Radiographic Investigation of Location and Angulation of Curvatures in Human Maxillary Incisors

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Abstract

The aim of this radiographic study was to evaluate the degree and location of root canal curvatures of human maxillary incisors. A total of 286 extracted human maxillary incisors (145 central and 141 lateral incisors) were included in this investigation. Exclusion criteria were teeth with extensive carious lesions, restorations, and root canal treatment. For this in vitro study, the teeth were fixed in a special device and digitally x-rayed with the parallel technique. The distances from the cementoenamel junction (CEJ) to the first curvature and the according angle were recorded. The results were analyzed descriptively, and p values were calculated with the Wilcoxon Mann-Whitney test. The mean distance between the CEJ and the first curvature of the central maxillary incisors was 10.4 mm (standard deviation [SD] $\pm$ 2.8) and that of the lateral incisors was 11.1 mm (SD $\pm$ 3.0). Most of the central incisors (right: 94.2%, left: 98.7%) and all of the lateral incisors exhibited curvatures. Statistically significant differences between central and lateral maxillary incisors could be observed regarding the canal curvature locations ($p = 0.016$) and the angle values ($p < 0.001$), but there was no statistical difference between the right and the left side. The results showed the high percentage of root canal curvatures in maxillary incisors with a mean curvature located 10.7 mm apical from the CEJ. These findings are important to minimize failures during post insertion. *(J Endod 2008;34:1052–1056)*

Key Words

Maxillary incisors, radiographic study, root canal curvatures

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0099-2399/$0 - see front matter

doi:10.1016/j.joen.2008.06.021

Over the past decades, a steady development in endodontic treatment needs and a significant improvement in therapy methods and available devices have been observed. The reasons for the enhanced success rates for endodontic treatments can be found in technical developments such as the use of optical devices, nickel-titanium files, thermoplastic root canal–filling materials, and different post techniques (1–4). Besides the instrumental advantages, the precise knowledge of the root canal morphology is essential for a successful endodontic treatment outcome. Furthermore the sufficient definitive restoration is necessary for the long-term stability (5, 6). Previous studies on root canal anatomy, which predominantly have been performed on different tooth types of whites and Asians, have indicated variations in configuration. These findings suggest that variations in the root canal morphology may be attributed to racial differences (7, 8). The information about the accurate working length is also one of the main factors leading to success in the outcome of endodontic therapy (9). Numerous studies were able to show that root canal morphology and the pulpodentinal complex show age-related physiologic and pathologic changes that can also be influenced by trauma, orthodontic movement, pulp inflammation, or periodontal diseases (10, 11).

Besides all these new technologies, a precise knowledge of the root canal system and the information about the bacterial invasion of the pulp are essential to perform a successful endodontic treatment and definitive restoration (12). Many investigations have been conducted to acquire information about the morphology of the root canal systems and pulp chambers (13–15). Some studies used polyester resin impressions in order to create transparent samples, whereas others used radiographs in both in vivo and in vitro (5, 16).

In the majority of cases, the studies are concerned with morphologic investigations, digital radiologic procedures (6, 17), and conventional radiographs, and some studies used computer-assisted three-dimensional methods (18, 19). In further research, the morphologic root canal variations have been investigated by means of radiopaque contrast media (20) or a microcomputed tomography scan (21). A mathematical formula was proposed by Nagy et al. (22) to determine and classify root canal curvatures, whereas Schneider (23) divided the root canal curvatures into different root angles after drawing a straight line in the longitudinal axis of the root canal on the x-ray and a second line from the apical foramen to the point where the canal deviates from the longitudinal axis of the tooth. Luiten et al. (24) determined the root canal curvature by means of two straight lines. Based on the approaches of Cunningham and Senia (1), there are several investigations concerning the location and frequency of root canal curvatures (19, 25). Huang et al. (26) examined a high number of Chinese mandibular permanent incisors radiographically, whereas in the study of Rwenyonyi et al. (8) the root canal morphology of maxillary first and second permanent molar teeth in a Ugandan population was measured. Nevertheless, only limited information is available on the determination and frequency of root canal curvatures and the linear distances from the CEJ to the first curvature, necessary for the successful application of post systems. In cases in which post placements are inevitable, curved canals bear some hazards like a strip perforation, which leads to a higher risk of fracture. The aim of this radiographic study with extracted permanent maxillary anterior teeth was to gain knowledge about the frequency and localization of root canal curvatures.

