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The Clinical Relevance and Correlation between the Initial Straight Length to the First Curvature in Human Second Maxillary Premolars

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Abstract
The aim of this study was to evaluate the straight lengths of the root canal of human second maxillary premolars using standardized radiological techniques in vitro. The distances were examined starting from the cemento-enamel junction (CEJ) to the appearance of a curvature. In particular recommendations which may facilitate decision making with regard to the length of post systems after successful endodontic treatment should be available. Extracted human second maxillary premolars (n = 210) were used; teeth with root caries, artificial crowns, extensive fillings or with previous endodontic treatment were excluded from this investigation. The teeth were fixed in a specially developed device with standardized and reproducible distances and digital radiographs using the parallel technique were made. A descriptive statistical analysis and the calculation of the cumulative frequencies were made. The values for the distance starting from the CEJ to a first curvature were as follows: a) For right second premolars: median value=10.3mm (min.: 5mm; max.: 15.8mm) and mean value= 10.4 SD±2.6mm; b) left second premolars: median value=10.2mm (min.: 5mm; max.: 17mm) and mean value=10.3mm SD ±2.2mm. Based on our data, high number of second maxillary premolars showed a curvature (30.4%) 9mm apically from the CEJ. These findings should be taken into consideration for endodontic treatments and post insertions.

Key words: maxillary second premolars, root canal morphology and curvature

Introduction

A continuous development in endodontic treatments, especially concerning materials, techniques as well as for the definitive restoration after endodontically treated teeth has taken place over the last years. Accurate knowledge of the root canal anatomy is essential in order to execute a successful endodontic treatment and a following definitive restoration [5]. Many studies using various techniques and methods dealt with the question of the root canal anatomy [6]. Methods for the evaluation of morphological conditions were carried out by means of computer 3-D techniques [7], digital X-ray procedures [4], also with radioopaque contrast media [2], SEM [8], microcomputer tomography [10] and with magnet resonance imaging microscopy [1]. In summary, these investigations and methods showed high differences and variations in the root canal morphology. A first method to examine a root canal curvature mathematically was established by Schneider in 1971 [11]. He divided the root canal curvatures into a) straight root canals (<5°), b) slightly curved canals (10-20°) and c) severe curved canals (25-70°). In 1992 Cunningham & Senia modified this method to describe root canal curvatures taking into consideration the bucco-lingual and mesio-distal aspects of mandibular molars [5]. Investigations regarding the initial relevant straight length and the location and frequency of root canal curvatures are rare. Nevertheless, the lengths of the initial straight distances are relevant if a post insertion is necessary after successful endodontic treatment. The aim of this in vitro study was to determine these lengths in second maxillary premolars.

Materials and Methods

A total of 210 extracted human second maxillary premolars were used for this study. Non-definable cemento-enamel junction (CEJ) or apex, and endodontically treated teeth were defined as exclusion criteria. Further reasons for exclusion were: a non-definable clinical crown and/or root, root caries, artificial crowns or extensive fillings and second premolars with two root canals (4 such cases were omitted from this study). A fixation device, specially constructed for this investigation, with standardized, defined and reproducible lengths (object holder without vertical adjustment; distances: focus to object=500 mm; object to sensor=50 mm; and focus to sensor=550 mm) was used (Fig. 1). The teeth were fixed and digitally radiographed (Heliodent MD, Sirona Benzheim, Germany; Merlin 2.1) and measured (Adobe Photoshop 7.0) in an oral-vestibular projection. The exposure time was 0.2 sec (60 kV) and the parallel technique was used. The constancy of the x-ray beam was controlled by means of an aluminum key (Hounsfield-scale) and the radiographs were taken horizontally and in 20° from the mesial and distal tooth axis aspects. A straight line between the mesial and distal cemento-enamel junctions (CEJ) served as the reference level. The intersection

