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Original

Localization of impacted maxillary canines using panoramic radiography

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Abstract: We aimed to establish a reliable method of localizing an impacted maxillary canine on the sole basis of assessment of a single panoramic radiograph, and to determine the validity and reproducibility of the method. Panoramic radiographs of 50 subjects with a total of 68 impacted canines were analysed. The Canine Incisor Index (CII), Canine Canine Index (CCI), control Canine Incisor Index (c-CII), Zone (apical, middle, coronal) and Sector (I, II, III, IV) were determined on digitized panoramic radiographs. Comparison of the CII and CCI values of labially or palatally impacted canines revealed a statistically significant difference (P < 0.05). Comparison of labial and central canine impactions revealed no relation to CII or CCI (P > 0.05). There was a significant difference between palatal and central canine impactions in relation to CII (P < 0.05), but no significant difference between the two with respect to CCI (P > 0.05). Correct prediction of palatal canine impactions by differential magnification on a panoramic radiograph is possible in 77% of cases. Vertical and horizontal restrictions have no value in recognition of labiolingual position of impacted maxillary canines. The panoramic radiograph cannot be used as a sole radiograph for reliable localization of impacted maxillary canines. (J Oral Sci 51, 37-45, 2009)

Keywords: panoramic; localization; impacted; maxillary canine.

Introduction

The term “localization” means: “determination of the site or place of any process or lesion” (Dorland) (1). Accurate knowledge of the position of an impacted canine may contribute to the decision to perform a less invasive procedure when exposure of the canine is required (2). A periapical repositioning flap procedure might be the choice in labially impacted canines, whereas extensive removal of bone might be necessary in the case of palatal impaction. Also, the prognosis of an impaction can be assessed accurately only when the exact position of the impacted tooth is known (2). The use of various techniques, including the parallax method (3,4), vertex occlusal radiography (5), radiographic views taken at contrasting angles (6), stereoscopy (6,7), panography (6), the multiple exposure method (7), image superimposition (8), and computed tomography (9) has been advocated for localization.

Localization by panoramic radiography is an accepted technique but is not executed in routine practice. It is probably true that in today’s routine orthodontic practice most preliminary consultations include a panoramic radiograph. In the panoramic radiograph, maxillary canine impaction is an occasional but significant finding. It would be advantageous if this single film could be reliably used for localization of the unerupted tooth. These films are often taken in patients undergoing orthodontic appraisal, and no additional films would need to be taken in such patients.

We therefore conducted this study to establish a method of localizing impacted maxillary canines from a single panoramic radiograph by utilizing inherent panoramic

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distortions. We then determined the validity and reproducibility of the method.

Materials and Methods

The study was performed at the Department of Oral Medicine and Radiology, MCODS, Manipal under the approval of IREC (Institutional Research Ethical Committee). The study group comprised patients with impacted permanent maxillary canines (either unilateral or bilateral). The material for investigation was gathered from the records of three dental teaching clinics and two orthodontic clinics in Mangalore. Patients coming to the department in whom radiographs were indicated for pre-treatment orthodontic evaluation were also included in the study.

The following criteria were used to select samples.

Inclusion criteria:

(a) Subjects more than 13 years of age with unerupted maxillary canine or canines needing orthodontic treatment.

(b) Panoramic radiographs of acceptable diagnostic quality from selected patients.

Exclusion criteria:

(a) Erupted rotated canine.

(b) Horizontally placed canine and labio-palatal canine impaction.

(c) Malaligned upper central incisors or Class II division 2 malocclusion.

(d) Gross distortions of dental arches, as in craniofacial syndromes.

(e) Insufficient number of erupted teeth in the maxillary incisor region.

(f) Difference of more than 5 mm (radiographic measurement on a digitized panoramic radiograph) in the widest mesio-distal dimension of the maxillary central incisors.

A total of 90 subjects (117 impacted canines) were considered for inclusion in the study. After application of the selection criteria, 50 subjects (19 males and 31 females) with a total of 68 impacted canines were included. Each impacted canine was considered as a single sample. Patient age ranged from 13 to 25 years, with a mean age of 14.7 years. An oral radiologist, in accordance with the prescribed format, interpreted all the panoramic radiographs. The work of the examiner, who had 4 years of experience, was standardized against examination of a sample of the radiographs by a skilled oral radiologist with 15 years of teaching and radiography experience. To add precision to the measurements each film was measured three times and the average of the values was taken.

