The Accuracy of the Cementoenamel Junction Identification on Periapical Films

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Abstract: In the study of orthodontically induced inflammatory root resorption, many researchers use the cementoenamel junction (CEJ) as a bisecting reference point to measure the amount of root shortening. The accuracy of the identification of the CEJ point might affect the conclusions of those studies. This study aims to find the effects of angular changes between the tooth and the film on the validity and reproducibility of identifying three different CEJ points, ie, the most apical CEJ point between the crown and the root, the most mesial CEJ point, and the most distal CEJ point. An extracted maxillary central incisor was placed in a special jig and radiographed at four different tooth to film angulations. Eight examiners were asked to identify the buccal and palatal CEJ, whereas six examiners were asked to identify and na computer monitor. The distances between the identified points and the apex were computed and compared with the actual ones. The angular changes between the tooth and the film did have a statistically significant effect on the identification of some of these CEJ points. The difference was significant on the identification of the buccal and palatal points but not on the mesial and the distal ones. (*Angle Orthod* 2004;74:496–500.)

Key Words: CEJ; Identification; Angulation

INTRODUCTION

Orthodontics is a dental specialty where landmark identification serves as an important tool in diagnostic and treatment procedures.^{1–5} Difficulties in this process might lead to a misdiagnosis that could cause faulty treatment plans or incorrect conclusions for studies that depend on the identification of accurate points on radiographic films. Baumrind and Frantz^{1,2} described this issue with regard to cephalometric films. The identification of cementoenamel junc-

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tion (CEJ) points on a periapical film, although seemingly simple, is no less complicated.

The exact identification of CEJ points is essential for all those who study orthodontically induced inflammatory root resorption (OIIRR). In many studies, the CEJ serves as a point to measure the amount of root shortening that might have occurred with orthodontic treatment.^{6–10} For example, if the tooth length is 25 mm, each one mm of inaccuracy in CEJ identification might have a significant effect on the conclusion of the OIIRR study. The literature on OIIRR reports the use of three CEJ points, ie, the most apical point,⁶ the most mesial CEJ point, and the most distal CEJ point.^{10–13} All points are used in different studies that analyze the amount of OIIRR.

The objective of this study was to examine the effect of angular change between the tooth and the film with respect to the validity and reproducibility of identifying three CEJ points on periapical radiographs. The identification of the points was compared among different examiners and the same examiner on two different occasions.

MATERIALS AND METHODS

A human maxillary central incisor, extracted for periodontal reasons, was used in this study. The tooth was placed in a special jig built to imitate the actual clinical conditions of the paralleling periapical radiographic technique. The film was placed 25 mm away from the edge of

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FIGURE 1. The scheme of the jig and the holding device demonstrating 10° (left) and 20° (right) angle between the tooth and the film (the black line at the bottom of the scheme).

the tooth crown, and the cone was positioned 100 mm away from the center of the tooth. A special holding device and the jig kept the film always parallel to the roentgen cone, meaning that the central X-ray beam was always perpendicular to the film. The tooth was exposed at angles of 10°, 20° , 30° , and 40° to the film (Figure 1), with the center of the tooth serving as the center of rotation. The distance from the edge of the crown to the cone was kept constant. The films were all developed under the same conditions (Dentax 810 Basic) and later scanned using an Umax Astra 2400S scanner. The image of the tooth was enlarged seven times and was analyzed using Adobe Photoshop 5 software (Adobe, San Jose, Calif). On each image, the most apical point of the root was marked and verified by two senior residents (Dr Goren and Dr Zoizner).