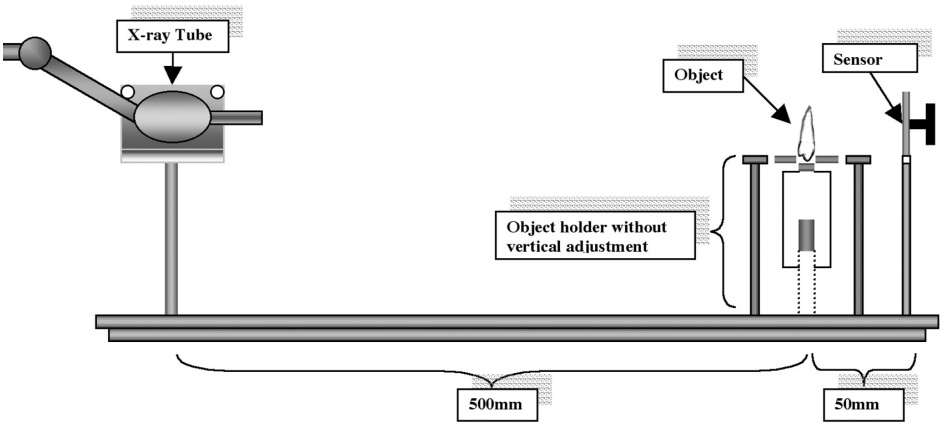

Fig. 1. Illustration of the specially developed fixation device with standardized and defined lengths.
Distance x-ray tube/ object: 500 mm; Distance object/ sensor mount: 50 mm; Distance sensor mount/ x-ray tube to object: 550 mm

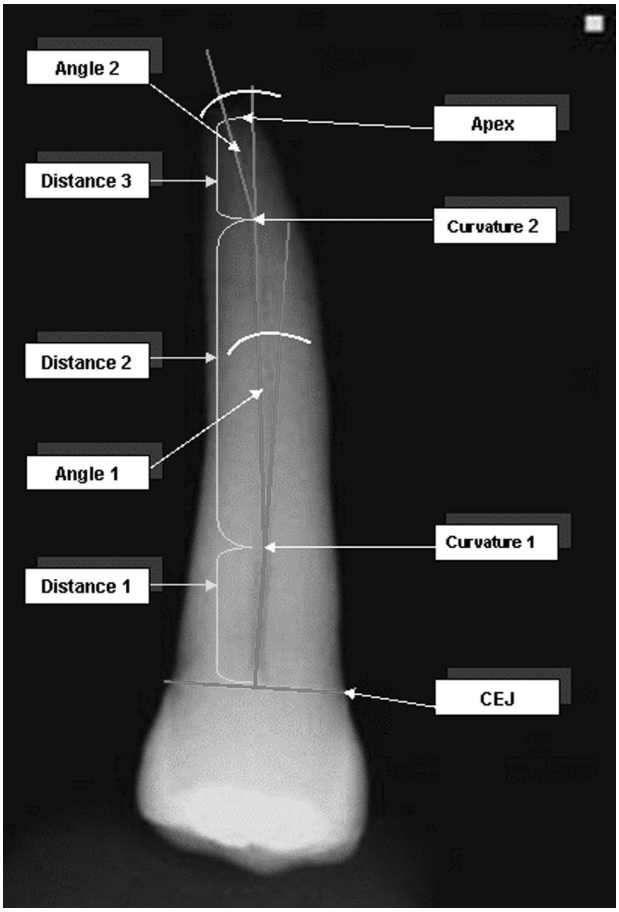

Fig. 2. Schematic description of the measured distances (tangents), angles and curvatures.
CEJ = A horizontal line starting from the mesial to the distal cemento-enamel junction served as coronal reference level
Distance 1: distance from the CEJ to the first curvature
Distance 2: distance from the first curvature to the second curvature (if existing)
Distance 3: distance from the first or second curvature to the radiological apex
Angle 1: angle of the first curvature
Angle 2: angle of the second curvature
Apex: radiological apex