Patients coming to MCODS, MANIPAL

Panoramic radiographs were taken in non-syndromic patients with clinically unerupted maxillary canines. These patients had been selected for orthodontic treatment. Panoramic radiographs were taken with a Planmeca 2002CC Proline machine with a peak voltage of 68 kVp and current of 7 mA and an exposure time of 18 s. Patients were positioned by viewing the laser lines (Midline, Frankfurt horizontal plane, and Canine line). The radiographs were processed in a Promax X-ray film processor. Impacted canines were localized by using the SLOB (same lingual opposite buccal) rule. IOPA (Intra-oral periapical radiograph) radiographs were taken by a short-cone IOPA machine (Confident Evolution ×3,000) at 70 kVp and 8 mA and with an exposure time of 0.6 s.

Records from other institutions

Panoramic radiographs of other patients with impacted maxillary canines were obtained from the patients' radiographic records. Clinical records showed the position of the impacted canine (labial or palatal or mid alveolar). Photographs showing surgical exposure of the impacted canine were evaluated.

All panoramic radiographs were digitized with a digital camera (3.1 megapixels) for the purpose of computer-aided measurements of various parameters. This was done in a lightproof darkroom. The radiographs were mounted on a viewing box, with all stray light blocked out. To calibrate the images a 10-mm, 24-gauge orthodontic wire was stuck to the panoramic radiograph with an adhesive plaster before digitization.

Digitized images were transferred to the computer and numbered. The images were randomly analyzed on a monitor. No information on the location of the impacted maxillary canine was given to the radiologist before the interpretation. Dimaxis software (Planmeca) was used for computer-aided measurements (Fig. 1).

The widest mesio-distal dimension of each maxillary central incisor was measured perpendicular to the long axis of the tooth. If the difference in dimension between the two teeth was more than 5 mm the patient was excluded from the study. This was done to rule out gross horizontal magnification of one side.

The following parameter assessments were made:

1. (a) The widest mesio-distal dimension of the impacted canine was measured on a line perpendicular to the long axis.

   (b) The widest mesio-distal dimension of the erupted, properly positioned canine was measured on a line perpendicular to the long axis.

(c) The widest mesio-distal dimension of both central incisors was measured on a line perpendicular to their long axes.

The ratio of the widest mesio-distal dimension of the impacted canine to the widest mesio-distal dimension of the ipsilateral central incisor was defined as the Canine Incisor Index (CII). The ratio of the widest mesio-distal dimension of the erupted canine to the widest mesio-distal dimension of the ipsilateral central incisor was defined as control Canine Incisor Index (c-CII); this ratio was taken as the control. The widest mesio-distal dimension of the impacted canine to that of the erupted canine was defined as the Canine Canine Index (CCI) (Fig. 2).

2. On the panoramic radiograph, the height of the tip of the crown of each displaced canine was assessed in the vertical plane relative to the ipsilateral central incisor. A horizontal line was drawn passing through the root apex of the central incisor. Another line was drawn parallel to the previous one, passing through the cementoenamel junction of the central incisor. The distance between the two lines was calculated and the root of the central incisor was thus divided into three equal zones (apical, middle and coronal). The tip of the crown of the impacted canine was then located as a landmark in one of the three zones relative to the central incisor (Fig. 3).

3. We used a modification of Ericson and Kurol's definition (10) of sectors. The lateral incisor was used to assess the distance of the impacted canine from the midline.

(a) A line was drawn tangentially through the distal outline of the crown and root of the lateral incisor.

(b) One line was drawn along the long axis of the lateral incisor, dividing the incisor into two halves.

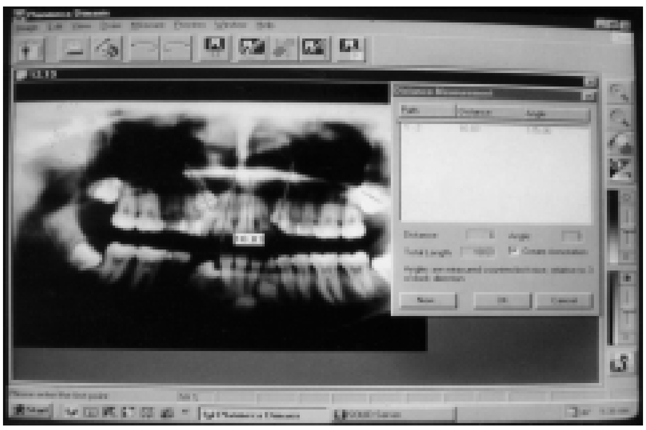

Fig. 1 Computer-aided measurement on a digitized panoramic radiograph using Planmeca Dimaxis software.