A total of six orthodontists, tutors in the orthodontic department, and two junior residents were asked to identify and mark the most apical point of the CEJ directly on the computer monitor using the mouse-controlled cursor. Each examiner could choose the light and the contrast of the computer monitor according to personal preference. There was no time limit to perform this procedure. Four orthodontists from the above group and the two junior residents were also asked to mark the mesial and the distal CEJ points as well. Two weeks later, all eight examiners were asked to identify and mark the same points again. Two senior residents (Dr Goren and Dr Zoizner) measured the distance from each CEJ point marked on the screen (by all examiners) to the apical premarked point at two different times, using the tools of the Photoshop software. No definition of the CEJ landmarks was given to the examiners, therefore none of them was aware of the possibility of marking the buccal or the palatal CEJ.

To verify the validity and reproducibility of all CEJ points and to compare the examiners' results with the true points, the most apical points of the buccal and palatal CEJ

as well as the mesial and distal CEJ points were marked on the same tooth with special dots made of stainless steel wire. The tooth and the films went through the same procedure described above. All measurements served as a database for the statistics.

Statistics

Student's t-test was used to compare the intraexaminer differences (reproducibility) between the first and second readings. The Type II statistics of analysis of variance (AN-OVA) and the general linear method (GLM) procedures were used to compare the interexaminer differences and the differences between the actual points and the marked points (validity), respectively. The Statistical Package for the Social Sciences (SPSS, Chicago, Ill) was used to analyze the data. A value of P < .05 was considered statistically significant.

Method error

Method error was analyzed by two researchers (Dr Goren and Dr Zoizner) randomly measuring 10 different parameters on two separate occasions. The size of the error was calculated by the formula: $\sqrt{\Sigma d^2/2n}$, where d is the difference between the two measurements of a pair and n is the number of double measurements.14 The method error of the measurement was less than 0.1 mm.

RESULTS

Table 1 presents the results for identifying the buccal and palatal CEJ. Tables 2 and 3 present the results for identifying the mesial and distal CEJ, respectively.

When the results were analyzed using the Student's ttest, they show that there was no statistically significant difference in the two measurements done by the same examiner at different times. This was true for all three different CEJ points.

When the results of the measurements were analyzed with Type II ANOVA and GLM procedures, there was a statistically significant difference among the different examiners (P < .0001). The variance among the examiners was dependent on the angle between the tooth and the film. At all angles between the tooth and the film except at 10° . the average buccal or palatal point marked by the examiners was significantly different from the actual buccal or actual palatal point (P < .0001). There were no statistical differences between the points marked by the examiners and the actual mesial and distal points.

DISCUSSION

The consistent identification of most points on radiographic films is not an easy task.¹⁻⁴ The results of this study revealed that the most apical CEJ point is no exemption to this rule, at least among different examiners. If the peri-

The Angle	10°	20°	30°	40°
Examiner 1	12.05 ± 0.70	11.65 ± 0.70	11.05 ± 0.21	10.20 ± 0.10
Examiner 2	11.55 ± 0.35	11.35 ± 0.50	11.35 ± 0.07	10.05 ± 0.50
Examiner 3	10.55 ± 0.35	9.65 ± 0.71	8.45 ± 0.35	7.15 ± 0.21
Examiner 4	12.95 ± 0.50	12.75 ± 0.21	11.25 ± 0.07	10.20 ± 0.28
Examiner 5	10.55 ± 0.50	10.05 ± 0.21	9.00 ± 0.14	7.60 ± 0.14
Examiner 6	10.65 ± 1.20	10.15 ± 0.49	8.00 ± 0.10	7.00 ± 0.28
Examiner 7	11.60 ± 0.10	10.60 ± 0.28	9.35 ± 0.35	9.65 ± 0.78
Examiner 8	13.40 ± 0.10	13.10 ± 0.28	12.25 ± 0.07	11.30 ± 0.28
Examiners' average	11.66 ± 1.12	11.16 ± 1.25	10.09 ± 1.53	9.14 ± 1.61
Actual buccal	10.90 ± 0.25	11.30 ± 0.20	11.60 ± 0.22	11.20 ± 0.15
Actual palatal	9.90 ± 0.15	8.80 ± 0.20	7.70 ± 0.18	6.30 ± 0.20
Values of <i>P</i> among examiners	0.003	< 0.001	< 0.001	< 0.001
Values of P in reference to the actual buccal and actual palatal CEJ	ns	< 0.001	< 0.001	< 0.001

TABLE 1. The Mean Distance (mm \pm SD) Between the Premarked Point on the Apex and the Most Apical CEJ Point on the Crown as Marked by the Eight Examiners and the Actual Buccal and Palatal CEJ Points^a

^a CEJ indicates cementoenamel junction; ns, not significant.