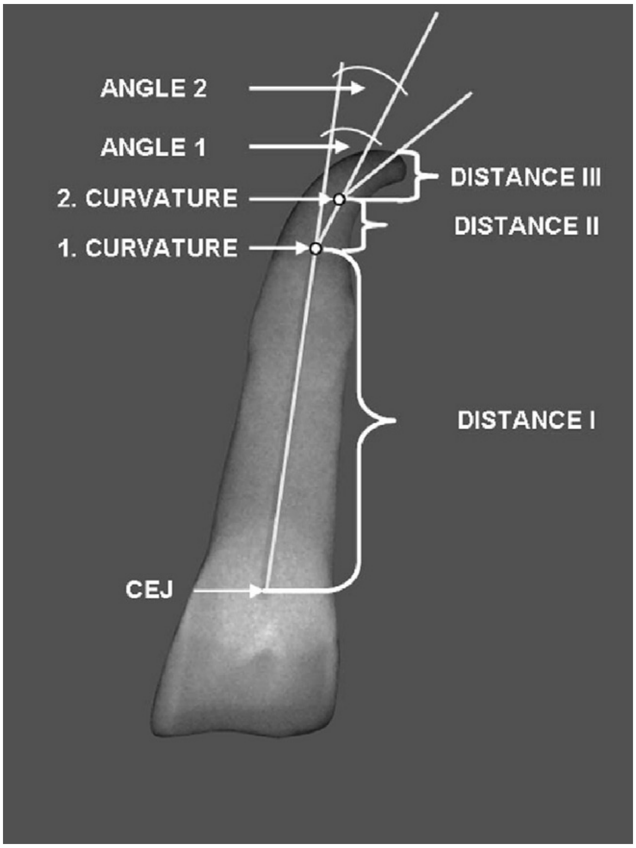

Figure 1. A schematic description of the digitally measured straight distances (tangents), angles, and curvature localizations of one selected maxillary lateral incisor. A horizontal line between the mesial and distal cementoenamel junction (CEJ) served as coronal reference level. The middle of the root canal was used as a reference for the straight lines and tangents. Distance I: distance from the CEJ to the first curvature; distance II: distance from the first curvature to the second curvature or radiological apex; distance III: distance from the second curvature to the radiologic apex; angle I: angle of the first curvature; angle II: angle of the second curvature.

Materials and Methods

In this study, extracted human maxillary central and lateral incisors ($n = 286$) were included. The teeth were collected from the Department of Oral Surgery and private dental center practices located in Rhineland Palatinate in Central Europe (white population). No information was available about the patients' age, sex, and general health condition. Exclusion criteria for further detailed analysis were the following: teeth with a nondefinable cementoenamel junction (CEJ) or apex; endodontically treated teeth; a nondefinable clinical crown and/or root; teeth with root caries, crowns, or extensive fillings; type II and type IV root canal configurations (5); and maxillary incisors with two root canals. A specially developed fixation device was used (25). The teeth were digitally radiographed (Heliodent MD, Sirona Benzheim, Germany/Merlin 2.1) in a buccolingual plane, with an exposure time of 0.2 seconds (60 kV) and with the parallel technique. The teeth were fixed and radiographed at pre-established distances (focus to object: 500 mm, object to sensor: 50 mm, and focus to sensor: 550 mm). The reliability of the x-ray beam was controlled throughout the entire investigation by means of an aluminium key (Hounsfield scale). Radiographs were taken horizontally and in 20° from the mesial and distal tooth axis aspects. A horizontal line between the mesial and distal CEJ served as the coronal reference level. The incisal edges of the teeth were not used as a landmark because they can have indeterminate age and wear characteristics as well as different restorations.

The intersection point in the middle of the root canal was used as a reference for the straight lines and tangents (Fig. 1). To achieve objective results and guarantee accuracy, the investigators were calibrated by experienced operators of the endodontic and radiologic departments. All relevant distances, angles, tangents, reference level (CEJ), and the length of the tangent leaving the pulp cavity were determined by an experienced endodontist. The length of the straight line between the CEJ to the first curvature was recorded. The corresponding angle was determined as the angle between distance I (CEJ to the first curvature) and distance II (second curvature to the radiologic apex/third curvature). The mean values of the measurements of 10 pilot radiographs were used as a reference (Adobe Photoshop 7.0 (Adobe Systems, San Jose, CA); 36 pixels = 1 mm and 1 pixel = 0.027 mm).

The data were collected with Microsoft Excel 2003 (Microsoft Corp., Redmond, WA), and, after transformation of data, statistical analysis was performed with statistical package SPSS (Version 16.0; SPSS Inc, Chicago, IL). Statistical measurements were determined for the characteristics. For categoric characteristics frequency and for metrical characteristics mean, standard deviation and also median values were calculated. To test the statistical significance between different parameters (lateral vs central and separately also left vs right side) and the number of curvatures, a Fisher exact test was used. Statistical significant differences between the position and (separately also side) concerning the total root canal length and the

TABLE 1. Statistical Parameters for Maxillary Incisors

Tooth/Group	$n = 286$		Length of the Total Root Canal (mm)	Distance CEJ to the 1 curvature (mm)	Angle (°)
Right central incisors	69	Mean ± SD	14.5 ± 2.6	10.6 ± 2.8	7.7 ± 4.4
		Median	14.8	10.6	6.7
		Minimum	3.2	4.9	1.0
		Maximum	20.3	17.2	19.0
Left central incisors	76	Mean ± SD	14.9 ± 2.2	10.1 ± 2.8	7.9 ± 5.2
		Median	14.7	9.7	6.1
		Minimum	10.5	4.2	1.8
		Maximum	22.1	18.2	28.0
Right lateral incisors	68	Mean ± SD	16.7 ± 2.6	11.3 ± 2.4	10.9 ± 7.6
		Median	16.2	11.4	7.4
		Minimum	1.0	6.0	1.1
		Maximum	20.4	16.4	35.1
Left lateral incisors	73	Mean ± SD	18.4 ± 2.2	10.8 ± 3.5	10.7 ± 6.9
		Median	16.3	11.2	8.6
		Minimum	12.0	2.5	0.4
		Maximum	22.9	18.7	39.7

CEJ, cemento-enamel junction.