(c) Another line was made tangentially through the mesial outline of the crown and root of the lateral incisor.

These 3 lines divided the area into 4 sectors (Sectors I, II, III, and IV) (Fig. 4). The tip of the crown of the impacted canine was used to determine the sector in which the canine lay (Fig. 4).

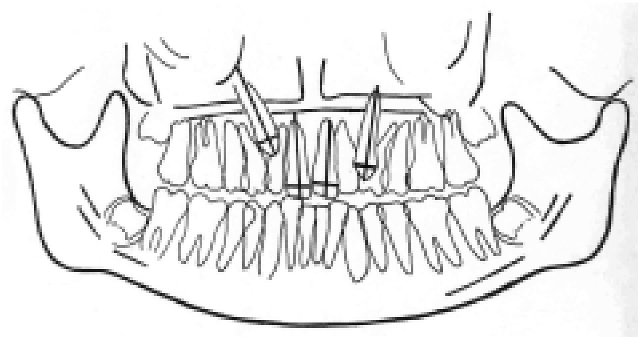

Fig. 2 Measurement of the widest mesio-distal dimensions of impacted canines and central incisors.

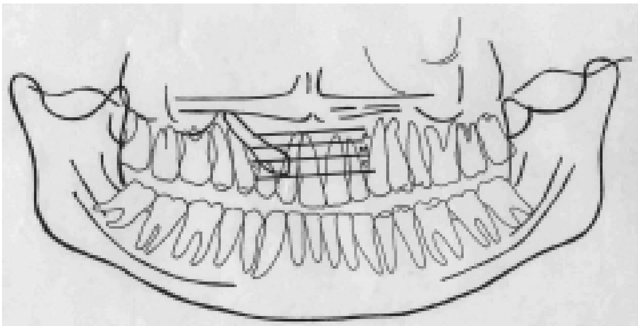

Fig. 3 The three vertical zones: A, Apical; M, Middle; C, Coronal.

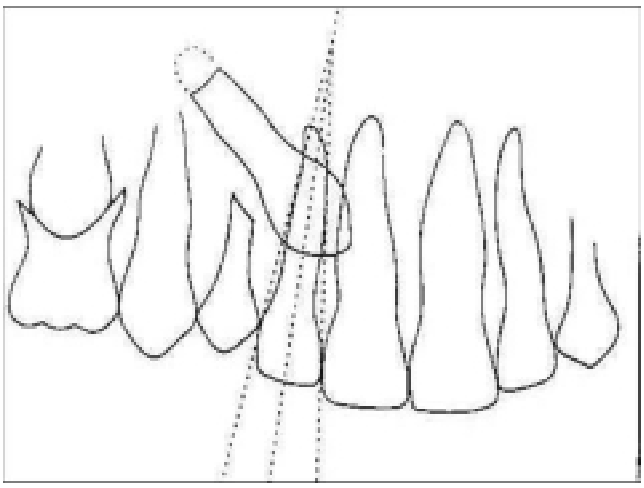

Fig. 4 Various sectors according to Ericson and Kurol's criteria.

Twenty panoramic radiographs were reanalyzed by the first examiner 10 days after the initial examination to assess the reproducibility of the diagnosis. This sub-sample of 20 radiographs was selected randomly from the initial sample. The principles and procedures were explained to another oral radiologist, who analyzed a sub-sample of randomly selected 20 panoramic radiographs. The intra-observer and inter-observer variability were determined.

The CII and CCI values of palatally, labially, and centrally impacted canines were compared by using the Mann-Whitney *U*-test. The Kruskal-Wallis Test was used to determine any correlation of CII or CCI with respect to zone or sector. Since there was an insufficient number of labially impacted canines in the apical zone, the Mann-Whitney *U*-test was performed and the apical zone was not taken into consideration. A paired *t*-test was applied to determine the inter- and intra-examiner variability. A *P* value of < 0.05 was considered to indicate statistical significance for all tests.

