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A COMPARATIVE STUDY OF THE ANGLES BETWEEN CROWN AXIS AND ROOT AXIS IN MESIODISTAL DIRECTION BY USING ORTHOPANTOMOGRAM

Young Joon Kim, Hyun Sil Choi

Orthopantomogram is commonly used to evaluate root parallelism. "Good parallelism" between roots is widely accepted as one of the guidelines of a successful orthodontic treatment.

In case there was a large angle between crown axis and root axis, and if we valued only the position of crown in establishing occlusal relationship without considering of the situation of root, the problem of root arrangement between adjacent teeth would be occurred. The estimate of root parallelism in mesiodistal direction before and after orthodontic treatment must be emphasized.

The intent of this study was to determine the clinical importance and correlation of the angle between crown axis and root axis. Orthopantomograms of 105 orthodontic patients being treated in Yonsei university were used in this study. Twenty-eight teeth in both maxilla and mandible were selected and analyzed quantitively to evaluate the angle between crown axis and root axis, and obtain the correlationship among the individual teeth. The results are as follows:

1. Among the teeth presenting normal distribution, the maxillary right canine showed the largest mean value(5.73± 4.42°), which was composed of the crown-root angles, and the mandibular left lateral incisor showed the smallest mean value(0.60±3.76°).
2. The crown-root angles of the maxillary incisors and the first molars, and the mandibular central incisors and the first molars didn't show normal distribution and the ranges of these angles were dispersed.
3. Significant differences were present between the crown axis and the root axis except for lower first premolars. ($p<0.05$)
4. No significant difference was present for the crown-root angle between right and left side. ($p<0.05$)
5. No significant difference was present for the crown-root angle between male and female except for lower left first premolar. ($p<0.05$)
6. In the upper right quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor, lateral incisor and canine.
   In the upper left quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor.
   In the lower right quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor, first molar and second molar.
   In the lower left quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor, lateral incisor and canine, first molar and second molar. ($p<0.05$)

Key words : crown axis, root axis, crown-root angle

The position of brackets on tooth with fixed appliance should be accurate and since the introduction of the straight wire appliance(SWA), which serves to apply the first, the second and the third order bend, more importance has been placed in the positioning of the brackets. In 1952, Holdaway[22] used pre-angulated bracket to eliminate the second order bend, and in 1960 Jarabak, Fizzell[24] introduced the modified edgewise technique which carries the second and the third order bend. In 1972, Andrews[2] developed the SWA system which applies all three order bends to satisfiy the six keys to optimal occlusion and in 1972, Roth[35] included the concept with gnathologic centric relation.

The main goal of orthodontic treatment is to arrange the upper and lower teeth, basal bone and allows the jaws in to a position which surrounding muscle tissues to be in harmony of each other, and to position the teeth which satisfy both cephalometric and occlusal standard in three dimensional terms.[11,20,33] Among the criteria of ideal position of tooth, the mesiodistal angulation should be given a place for it is needed to distribute the occlusal forces approximately through tight interproximal contacts.[2,3,10,47] Robert[32] suggested that in order to prevent the recurrence of malocclusion you should either correct the tooth axis or adjust them to resist the stress force. When orthodontic treatment is completed, one should always confirm the tooth angulation by clinical radiography. Ricketts[32], Roth[35], Schwaninger[40], Yoon[52] etc. measured the angulations of 14 teeth of upper and lower jaws in relation to the crowns. Kim[50] measured the tooth axis angulation including the root by using 45° lateral cephalogram. Andrews[4] postulated that the reference in measuring the tooth axis angulation is more accurate by using Facial Axis of Clinical Crown(FACC) than the conventionally used factors such as the axis of tooth, incisal edge, marginal ridge and contact point etc. The axis of teeth and contact point is not clearly defined clinically and incisal edge is susceptible to attrition, fracture which would result in deviation. This was most obvions in maxillary lateral incisors where large amount of curvature existed. The marginal ridge is readily observed but there is distance the bracket being placed not making it a good reference line.

If the crown-root axis angulation is not considered during the treatment and only the clinical crown is allowed to participate in the occlusion, it will result in misalignment between the adjacent roots. Therefore, it is essential to include the mesiodistal angulations of the roots in the process of diagnosis and evaluation of parallelism of roots after treatment. Thus, in our study we used orthopantomography to quantitatively analyze the crown-root axis difference, to investigate which particular tooth has the greatest variation and its relation with adjacent roots. We also think that it will help in the evaluation of the alignment of the roots during treatment planning and after treatment.