point in the middle of the pulp cavity was used as a reference point for the specified straight distances and tangents. To achieve objective results the investigators were calibrated by experienced dentists of the endodontic and radiological disciplines. After a pilot investigation of 10 teeth the measured distances and corresponding angels were defined as follows: distance 1 = CEJ to the first curvature; distance 2 = from the first curvature to the second curvature (if existing) and distance 3 = from the first or second curvature to the radiological apex; angles were defined as: angle 1: between distance 1 and distance 2 and angle 2: between first or second curvature and the radiological apex (Fig. 2). The images (JPEG format) were imported into Adobe Photoshop (7.0). 36 pixels correspond to 1 mm and 1 pixel to 0.027 mm. A descriptive statistical analysis (absolute and relative frequencies) was carried out and the cumulative frequencies were calculated (Microsoft Excel 2003® and SPSS 9.0). Statistically significant differences between the left and right second premolars were determined using the Mann-Whitney U Test and the modified Wilcoxon Test (p value < 0.05).

Results

A total of 210 second maxillary premolars were investigated (n = 105 left and n = 105 right second premolars). According to the exclusion criteria 4 second right premolars with two root canals were omitted from this study. The straight length of distance 1 (CEJ to a first curvature) was for the second right premolars as follows: median value = 10.3mm (min.: 5mm; max.: 15.8mm) and mean value = 10.4mm SD ± 2.6; for the left second premolars: median value = 10.2mm (min.: 5mm; max.: 17mm) and mean value = 10.3mm SD ± 2.2 (Fig. 3).

The median distance 2 from a first to a second curvature was for the second right premolars 4.6mm (min.: 2mm; max.: 7.7mm). The mean value was 4.4mm SD ± 1.5. For the second left premolars the median value for the distance 2 was 4.9mm (min.: 1.1; max.: 7.4mm) and the mean value was 4.5mm SD ± 1.4 (Table 1).

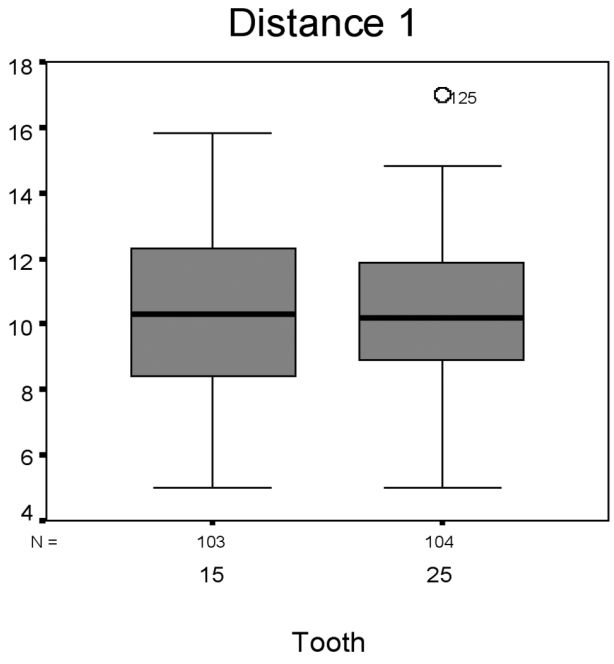

Fig. 3. Measured length of the distance for the second maxillary premolars.
15 = right second premolars
25 = left second premolars