Results

Out of 50 panoramic radiographs of impacted maxillary canines, 21 showed bilateral impactions and 29 showed unilateral impactions. There was therefore a total of 71 canine impactions. In 3 patients with bilateral impactions, the canine on one side was excluded from the study, giving a final total of 68 canine impactions. On localization by the SLOB rule and later confirmation by surgical exposure, there were 37 labially impacted canines, 26 palatally impacted canines, and 5 mid-alveolar impactions.

Of the 37 labially impacted canines, 31 (83.78%), 5 (13.51%), and 1 (2.7%) were in the coronal, middle, and apical zones, respectively. The palatal canines, with respect to vertical position, were localized as follows: 13 (50%) in the coronal zone, 10 (38.46%) in the middle zone, and three (11.53%) in the apical zone (Table 1). Most of the labially impacted canines were found in sector I (28: 75.67%) whereas only 6 (23.97%) palatally impacted canines lay in sector I. Ten (38.46%) palatally impacted canines were found in sector IV, in contrast to no labial canine impactions in sector IV (Table 2).

Tables 3 and 4 show the means and standard deviations of the CII and CCI values for canines in the different zones and sectors, respectively. The ranges of CII and CCI overlapped with respect to zones and sectors and could not be segregated.

Application of a paired *t*-test to determine the inter- and intra-examiner variability showed no statistically significant ($P > 0.05$) differences, indicating that the measurements were reliable (Table 5).

Discussion

The permanent canines are well recognized as very important teeth, by virtue of their pivotal role in establishing the arch form, their contribution to an esthetic smile, and their participation in functional occlusion. Moreover, they are second only to the third molars as the most frequently impacted teeth. Proper localization of the impacted tooth plays a fundamental role in determining the feasibility of the surgical approach and the best access to use, as well as the proper direction of application of orthodontic forces.

Cone-beam CT is a superior, easier, and less laborious option, but it is more expensive. We evaluated the use of the panoramic radiograph as a preference for localization, since these radiographs are often taken in patients undergoing orthodontic appraisal; no additional radiation exposure would therefore be necessary, and the procedure is comparatively inexpensive. One of the shortcomings of

Table 1 Distribution of impacted maxillary canine location with respect to zone

	Buccal			Palatal			Central			Total	
Zone	n	% of buccal	% of total	n	% of palatal	% of total	n	% of central	% of total	n	% of total
Apical	1	2.7	1.47	3	11.53	4.41	1	20	1.47	5	7.35
Middle	5	13.51	7.35	10	38.46	14.7	1	20	1.47	16	23.52
Coronal	31	83.78	45.58	13	50	19.11	3	60	4.41	47	69.11
Total	37	100	54.41	26	100	38.23	5	100	7.35	68	100

Table 2 Distribution of impacted maxillary canine location in relation to sector

	Labial			Palatal			Central			Total	
Sector	n	% of labial	% of total	n	% of palatal	% of total	n	% of central	% of total	n	% of total
I	28	75.67	41.17	6	23.07	8.82	3	60	4.41	37	54.41
II	6	16.21	8.82	6	23.07	8.82	0	0	0	12	17.64
III	3	8.01	4.41	4	15.38	5.88	0	0	0	7	10.29
IV	0	0	0	10	38.46	14.07	2	40	2.94	12	17.64
Total	37	100	54.41	26	100	38.23	5	100	7.35	68	100

panoramic radiography is the differential magnification of structures outside the image layer; we utilized this shortcoming here to localize impacted maxillary canines.

The basic radiographic principle applied was that an object placed closer to the panoramic film (i.e. farther from the X-ray source) throws a smaller shadow than an object placed at a greater distance from the film and closer to the X-ray source. The mesio-distal dimension of the canine is, on an average, 90% of the mesio-distal dimension of the central incisor, or 1 mm less. In an ideal dental arch, the canine is slightly more distant from a panoramic film than its ipsilateral incisor. The result is a 10% magnification