SUBJECT & METHOD

1. Subject

The present study consist of 105 patients (43 males, 62 Females) who have completed the treatment at Yonsei Dental College, Department of Orthodontics from August of 1994 to October of 1996, has fully erupted second molars and experience no root resorption during the course of the treatment.

2. Method

1) Radiographic method

In our study, we used PANOURA 10-C from Yoshida Co. and radiographs were taken with patients in centric occlusion.

2) Measuring points

Tracing paper was to trace the panorama film and the following measuring points were located.

a) midpoint of mesiodistal distance of crown portion
b) midpoint of cementoenamel junction line(CEJ)
c) incisor, canine, premolar : midpoint of mesiodistal width of apical third of the root
molar : furcation fornix

3) Definition of the terms (Fig. 1, 2)

a) Crown axis
incisor, canine, premolar : line joining the midpoints of the distance of the mesiodistal width of crown and CEJ
molars : line joining the midpoint of mesiodistal width of crown and midpoint of CEJ line

b) Root axis
incisor, canine, premolar : line joining the midpoint of CEJ line and midpoint of mesiodistal width of apical third of the root
molar : line joining the midpoint of CEJ line and

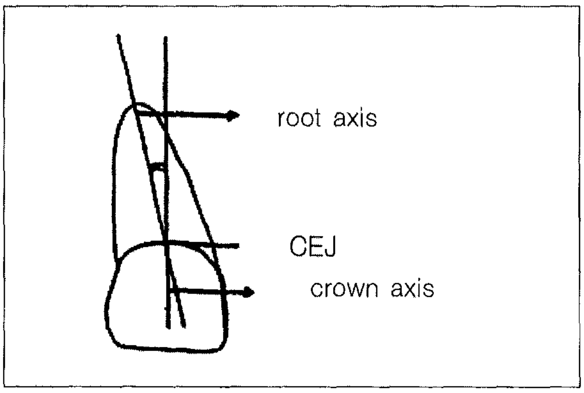

Fig. 1. Crown axis & root axis of single root

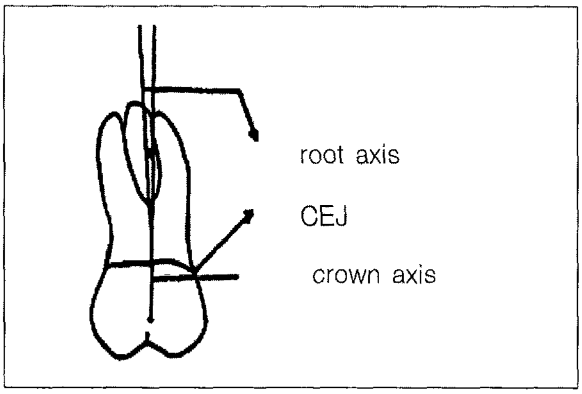

Fig. 2. Crown axis & root axis of mutilated root

furcation fornix

c) Crown-root angulation : angle between the crown axis and root axis

4) Measuring method

When the crown axis and root axis is defined, the crown-root angulation is measured to 0.5° and the position of the root is defined in relation to the crown as below. (Fig.3)

a) root positioned distally to the long axis of the crown : +

b) root positioned parallel to the long axis of the crown : o

c) root positioned mesially to the long axis of the crown : -

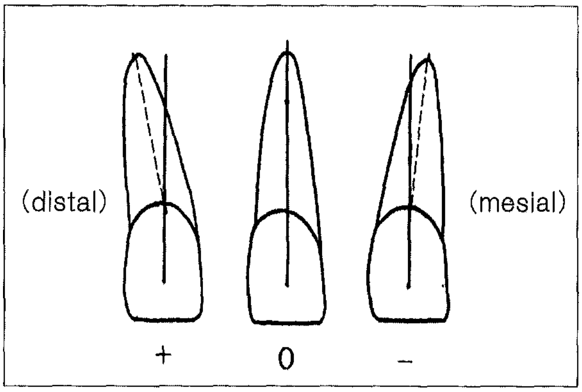

Fig. 3. Measuring method of the crown-root angulation (— crown axis --- root axis)

5) Statistical analysis

The measurements of the relations between the long axis of crown and roots were collected by orthopantomogram and statistcally analysis was carried out using SAS 6.04 package to perform t-test, and paired t-test.

