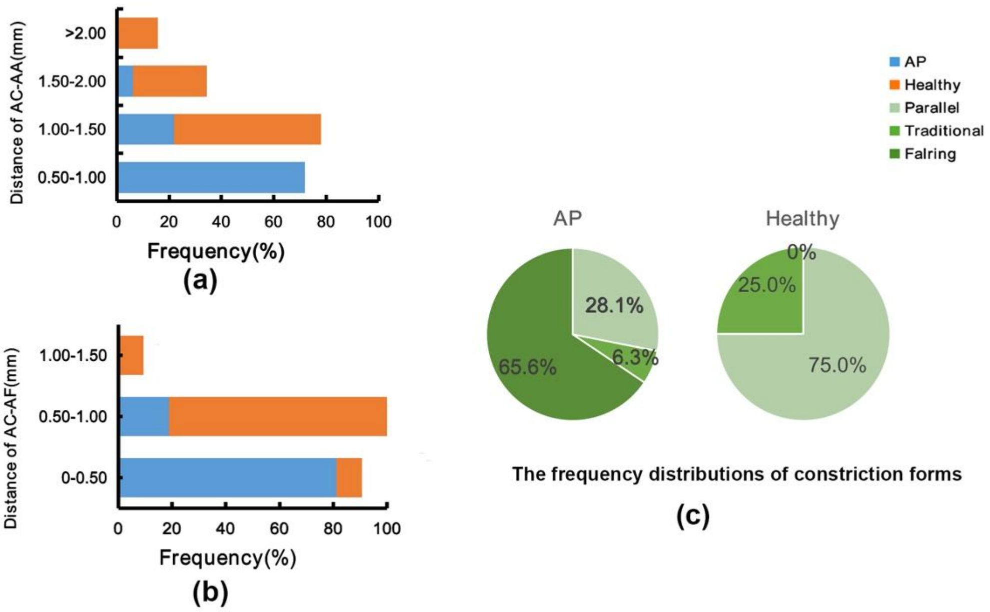

Figure 4: The distributions of AC-AA, AC-AF and constriction forms in periapical periodontitis and healthy teeth.

Figure (a) and (b) showed the distances and distributions of AC-AA and AC-AF in periapical periodontitis and healthy teeth. Figure (c) showed the proportions of different constriction forms in teeth with periapical periodontitis and healthy ones.

Table 1: The difference value between BL and MD diameters(mm) at apical constriction.

Group	BL diameter	MD diameter	BL-MD
	Mean±S.D.	Mean±S.D.	Mean±S.D.
Periapical lesions	0.32±0.10*	0.26±0.06	0.06±0.09*
Healthy teeth	0.28±0.08	0.24±0.07	0.04±0.04

* p<0.05, paired t tests

S.D.: Standard Deviation

Table 2: The distributions of constriction forms in periapical lesions and healthy teeth.

Gender	Periapical lesion(N,%)			Healthy teeth(N,%)			Total
	Parallel	Traditional	Flaring	Parallel	Traditional	Flaring	
Male	3（4.7）	-	11(17.2)	10(15.6)	4(6.25)	-	28(43.8)
Female	6(9.4)	2(3.1)	10(15.6)	14(21.9)	4(6.25)	-	36(56.3)
Total	9(14.1)	2(3.1)	21(32.8)	24(37.5)	8(12.5)	-	64(100)

* *p <0.05*, Fisher exact test

Table 3: Distances of AC-AA and AC-AF (mm) in periapical lesions and healthy teeth.

Group	AC-AA	AC-AF
	Mean±S.D.	Mean±S.D.
Periapical lesions	0.97±0.25*	0.39±0.12*
Healthy teeth	1.59±0.48	0.70±0.18

* *p* <0.05, paired t tests

S.D.: Standard Deviation

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- RawData.xlsx
- dataprocessingd1.zip