Table 3 Means and standard deviations of CII/CCI values for different zones

Localize			n	Mean	Std. Deviation	Minimum	Maximum
Labial	CII	APICAL	1	.9600	-	.96	.96
		MIDDLE	5	.9690	8.674E-02	.90	1.12
		CORONAL	31	.9803	9.760E-02	.80	1.15
		TOTAL	37	.9782	9.380E-02	.80	1.15
	CCI	APICAL	1	.9700	-	.97	.97
		MIDDLE	2	1.0975	.1237	1.01	1.19
		CORONAL	3	1.0447	.1181	.97	1.18
		TOTAL	6	1.0498	.1041	.97	1.19
Palatal	CII	APICAL	3	1.3673	.2999	1.14	1.71
		MIDDLE	10	1.2905	.1790	1.01	1.55
		CORONAL	13	1.1832	9.960E-02	.91	1.37
		TOTAL	26	1.2457	.1677	.91	1.71
	CCI	APICAL	0	-	-	-	-
		MIDDLE	5	1.1584	.1658	.86	1.25
		CORONAL	10	1.2028	7.275E-02	1.10	1.32
		TOTAL	15	1.1880	.1083	.86	1.32
Central	CII	APICAL	1	1.1470	-	1.15	1.15
		MIDDLE	1	1.0100	-	1.01	1.01
		CORONAL	3	.9827	8.658E-02	.89	1.07
		TOTAL	5	1.0210	9.407E-02	.89	1.15
	CCI	APICAL	1	1.1830	-	1.18	1.18
		MIDDLE	1	1.2100	-	1.21	1.21
		CORONAL	1	.9150	-	.92	.92
		TOTAL	3	1.1027	.1631	.92	1.21

Table 4 Means and standard deviations of CII and CCI values for different sectors of canines

Localize			n	Mean	Std. Deviation	Minimum	Maximum
Labial	CII	SECTOR I	28	.9647	9.045E-02	.80	1.15
		SECTOR II	6	1.0007	.1030	.88	1.15
		SECTOR III	3	1.0593	8.623E-02	.96	1.12
		TOTAL	37	.9782	9.380E-02	.80	1.15
	CCI	SECTOR I	3	1.0570	.1084	.98	1.18
		SECTOR II	0	-	-	-	-
		SECTOR III	3	1.0427	.1233	.97	1.19
		TOTAL	6	1.0498	.1041	.97	1.19
Palatal	CII	SECTOR I	6	1.3520	.2236	1.15	1.71
		SECTOR II	6	1.1628	3.017E-02	1.12	1.20
		SECTOR III	4	1.3238	.1425	1.17	1.50
		SECTOR IV	10	1.2004	.1610	.91	1.47
		TOTAL	26	1.2457	.1677	.91	1.71
	CCI	SECTOR I	3	1.2363	8.503E-02	1.15	1.32
		SECTOR II	4	1.1338	.1824	.86	1.26
		SECTOR III	1	1.1910	-	1.19	1.19
		SECTOR IV	7	1.1979	7.124E-02	1.10	1.28
		TOTAL	15	1.1880	.1083	.86	1.32
Central	CII	SECTOR I	3	.9827	8.658E-02	.89	1.07
		SECTOR IV	2	1.0785	9.687E-02	1.01	1.15
		TOTAL	5	1.0210	9.407E-02	.89	1.15
	CCI	SECTOR I	1	.9150	-	.92	.92
		SECTOR IV	2	1.1965	1.909E-02	1.18	1.21
		TOTAL	3	1.1027	.1631	.92	1.21

Table 5 Results of paired *t*-test: $P > 0.05$

		Mean	n	Std. deviation	p value
Pair 1	CII	1.0823	29	0.1565	0.369
	INTRACII	1.0884	29	0.1637	0.369
Pair 2	CCI	1.2516	10	0.1153	0.701
	INTRACCI	1.2335	10	7.594E-02	0.701
Pair 3	ZONE	2.6897	29	0.6038	0.326
	INTRAZONE	2.6552	29	0.6695	0.326
Pair 4	CII	1.0823	29	0.1565	0.343
	INTERCII	1.0731	29	0.1596	0.343
Pair 5	CCI	1.2516	10	0.1153	0.290
	INTERCCI	1.2073	10	0.1163	0.290
Pair 6	ZONE	2.6897	29	0.6038	0.326
	INTERZONE	2.6552	29	0.6139	0.326

of the canine on the panoramic radiograph, yielding nearly identical mesio-distal dimensions; this is the key to using the central incisor as the reference in the canine incisor index (CII) (11).

Another consideration was the influence of distance of the impacted maxillary canine from the radiation source on the vertical location of the object on the panoramic radiograph. The central ray in panoramic radiography is directed from a slightly negative angulation. Accordingly, palatally located teeth will be projected higher, even though they may be at the same height above the occlusal plane. As a result, the height of the image of the tooth on the panoramic film will be exaggerated by both its labio-palatal displacement and its vertical height above the occlusal plane (11).