RESULTS

1. The mean, standard deviation and the normal distribution pattern of crown-root angulation(table 1)

The mean value, standard deviation and normal distribution pattern was obtained for each tooth and the largest mean value found within the normal distribution was 5.73±4.42° for right maxillary canine and the smallest mean value was 0.60±3.76° for left mandibular lateral incisor.

2. The median and range of the tooth which are not normally distributed(Table 2)

The crown-root angulation of maxillary central incisor, lateral incisor and first molar and mandibular central incisor and first molar was found not to distribute normally and the outcome of range was variable.

3. The classification of teeth in relation to the angulation pattern (Table 3)

The left maxillary lateral incisor was found to have the greatest ratio of negative value regarding to the crown-root angulation

Table 1. The mean value, standard deviation and normal distribution pattern of the crown-root angulation (degree)

Right	MEAN	SD	ND	Left	MEAN	SD	ND
Upper				Upper			
1	1.27	3.92	.9111*	1	0.98	3.92	.9280*
2	-0.71	3.86	.8849*	2	-0.82	3.79	.8896*
3	5.73	4.42	.9679	3	5.40	4.44	.9676
4	3.96	3.02	.9631	4	3.61	2.89	.9629
5	3.92	2.41	.9637	5	3.45	3.12	.9647
6	4.09	5.03	.9425*	6	3.84	4.91	.9281*
7	5.10	4.47	.9457	7	4.68	4.22	.9548
Lower				Lower			
1	0.90	2.90	.9046*	1	0.71	2.95	.8930*
2	0.66	2.12	.9776	2	0.60	3.76	.9548
3	3.47	3.94	.9649	3	3.23	4.21	.9641
4	0.83	4.28	.9677	4	0.79	4.45	.9631
5	2.47	3.85	.9658	5	2.14	4.00	.9678
6	3.57	4.60	.9340*	6	3.39	4.67	.9654*
7	5.23	4.38	.9691	7	5.52	5.16	.9654

* statistically significant difference at $p<0.05$

Table 2. The median and range of the teeth not distributed normally. (degree)

Right	MEDIAN	RANGE	Left	MEDIAN	RANGE
Upper			Upper		
1	0	25.5	1	0	19.7
2	0	19.3	2	0	18.8
6	4.5	28.3	6	4.5	27.3
Lower			Lower		
1	0	16.5	1	0	16.5
6	3.5	26.5	6	3.3	26.5

Table 3. The classifcation in relation to the angulation pattern (%)

Right	−	0	+	Left	−	0	+
Upper				Upper			
1	18.1	41.9	40.0	1	17.0	40.3	42.7
2	30.5	55.2	14.3	2	37.1	48.6	14.3
3	4.8	13.3	81.9	3	4.8	16.2	79.0
4	15.2	15.2	69.6	4	13.3	24.8	61.9
5	8.6	22.9	68.5	5	12.4	24.8	62.8
6	9.5	28.6	61.9	6	5.7	34.3	60.0
7	2.9	26.7	70.4	7	2.9	31.4	65.7
Lower				Lower			
1	20.0	45.7	34.3	1	21.9	47.6	30.5
2	20.0	41.9	38.1	2	22.9	41.0	36.1
3	5.7	28.6	65.7	3	9.5	27.6	62.9
4	23.8	41.0	35.2	4	24.8	39.0	36.2
5	13.3	29.5	57.2	5	17.1	30.5	52.4
6	5.7	34.3	60.0	6	6.7	36.2	57.1
7	3.8	20.0	76.2	7	3.8	21.0	75.2

Table 4. The statistically significant difference of crown-root angle (degree)

Right	t-value	Left	t-value
Upper		Upper	
1	3.29 **	1	2.89 **
2	-2.85 *	2	-2.13 *
3	13.15 **	3	12.39 **
4	11.90 **	4	10.03 **
5	7.68 **	5	5.99 **
6	8.13 **	6	7.98 **
7	11.62 **	7	10.08 **
Lower		Lower	
1	3.05 **	1	2.36 *
2	2.87 **	2	2.23 *
3	8.97 **	3	7.75 **
4	1.89	4	1.81
5	6.43 **	5	5.38 **
6	7.88 **	6	7.37 **
7	11.70 **	7	10.92 **

* statistically significant difference at $p<0.05$
** statistically significant difference at $p<0.01$

4. Statistically significant difference of the crown-root angulation (Table 4)

There was significant difference between the crown and root angulation for all teeth except for the right and left mandibular first premolar.

5. The comparison of the crown-root angulation between the left and the right teeth (Table 5)

There are no significant difference between the left and the right teeth in relation to the crown-root angulation values.

