Published online: 2019-09-16

Comparative evaluation of apical constriction position in incisor and molar teeth: An *in vitro* study

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ABSTRACT

Objective: The apical constriction (AC) and the apical foramen (AF) are the principal reference points used to determine the apical limit for instrumentation and root canal filling. AC varies in different races, and the aim of the current study was to measure and compare the distances from AC to AF and the anatomical apex (AA) in incisor and molar teeth in the Iranian population. **Materials and Methods:** Forty-five roots of incisor teeth and 45 roots of molar teeth were selected randomly in Isfahan Province, Iran. If the foramen was located toward the mesial or distal side of the apex, the cut was made mesiodistally, and if it was toward the buccal or lingual side, the section was made accordingly. Roots were examined under a microscope at ×25 magnification. The distances from AC to AF and AA were then estimated using a Motic camera. Descriptive statistics were used. The independent *t*-test was also used to compare distances in incisors and molars, and $P = 0.05$ was deemed to indicate statistical significance. **Results:** The mean distances between AC and AF were 0.847 ± 0.33 mm in incisors and 0.709 ± 0.27 mm in molars. The mean distances between AC and AA were 1.23 ± 0.39 mm in incisors and 1.01 ± 0.38 mm in molars. In an independent *t*-test, the distances between AC and AF differed significantly in incisors and molars ($P = 0.035$), but the distances between AC and AA did not ($P = 0.172$). **Conclusion:** The end points for root canal therapy should be 0.85 mm in incisors and 0.70 mm in molars.

Key words: Anatomical apex, apical constriction, apical foramen

INTRODUCTION

Biomechanical cleaning of the pulp chamber and preparation of a root canal system are mandatory steps when aiming to achieve long-term success in root canal therapy. Insufficient cleaning and shaping of the apical zone usually lead to infected tissue and debris remaining in the canal. These undesirable residues in the apical area can lead the resistance of periapical lesions and root canal therapy failure.[1]

In normal root canals, the apical constriction (AC) is considered the narrowest and more apical area

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How to cite this article: Mousavi SA, Farhad A, Shahnaseri S, Basiri A, Kolahdouzan E. Comparative evaluation of apical constriction position in incisor and molar teeth: An *in vitro* study. Eur J Dent 2018;12:237-41.

DOI: 10.4103/ejd.ejd_54_18

to the apex. From AC or minor apical diameter, the canal widens as it approaches the apical foramen (AF) or major apical diameter.[2] The main path between pulp tissue and periodontal tissue is through the apical and lateral foramen. Treatment is only likely to be successful when the entire path of the root has been cleaned and shaped in accordance with a predetermined precise working length (WL).[3]

The exact location of the reference point and obturation can affect the results. By studying preradicular tissue, researchers have concluded that the best prognosis is achieved when root canal treatment terminates at the cementodentinal junction (CDJ).[4] Although the exact location of CDJ is immeasurable, AC is an appropriate and reliable location as the terminus of root canal procedures.[4]

New methods of measuring WL such as electronic apex locators can locate CDJ, and thus, it can be used as the termination point of procedures.[5] All modern canal preparation techniques aim to differentiate between the canal and apical tissue.[6] AF does not normally exit at the anatomical apex (AA), but it is laterally offset 0.5–2.0 mm in the coronal of AA.[2] Conditions such as aging and root resorption can affect the position of AC, for example, aging and cementum apposition in the apical area cause increased space between AC and AF.[3] AC can be a simple constriction, tapering constriction, multiple constriction, or parallel constriction, and in a few cases, it is filled with restorative dentin or cementum.[6] Various methods have been used to study root canal morphology, including tooth decalcification, staining and clearing techniques, root sectioning and radiographic examination (*in vitro*),[7] alternative radiographic techniques,[8] and evaluation with contrast media.[9]

Modern radiographic techniques such as spiral computed tomography and micro-computed tomography are very useful.[10,11] Despite the accuracy of these modern techniques, they require expensive equipment.[12] In view of the importance of the precise WL[4] and variable root canal systems in different races[13,14] and the difference between incisors and molars,[15,16] the current study attempted to determine the distances from AC to AF and AA and compare the mean distances in incisors and molars.

MATERIALS AND METHODS

In this cross-sectional study, 90 teeth including 45 incisors (single-rooted tooth) and 45 molars (multi-rooted tooth) that had been gathered from personal offices, clinics, and the dental faculty of Isfahan Province, Iran, were used. The results of a pilot study were used to determine the sample size. In the pilot study, the difference between AC and AA in both incisors and molars was 0.1 mm, with a standard deviation of 0.25 mm. Incorporating $\alpha = 0.05$ and 80% power of the final sample size, 90 teeth were used in the current study.