We also took into account the effect of the distance of the radiation source from the impacted maxillary canine on the distance from the mid-sagittal plane. Conflicting evidence about this has been encountered in previous studies. Wolf and Mattila (8) observed that 47 impacted maxillary canines projected on the root or neck of the central incisor were positioned palatally, and they drew the conclusion that this was an almost invariable clinical finding.

In 1999, Gavel and Dermaut (2) found that the crown tip of the canine tended to move towards the mid-sagittal plane when it was impacted labially. In 2002, Smailiene (12) found that canines medial to horizontal sector III were located palatally. Similarly to us, they used a modification of the method of Ericson and Kurol (10) to record the location of the unerupted canine cusp tip relative to the lateral incisor root in one of four sectors.

A large number of impacted maxillary canines were excluded from the study because they were rotated, resulted in a projection that was the mesial or distal view of the same tooth on the panoramic radiographs. The sample size was small-only 68 impacted canines in comparison with the sample size of 160 in the 1999 study by Chaushu et al. (11). However, unlike us, they did not specify exclusion criteria (rotated canines, horizontal canine impactions, malaligned teeth).

In this previous similar study, the widest mesio-distal dimensions of the first molars on both sides were compared to ensure that the horizontal magnification was equivalent. A difference greater than 5% resulted in exclusion of some panoramic radiographs from the study (11). In our investigation, the widest mesio-distal dimensions of both maxillary central incisors were compared. Radiographs that showed a difference greater than 5 mm were discarded. Maxillary central incisors were preferred over mandibular molars as they were closer to the impacted maxillary canine, and measurements were to be done on the maxillary teeth on the panoramic radiograph.

In our investigation, we used the tip of the crown of the impacted canine as a landmark for the allocation of impacted canines to various zones and sectors; in contrast, the 1999 study by Chaushu, Chaushu, and Becker mentioned no such criterion (11).

We divided the root of the central incisor into three equal zones to assess the location of the impacted canine in the vertical plane. The earlier study used the adjacent incisor, which could be a lateral incisor or sometimes a central incisor (11); hence their criteria for allotment of zones were not very well standardized.

We took into account central canine impactions, but these were in the minority of the sample. Fox et al. also included central canine impactions in their 1995 study (13), but they were not included in the study by Chaushu et al. (11) in 1999.

The greatest number of impacted canines were projected in the coronal zone: 31 (83.78%) labially impacted canines and 13 (50%) palatally impacted canines. In a previous study 66.15% of labially impacted canines overlay the coronal zone and 74.74% of palatally impacted canines were set in the middle zone (8). Only one (2.7%) labially impacted canine and three (11.53%) palatally impacted canines were projected in the apical zone (Table 1). This was in contrast to 14 (8.75%) labially and 6 (3.75%) palatally impacted canines in the apical zone in the study by Chaushu et al. (11). In our investigation, most of the impacted canines in the apical zone were excluded, as they were either rotated or horizontally placed.

Examination of the distribution of impacted canines in various sectors revealed that 75.67% of labial canine impactions were in sector I and 38.46% of palatal canine impactions were concentrated in sector IV (Table 2).

Panoramic radiographs were digitized so that we could make computer-aided measurements; digitization was performed with a 3.1-megapixel camera at a standard distance from the viewing box. All the stray light was blocked by placing black paper on the viewing box. The usefulness of digitization and application of software gave more accurate measurements with fewer errors. We used computer-aided measurements made with Dimaxis software to improve the accuracy of our results, but previous studies (3,13) considered relative diminution or magnification in the horizontal plane compared with the size of adjacent teeth lying in the arch; these measurements were arbitrary.

The CII ranges for the labially, palatally, and centrally impacted canines were 0.8 to 1.15, 0.91 to 1.71, and 0.89 to 1.15, respectively. There was overlap in these ranges, and we can infer that the CIIs for all types of impaction were close. The CCI ranges for labially, palatally, and centrally impacted canines were 0.97 to 1.19, 0.86 to 1.32, and 0.92 to 1.21, respectively, again showing overlap (Table 3, Figs. 5-8).