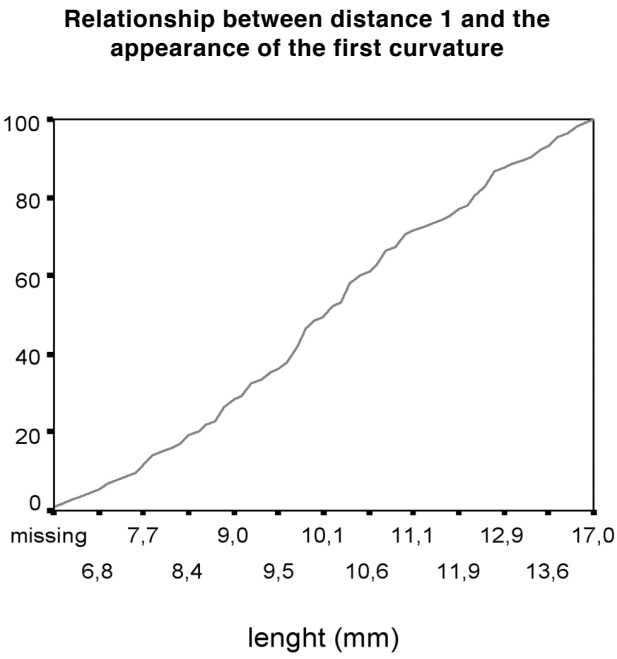

Fig. 5. Cumulative frequency and the relationship between the length of the distance 1 and the appearance of a first curvature for the second left premolars.

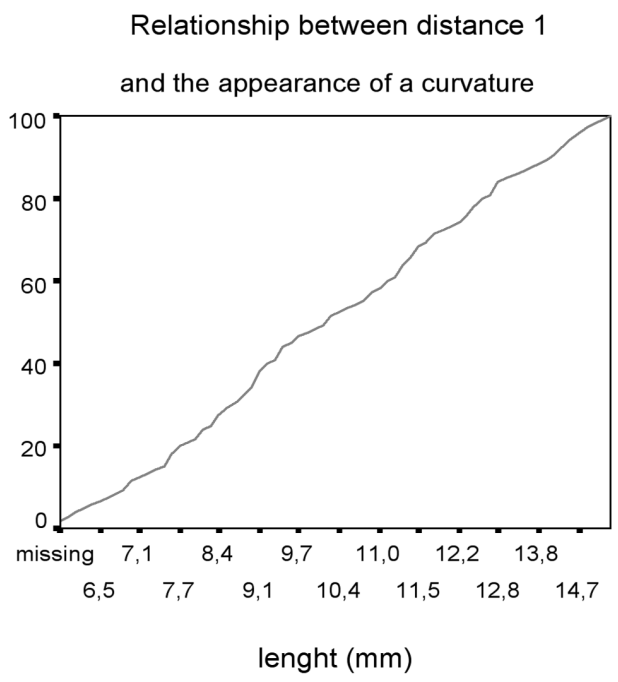

Fig. 4. Cumulative frequency and the relationship between the length of the distance 1 and the appearance of a first curvature for the second right premolars.

The length of distance 3 (from the first or second curvature to the radiological apex) for the second right premolars was as follows: median value = 6.1mm (min.: 1.2mm; max.: 10.6mm) and mean value= 5.6mm SD ± 2.4; for the second left premolars: median value = 5.5mm (min.: 1.2mm; max.: 10mm) and mean value = 5.4mm SD ± 2.2 .

The total length of the root canal starting from the CEJ to the radiological apex was as follows: for the second right premolars the total length of the root canal showed a median value of 16.9mm (min.: 12.4; max.: 22.8mm) and a mean value of 16.9mm SD ± 2.2; for the second left premolars the median value of the length of the root canal was 16.6mm (min.: 12.2mm; max.: 22.2mm) and the mean value was 16.6mm SD ± 2.2 .

Viewing the cumulative frequencies of the distance 1 of the second maxillary premolars, 35% of the left premolars and 27.9% of the right showed a curvature at a distance of 9mm after the CEJ; 46.6% of the right premolars and 48.1% of the left showed a curvature at a distance of 10mm (Figs. 4 and 5).

78.6% of the right premolars showed one and 21.4% two curvatures. Viewing the second left premolars one curvature could be detected in 79.8% and two in 20.2% of the cases.

Because of the considerable range of the results the median values were used for the description of the angles 1 and 2. The median angle 1 was for the right premolars 10.8° and for the left premolars 11.8°. The median angle 2 was for the right premolars 17° and for the left 17.5° (Table 1). For the values of the distance 1, 2 and 3 as well as for the angles 1 and 2 between the left and right second premolars the differences were not statistically significant.