No information about the age or sex of the tooth donors was available. All the teeth included had a reasonably intact crown and a relatively complete root – specifically a well-formed apex without any resorption or fracture. The reasons for tooth extraction were periodontal disease or orthodontic treatment. Classification of the teeth as incisors or molars was performed separately by endodontics experts, through Woelfel's standard. Only teeth selected by both experts were used in this study. The teeth selected were cleared of any soft tissue, bone fractions, and mass through manual scaling. For disinfection, the teeth were then put in 2.5% NaOCl (Orkyd, Tehran, Iran) for 2 days, washed with running water for 4 h, and floated in 10% formalin (Pars Chemistry, Tehran, Iran) before analysis.

To determine the position of AC, the following procedures were performed:

First, the crown of each tooth was sectioned using a diamond bur (D + Z, Frankfurt, Germany) to expose the root canal system. It was then rinsed with 2.5% NaOCl. The side where AF emerged was visualized by means of a stereoscopic magnifying glass (Citoval 2; Carl Zeiss, Germany). This allowed the roots to be oriented in such a way that the longitudinal sections were possible. If the foramen was located somewhat toward the mesial or distal side of the apex, the cut was made mesiodistally. If it was toward the buccal or lingual side, the section was made accordingly. If there were two foramens, the section was made on the same plane to enclose both of them. Root sections were divided with a modeling spatula (Schuler, Ulm, Germany). Sectioned roots were observed through a stereomicroscope (Hp, California, USA) with a magnification of ×25, and the distances from AC to AF and AA were measured through a digital camera (Motic Instruments Inc., California, USA) and Motic Images Plus software (Motic instruments Inc.). Microscopy images of AC and AF in the molar tooth root apex are shown in Figure 1, and corresponding images derived from incisors are shown in Figure 2.

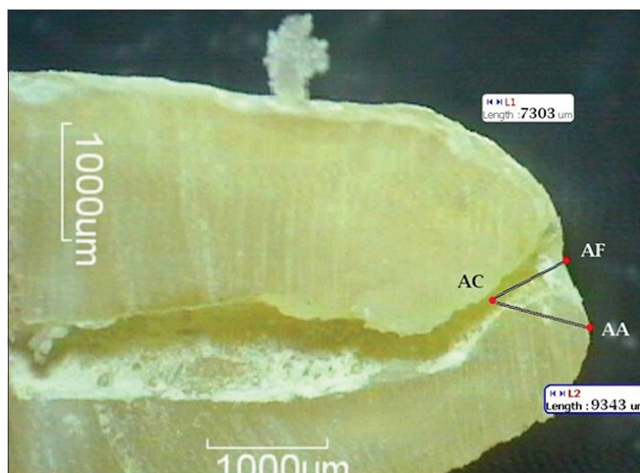

Figure 1: Microscopic view of molar root tooth apex, apical constriction, apical foramen, and anatomical apex

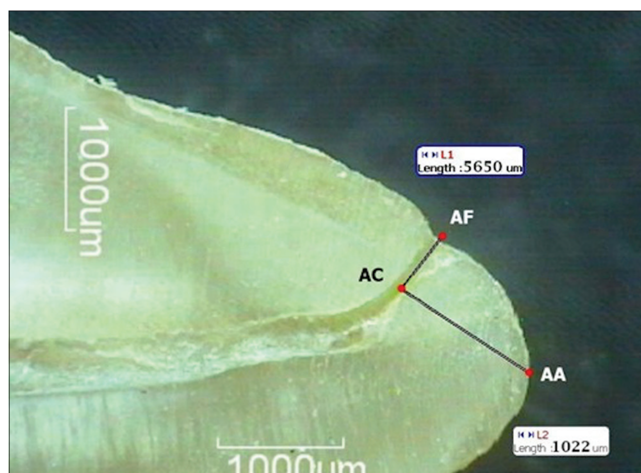

Figure 2: Microscopic view of incisor root tooth apex, apical constriction, apical foramen, and anatomical apex

Mean distances from AC to AF and AA and associated standard deviations were calculated and recorded, and data were analyzed with Statistical Package for the Social Sciences 22, SPSS(IBM, NY, USA). The independent *t*-test was used to compare the distances measured, and $P < 0.05$ was deemed to indicate statistical significance.

RESULTS

The mean distances between AC and AF were 0.84 ± 0.33 mm in incisors and 0.70 ± 0.27 mm in molars [Table 1]. The mean distances between AC and AA were 1.123 ± 0.389 mm in incisors and 1.010 ± 0.384 mm in molars [Table 2]. The mean distances between AC and AF differed significantly in incisors and molars ($P = 0.035$), but the mean distances between AC and AA did not ($P = 0.172$).