6. The comparison of the crown-root angulation between male and female (Table 6)

There was no statistically significant difference in crown-root angulation between male and female for all teeth except the right mandibular first premolar.

7. The relationship between the crown and root angulation (Table 7, 8, 9, 10)

1) Maxillary right side : central and lateral incisor, lateral incisor and canine
2) Maxillary left side : central and lateral incisor
3) Mandibular right side : central and lateral incisor, first and second molar
4) Mandibular left side : central and lateral incisor,

Table 5. The comparison of the crown-root angulation between the left and the right teeth (degree)

Right	MEAN	SD	Left	MEAN	SD	t-value
Upper			Upper			
1	1.27	3.92	1	0.98	3.47	1.28
2	-0.71	3.86	2	-0.82	3.79	-0.76
3	5.73	4.42	3	5.40	4.44	1.26
4	3.96	3.02	4	3.61	2.89	1.50
5	3.92	2.41	5	3.45	3.12	1.00
6	4.09	5.03	6	3.84	4.91	0.89
7	5.10	4.47	7	4.68	4.22	1.74
Lower			Lower			
1	0.90	2.90	1	0.71	2.95	-1.76
2	0.66	2.12	2	0.60	3.76	-1.63
3	3.47	3.94	3	3.23	4.21	-1.69
4	0.83	4.28	4	0.79	4.25	-0.96
5	2.47	3.85	5	2.14	4.00	1.40
6	3.57	4.60	6	3.39	4.67	-1.16
7	5.23	4.38	7	5.52	5.16	1.82

* statistically significant difference at $p<0.05$

Table 6. The comparison of crown-root angulation between male and female

right	male		female			left	male		female		
	MEAN	S.D.	MEAN	S.D.	t-value		MEAN	S.D.	MEAN	S.D.	t-value
U 1	1.80	3.97	0.63	3.76	1.65	U 1	1.00	3.24	0.97	3.49	1.83
2	-0.36	4.04	-0.78	3.39	0.60	2	-0.74	4.06	-1.24	3.59	-0.23
3	6.47	4.71	4.80	4.15	1.94	3	6.14	4.38	3.21	4.10	1.87
4	5.00	4.04	3.56	4.25	1.83	4	4.16	4.10	2.95	5.06	1.41
5	4.34	5.28	3.12	5.06	1.24	5	4.08	4.92	3.21	5.20	0.17
6	3.03	4.66	4.42	4.38	-0.68	6	3.87	5.61	3.83	4.15	0.03
7	4.85	4.66	4.87	4.45	-0.39	7	4.90	4.54	3.53	4.59	0.29
L						L					
1	0.72	2.00	0.75	3.23	-0.05	1	0.97	2.65	0.31	2.62	0.45
2	1.11	2.86	0.54	3.85	0.84	2	1.36	3.52	0.56	3.75	-0.28
3	3.08	4.00	3.43	3.91	-0.44	3	3.26	4.62	2.27	5.38	0.90
4	1.75	4.65	0.13	3.45	2.04*	4	1.66	4.41	-0.14	3.97	0.77
5	1.82	4.01	2.49	3.66	-0.89	5	1.97	3.17	1.60	3.42	-1.51
6	4.03	4.65	3.02	4.92	1.07	6	4.33	3.01	2.02	5.21	-1.04
7	4.77	4.54	6.51	4.60	-1.71	7	5.52	3.80	4.07	3.65	1.49

* statistically significant difference at p<0.05

Table 7. Correlation value of crown-root angulation of right maxillary teeth

Tooth	1	2	3	4	5	6
2	.2991*					
3	.0001	.2457*				
4	.0976	-.0946	.0773			
5	.0649	.0871	.1708	.1642		
6	.1008	.2214*	-.0525	.0541	.1759	
7	.0221	.1303	.1400	-.1129	.0326	.1329

* statistically significant difference at p<0.05

Table 8. Correlation value of crown-root angulation of left maxillary teeth

Tooth	1	2	3	4	5	6
2	.2028*					
3	.0489	.0957				
4	.0096	.0999	.1233			
5	.0292	.0421	.0425	-.0055		
6	.0616	.9590	-.0839	-.1340	-.0500	
7	-.1136	.0395	.0829	.0009	.1041	.0742