Discussion

In this study the location of curvatures and the initial straight length starting from the cemento-enamel junc-

Table 1. shows the results of the measured lengths, distances and angles (median and mean values).

Tooth/ Group (right and left)		Second premolars	Right premolars	Left premolars
[n]		210	105	105
Length of the crown [mm]	**Mean ± SD**	6.9 ± 0.9	7.1 ± 0.8	6.9 ± 1
	Median	7	7.1	6.9
	Min.	4.7	5.1	4.7
	Max.	9.7	9.7	9.6
Length of the root [mm]	**Mean ± SD**	14.4 ± 1.7	14.6 ± 1.7	14.2 ± 1.7
	Median	14.5	14.6	14.5
	Min.	7.8	10.4	7.8
	Max.	19.4	19.4	17.6
Distance 1 [mm]	**Mean ± SD**	10.3 ± 2.3	10.4 ± 2.6	10.3 ± 2.2
	Median	10.2	10.3	10.2
	Min.	5	5	5
	Max.	17	15.8	17
Distance 2 [mm]	**Mean ± SD**	4.4 ± 1.4	4.4 ± 1.5	4.5 ± 1.4
	Median	4.7	4.6	4.9
	Min.	1.1	2	1.1
	Max.	7.7	7.7	7.4
Distance 3 [mm]	**Mean ± SD**	5.5 ± 2.3	5.6 ± 2.4	5.4 ± 2.2
	Median	6.1	6.1	5.5
	Min.	1.2	1.2	1.2
	Max.	10.6	10.6	10
Total length of the canal [mm]	**Mean ± SD**	16.7 ± 2.2	16.9 ± 2.1	16.6 ± 2.2
	Median	16.7	16.9	16.5
	Min.	12.2	12.4	12.2
	Max.	22.8	22.8	22.2
Angle 1 [Degree]	**Mean ± SD**	12.5 ± 7.8	12.4 ± 8.8	12.7 ± 6.8
	Median	11.6	10.8	11.7
	Min.	0.1	0.1	0.5
	Max.	45.7	45.7	38.4
Angle 2 [Degree]	**Mean ± SD**	19.1 ± 8.4	18.5 ± 8.6	19.7 ± 8.2
	Median	17.5	17	17.5
	Min.	5.6	5.6	6.6
	Max.	35.9	39.5	35.9

tion were measured. For necessary post insertions after successful endodontic treatment and root canal filling, it is important to have exact information about the root canal morphology. Several studies and investigations have been carried out to examine the anatomic condition of the root and the configuration of the root canal systems [5]. Various techniques and methods were used to evaluate the root canal path [1], morphological variations [3, 9] and the angles of root canal curvatures [10, 11]. But few data exist concerning the location and the distance to the appearance of root curvatures. This information could be used as a guideline for the straight length for post insertions. E. g. almost a third of all second maxillary premolars showed a curvature at a length of 9mm. Viewed a length of 10mm this value increased to 47.3%. For example, Sorensen and Martinoff recommended in 1984 a post length of two thirds of the original root canal length [12]. The mean length of the root canal was in our study 16.7mm; two thirds of this length would be a distance of 11.2 mm starting from CEJ. If we look at this distance in the line graph of the cumulative frequencies from our study, this showed that 66.2% should have a curvature. From lengths of 9mm the probability for the appearance of a curvature clearly increases.

The initial straight portion of the root canal is essential for the decision-making process prior to a post insertion. Deviations from the original root canal path can cause weakening of teeth, perforations or even root fractures. In our study only teeth without endodontic treatment were used to preserve the original condition of the root canal curvature. Due to these criteria the root canals were unchanged in size and diameter. In this investigation it was important to establish a length parameter for second maxillary premolars, such as the initial relevant straight length of the root canal path up to the appearance of a first root

canal curvature. This would support the decision for an operator to choose the correct post length to restore endodontically treated teeth.

Knowledge concerning the total root canal length and the initial straight distance up to the first curvature are important to avoid the risk of possible root canal damages.

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