TABLE 2. The Mean Distance (mm \pm SD) between the Premarked Point on the Apex and the Mesial CEJ Point as Marked by the Examiners, and the Actual Mesial CEJ Points^a

The Angle	10°	20°	30°	40°
Examiner 1	14.20 ± 0.28	12.50 ± 0.28	11.40 ± 0.09	9.45 ± 0.21
Examiner 2	14.55 ± 0.35	12.95 ± 0.08	12.05 ± 0.29	10.30 ± 0.02
Examiner 3	14.95 ± 0.21	14.05 ± 0.22	13.30 ± 0.63	11.40 ± 0.03
Examiner 4	14.85 ± 0.07	13.60 ± 0.14	12.75 ± 0.35	10.90 ± 0.42
Examiner 5	14.60 ± 0.14	13.25 ± 0.27	12.15 ± 0.05	10.95 ± 0.77
Examiner 6	14.90 ± 0.14	13.65 ± 0.63	13.25 ± 0.07	11.50 ± 0.42
Examiners' average	14.68 ± 0.32	13.33 ± 0.57	12.48 ± 0.75	10.75 ± 0.79
Actual mesial CEJ	14.80 ± 0.15	14.40 ± 0.22	13.70 ± 0.19	12.30 ± 0.21
Values of <i>P</i> among examiners	< 0.001	< 0.001	< 0.001	< 0.001
Values of P in reference to the actual mesial CEJ	ns	ns	ns	ns

^a CEJ indicates cementoenamel junction; ns, not significant.

TABLE 3. The Mean Distance (mm \pm SD) Between the Premarked Point on the Apex and the Distal CEJ Point as Marked by the Examiners and the Actual Distal CEJ Points^a

The Angle	10°	20°	30°	40°
Examiner 1	14.85 ± 0.08	12.50 ± 0.45	11.30 ± 0.02	8.60 ± 0.28
Examiner 2	15.15 ± 0.21	14.20 ± 0.14	12.85 ± 0.21	11.80 ± 0.09
Examiner 3	15.10 ± 0.42	14.35 ± 0.63	13.40 ± 0.14	12.15 ± 0.01
Examiner 4	15.30 ± 0.01	14.50 ± 0.28	13.30 ± 0.56	11.70 ± 0.21
Examiner 5	14.80 ± 0.14	14.65 ± 0.35	13.15 ± 0.07	11.25 ± 0.49
Examiner 6	15.15 ± 0.09	14.40 ± 0.51	14.05 ± 0.21	12.05 ± 0.03
Examiners' average	15.06 ± 0.24	14.10 ± 0.83	13.00 ± 90.90	11.23 ± 1.28
Actual distal CEJ	14.90 ± 0.09	14.60 ± 0.15	13.30 ± 0.18	11.40 ± 0.12
Values of <i>P</i> among examiners	< 0.001	< 0.001	< 0.001	< 0.001
Values of P in reference to the actual mesial CEJ	ns	ns	ns	ns

^a CEJ indicates cementoenamel junction; ns, not significant.

apical radiographic film of the incisor is properly exposed, the development and fixation processes are done according to the manufacturer's guidelines and instructions, and there is no overlapping between the different CEJ lines, there should be two CEJ lines (shadows) on the film ie, the buccal and the palatal CEJ lines. The mesial and the distal CEJ points are the images of the lines on their respective sides.