* statistically significant difference at p<0.05

Table 9. Correlation value of crown-root angulation of left mandibular teeth

Tooth	1	2	3	4	5	6
2	.3596*					
3	-.0769	.2019*				
4	.0531	.1200	.0537			
5	.0154	-.0312	-.0098	.1866		
6	-.0199	.0162	-.0180	.0671	-.0711	
7	-.0642	.0353	-.0129	-.0842	.1992*	.2564**

* statistically significant difference at p<0.05
** statistically significant difference at p<0.01

Table 10. Correlation value of crown-root angulation of right mandibular teeth

Tooth	1	2	3	4	5	6
2	.4583**					
3	-.0446	.1232				
4	.0462	.0852	.0535			
5	-.0000	-.0206	.0482	.1351		
6	-.0400	.0679	-.0038	.0218	.7440	
7	.0225	.1047	.0361	.1655	.0417	.2178*

* statistically significant difference at p<0.05
** statistically significant difference at p<0.01

lateral incisor and canine, first and second molar.

From the above relationship, positive correlation was obtained.

DISCUSSION

Root formation may be influenced by environmental factors and is neither affected by the size of the crown nor the jaw[1,13,14,15]. The number and structure of root is known to show wide range of variation[7,18,34]. From the previous studies carried out on patients with normal occlusion it can be concluded that the tip of root is generally directed distally in relation to the crown and the distal displacement of the root is extremely variable depending on the tooth[2,20]. As such, the crown of the tooth is more or less perpendicular to the occlusal plane. The axis of the individual tooth is not a straight line but a curvature disecting distally, when extending from the crown down to the root[10,48]. The individual tooth is aligned mesiodistally in an angle unique to the tooth to achieve a parallel relationship with the adjacent teeth[2,5,9,10]. The parallelism of the root is essential in achieving proper alignment of the teeth within the basal bone and obtaining normal occlusion between the maxillary and the mandibular teeth, in addition to retaining a stable treatment result[28].

Taylor[41] postulated that the relationship between the crown and the root is extremely variable and the line extended from the root tip towards the crown will not pass the center of the cementoenamel junction. Dewel[10] stated that the axis of the crown is very different to the axis of the root and the line dividing the tooth tends to direct distally as you move down to the root tip. Wheeler[48] strongly suggested that the root curvature of individual teeth is relatively constant and has significant relationship with the periodontal health regarding its physiological importance. Magness[27] suggested that orthodontists using the SWA should have in mind that not all teeth are morphologically ideal and small adjustments in regard to such deviation is required.

On the other hand, studies of crown-root axis from buccolingual surface have been reported while Charlsson and Ronnerman[6] measured the difference of crown and root axis of extracted teeth and Delivanis, Kuftnec[8] studied the crown-root angulation in Class II malocclusion patients and found that the value of the angulation was high and when maxillary incisors are moved, either by intrusion or applying torque, the root will be in contact with the lingual compact bone and subsequently induce root resorption. Harris[19] et al had also reported large values of crown-root angulation in Class III malocclusion patients.

The evaluation of tooth axis is generally measured by using 45° lateral cephalogram but when the parallelism of molar root was compared for reliability was compared by using either the orthopantomogram or the 45° lateral cephalogram, orthopantomogram showed to produce better reliability for testing the parallelism of molar crown-root parallelism[51].

Graber, Mayoral, Hauck, Thorpe, Tronje advocated the use of panorama film in evaluating tooth axis angulation[16,21,28,42,43]. The panoramic radiography projects all images into a single film without superimposition of the maxillary, mandibular and adjacent structures between the left and the right arch. It also has advantages of low radiation exposure, comfortable patiens manipulation and simple handling[21,30,44]. The image of a structure from orthopantomogram may be magnified depending on the geometrical principle and linear measurement such as horizontal distance may be influenced by projection factors and object movement, and thus lowers the reliability of the measurement whereas the measurement of angulation between adjacent structures is clincally acceptable[26,28,30,38]. In order to achieve a clinical objective a difference of 5° between adjacent structures or of 5° after another consecutive radiographic taking, may be acceptable [12,38,49]. The reliability of orthopantomogram in the measurement of angulation is not only reliable but taking into account of the fact that there is ± 5° of error after repeated exposures of film, it is reasonable to suggest that it is an acceptable instrument to be used clinically[12,28,39,46]. In a recent study, 4 different models of panorama radiographic machine were compared for the angulation of tooth axis of dry skull, in different position and angle. The result was that with a ± 5° error tolerlance, abnormal positioning of patient will not dramatically influence the tooth axis measurement[49].