DISCUSSION

One of the important goals of endodontic treatment is biomechanical cleaning of the root canal system. This biomechanical cleaning involves mechanical removal and chemical dissolution and neutralizes content of the canal, while the primary aims of canal preparation include due determination of obligate canal geometrics for adequate obturation without any extension beyond the apical region. AC is an appropriate terminus location in root canal therapy.[4]

Few studies have investigated AC in Iranians; hence, determining the distances between AC and AF and AA in this race is important. Dummer *et al*.[6] investigated the apical anatomy of central and lateral incisors, canines, and premolars. On average, AC was 0.89 mm coronal to AA.

Table 1: Distance between apical constriction and apical foramen (mm)

Tooth type	Average	Standard deviation	*P*
Incisor	0.847	0.330	0.035
Molar	0.709	0.278	

Table 2: Distance between apical constriction and anatomical apex (mm)

Tooth type	Average	Standard deviation	*P*
Incisor	1.123	0.369	0.172
Molar	1.010	0.384	

Arora and Tewari[17] reported that this distance was 0.63–0.99 mm in posterior multi-rooted teeth. Nasseri *et al*.[18] reported a 0.9 mm distance between AA and AC. Marroquín *et al*.[19] reported that AC was 0.86 mm from AA in mandibular molars and 1.00 mm from it in maxillary molars [Table 3]. In the current study, the mean distances between AC and AA were 1.14 mm in single-rooted teeth and 1.03 mm in multi-rooted teeth. Kuttler[3] reported that the mean distance from AC to AF was 524 μ in a group aged 18–25 years and that it was 659 μ in a group aged over 55 years. Stein and Corcoran[20] reported a 0.91 mm distance [Table 3]. In the current study, the mean distances between AC and AF were 0.86 mm in single-rooted teeth and 0.72 mm in multi-rooted teeth. The results were concordant with the aforementioned previous studies. Piasecki *et al*.[21] investigated single-rooted premolars, and the 0.59 mm distance they reported from AC to AF is not similar to the corresponding observations in the present study. The smaller sample size in Piasecki *et al*.[21] and the more accurate measurement tool used in the current study may have contributed to the discrepancy between the two studies. Notably,

Table 3: Last studies about apical constriction, apical foramen, and anatomic apex

Researchers	Year	Studied tooth	Studied distance	Measured distance
Piasecki	2016	Single-rooted premolar	AC to AF	0.59 mm
Nasseri *et al.*	2012	Second maxillary premolar	AA to AC	0.9 mm
Arora and Tewari	2009	Posterior teeth	AA to AC	0.63-0.99 mm
Hassanien *et al.*	2008	Mandibular premolar	AC to AF	1.2 mm
Marroquín *et al.*	2004	Molar teeth	AA to AC	0.86-0.1 mm
Stein *et al.*	1991	Not mentioned	AC to AF	0.91 mm
Dummer *et al.*	1984	Central, lateral, canine and premolar	AA to AC	0.89 mm
Kuttler	1955	Anterior and posterior teeth	AC to AF	524 μ (18-25-year-old) 659 μ (over 55-year-old)

AC: Apical constriction, AF: Apical foramen, AA: Anatomical apex

Hassanien *et al*.[22] reported an average distance of 1.2 mm between AC and AF in mandibular premolar teeth – a greater distance than has been reported in previous studies and in the current study – which may also be related to the precision of the method they used and the lower number of samples.

In the current study, the distances from AC to AF differed significantly in single-rooted and multi-rooted teeth. This may be due to a difference in root diameter size between these teeth in the apical third; nevertheless, there was no corresponding significant difference in the mean distance from AC to AA. Although AC is often considered the terminus of obturation[4] and Electronic Apex Locators can show this region as the termination point of obturation,[23] some clinicians obturate based on the radiographic apex. As the apical termination of obturation does not differ significantly between single-rooted and multi-rooted teeth despite vital and necrotic teeth, clinician judgment should not affect which based on radiography.

The current study was rendered more precise than some of the aforementioned studies by the use of modern observation and measurement tools such as a digital camera and the Motic Images Plus software. Furthermore, vertical root sectioning facilitated informative observation and measurement of different parts of the apex, whereas previous studies have used radiographic, tooth decalcification, and staining techniques that preclude direct observation.

One of the limitations of the current study relates to evolutional tooth age. With aging, cementum absorption in the apex zone and the distance from AC to AF increase. Although the age of root formation is an important source of variation and incisor growth is faster than molar growth, it is not practically possible to source enough teeth of the same developmental age to perform a meaningful study. Another issue pertains to the anatomic variation in root canal systems.[13,14] Teeth were sourced from five provinces in Iran. A bigger sample size would have been preferable to reduce the potential effects of these variations.

CONCLUSION

The mean distances from AC to AF were 0.84 mm in incisors and 0.70 mm in molars. Since the prognosis is better when AC is considered the termination point of treatment, the terminus points should be 0.84 mm more coronal than AF in incisors and 0.70 mm more coronal in molars and 1.12 mm and 1.01 mm shorter than AA, respectively.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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