Because, no differences usually exist in the quality of the buccal and palatal CEJ lines on the tooth, and the palatal CEJ is closer to the film, it is expected that its image should be sharper. To our surprise, at 10° and 20° between the tooth and the film (Figure 2), the marked points are scattered on both sides of the actual buccal CEJ but not the palatal CEJ. In the 30° and 40° angle between the tooth and the film, the marked dots are closer to the actual palatal CEJ. Another interesting finding is that no examiner marked a point smaller or more apical than the actual palatal CEJ.

Point identification is more difficult in vivo than in vitro.



FIGURE 2. The average distances from the apex to the most apical CEJ point on the crown as marked by the eight examiners in four different angles. The distances to the real buccal and palatal CEJ are shown in the graph. CEJ indicates cementoenamel junction.

Several factors may affect the clarity or the observation of these points such as different width differences of the enamel of the two sides, amalgam or composite restorations, and crown morphology. The alveolar bone, tooth material overlap, and rotations are additional factors that might interfere with the identification of the CEJ on the mesial and distal sides. Certainly, as mentioned previously, technical factors in the manner the radiograph was exposed, ie, beam intensity, film development, and fixation are important factors that contribute to the clarity of different points on the film and, therefore, to their identification. To decrease the systematic error, the experiment was designed according to the suggestions published by Houston.¹⁵

Analyzing the behavior of the actual buccal and palatal distance values at the four different angles, the validity part of this study (Table 1), demonstrates that the mean buccal values were almost the same for all angles (around 11.25 mm, range 10.90 mm to 11.60 mm), and the palatal values decreased from 9.90 mm to 6.30 mm. The two points move apart from each other up to five mm only because of the angular changes between the tooth and the film.

The values measured by all examiners consistently decreased as the angle between the tooth and the film increased from 10° to 40° . This finding demonstrates the difficulties associated with trying to analyze OIIRR by measuring the tooth or root length directly on consecutive films without using any compensating formulas.

One of the significant results of this study is the scattering of the average distance measured by each examiner in all angles as seen in Table 1. For example, comparing the average in the 10° column, it is obvious that there is almost 2.5 mm difference between the points identified by examiner 4 and examiner 5. This same distance increases to almost 4.5 mm as the angle between the tooth and the film increases (eg, examiner 6 vs examiner 8 at 40°). Those numbers are by far larger than the 0.45-1.5 mm, which is the average amount of root loss quoted in many studies.^{6,7,10,15-18}

Therefore, the calculations of the amount of OIIRR can be easily distorted by an attempt to correct the amount of angulation of tooth to the film among films when using the CEJ as an invariant marker. It is obvious that including the identification of the edge of the crown as well as the apex in this study, as an invariant marker, might change the results. Nevertheless we decided to use the apex as a fiducial point to decrease the numbers of variables. Even though, in this study only one point was used as a variable, the results demonstrated statistical differences in the important variable measured.

It is noteworthy, that unlike the differences between the actual buccal and palatal points and the points marked by the examiners, there were no statistical significant differences between the actual mesial and distal CEJ points and those identified by the examiners (Tables 2 and 3). The importance of this finding lies in the recommendations made in another study that is going to be published in the near future. We found that the midpoint between the mesial and distal CEJ points serves well as a point for OIIRR accurate calculations. Because the severity of OIIRR is an important issue in the academic dental fields as well as in litigation, legislation, and ethics, it is extremely important to understand the way it is actually measured.

CONCLUSIONS

- Angular changes between the tooth and the film affect the identification of CEJ points on a periapical film taken with the paralleling technique.
- There is a statistically significant difference among different examiners in the identification of these points, but

no significance exists between the same examiner's results done at two different times.

• There is a statistically significant difference between the buccal and palatal CEJ points identified by the examiners and the same actual points as marked on the tooth itself. On the other hand, there is no statistically significant difference between the mesial and distal points as identified by the examiners and the actual points marked on the tooth itself.

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