FACC(Facial Axis of Clinical Crown) is defined as the buccal groove that divides the buccal cusps of molar tooth and other teeth that pass through the most prominent part of the central lobe. However, this landmark does not show up radiographically and after times, the line joining the middle of the greatest height of contour and the midpoint of the cementoenamel junction is used. The reason for using the anatomical crown by extending the cementoenamel junction is based on the fact that clinical crown is defiened as 1.8mm shorter in height[30]. The reference point for single rooted tooth is placed at the center of the apical third which accounts for the fact that the morphological deviation of the root is greatest at that point. The reason for selecting the furcation apex as the reference point in multirooted teeth is because roots of molar teeth originate from one root trunk located at the base of the crown, thus providing a reference for judging the axis of the root[48].

With respect to the normal distribution pattern of the crown-root angulation, all the teeth except for the maxillary central incisor, lateral incisor, and first molar, and mandibular central incisor and first molar showed normal distribution. The teeth that are normally distributed possess a mean value that is significant and otherwise, only the median and the range will describe the pattern of the distribution.

Among the teeth that normally distribute, the largest mean value of the crown-root angulation was found for right maxillary canine as $5.73 \pm 4.42°$ and the smallest value was for the left mandibular lateral incisor as $0.60 \pm 3.76°$.

Among the teeth that arre not normally distributed, the median value of the maxillary and mandibular anterior teeth was 0° and the range was variable between 16.5° and 25.5°. With respect to the angulation pattern of the teeth, the maxillary lateral incisor that had relatively high incidence of mesially tilted root also showed deformations of the crown and for the root, although higher incidence of root with distal dilaceration generally occurred, there were also roots that dilacerated mesially[47]. In our study, the appearence of negative value of maxillary central incisors was 17% and in reference to Ingle's report[23] of 4% for mesial tiling of the tooth, our study showed greater percentage.

All the teeth except the left and right mandibular premolars showed significant difference in the angulation of tooth axis, which supports the fact that the axis of the crown and roots are different. The left and right maxillary lateral incisor and left mandibular lateral incisor had 95% significance whereas in other teeth the significance was greater than 99%.

There was no significant difference between the left and right teeth for measurements comparing crown-root angulation.

There was no significant difference with respect to the difference in the sex in all the teeth except for the left and right mandibular first premolar.

Correlation was used to determine the relationship between the teeth and positive correlations were found for the following pairs of teeth :

Right maxillary quadrant : between central and lateral incisor, lateral incisor and canine

Left maxillary quadrant : between central and lateral incisor

Right mandibular quadrant : between central and lateral incisor, first and second molar

Left mandibular quadrant : between central and lateral incisor, lateral incisor and canine, first and second molar

Therefore, even if there is large difference of the angulation of tha axis of the crown and root, the pairs of teeth that show positive relationship tends to maintain a constant spacial relationship between each other.

In conclusion, there was a significant difference between the axis of the crown and the root and the amount of difference varied depending on the tooth. Therefore by understanding the pattern of deviation of roots in their axial relationships, the evaluation of the alignment of roots may be possible. As discussed previously, the crown-root angulation for different malocclusions have been studied by others but data for such measurements in mesio-distal dimension is lacking and more research is needed in this field. Moreover, our study using the orthopantomogram is a quantitative analysis which inherently retaines errors with true values. As such, we hope to improve such deficiency by measuring the angulation of crown-root axis of extracted teeth.

CONCLUSION

The following conclusions were made for the study of crown-root angulation.

1. Among the teeth presenting normal distribution, the maxillary right canine showed the largest mean value(5.73±4.42°), which was composed of the crown-root angles, and the mandibular left lateral incisor showed the smallest mean value(0.60± 3.76°).
2. The crown-root angles of the maxillary incisors and the first molars, and the mandibular central incisors and the first molars didn't show normal distribution and the ranges of these angles were dispersed.
3. Significant differences were present between the crown axis and the root axis except for lower first premolars. ($p<0.05$)
4. No significant difference was present for the crown -root angle between right and left side. ($p<0.05$)
5. No significant difference was present for the crown -root angle between male and female except for lower left first premolar. ($p<0.05$)
6. In the upper right quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor, lateral incisor and canine.

   In the upper left quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor.

   In the lower right quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor, first molar and second molar.

   In the lower left quadrant, significant correlations were present between crown-root angles of the central incisor and lateral incisor, lateral incisor and canine, first molar and second molar. ($p<0.05$)

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KOREA. J ORTHOD. 1996 ; 26 : 657-666