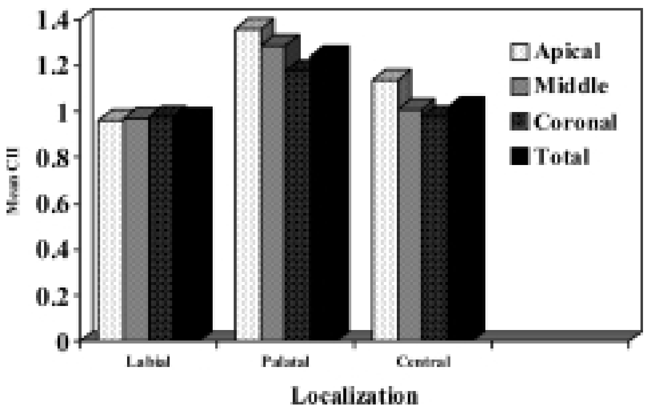

Fig. 5 Comparison of mean CII values with respect to various zones. There were no significant differences in these values between the various zones in the labially, palatally or centrally impacted teeth groups.

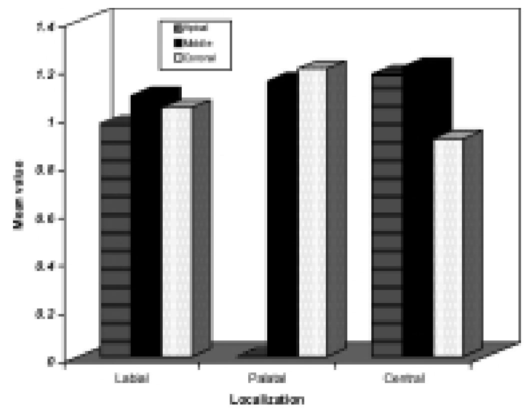

Fig. 7 Comparison of mean CCI with respect to various zones. There were no significant differences in these values between the various zones in the labially, palatally or centrally impacted teeth groups.

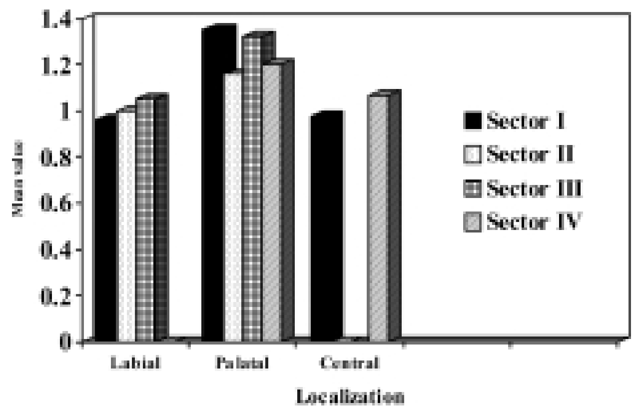

Fig. 6 Comparison of mean CII values with respect to various sectors. There were no significant differences in these values between the various sectors in the labially, palatally or centrally impacted teeth groups.

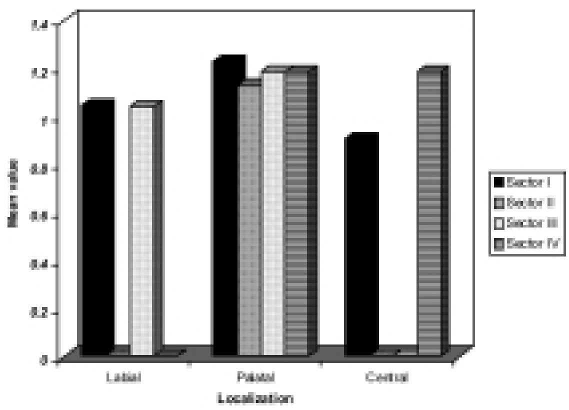

Fig. 8 Comparison of mean CCI with respect to various sectors. There were no significant differences in these values between the various sectors in the labially, palatally or centrally impacted teeth groups.

Comparison of the CII and CCI values of labially or palatally impacted canines revealed a statistically significant difference between the two ($P < 0.05$). Comparison of labial and central canine impactions with respect to CII or CCI readings revealed no statistically significant difference ($P > 0.05$). There was a statistically significant difference between palatal and central canine impactions in relation to CII ($P < 0.05$), but no significant difference was observed between the two with respect to CCI ($P > 0.05$). The Mann-Whitney *U*-test was employed to make the above comparisons.

According to Langland (14), "The horizontal magnification factor increases steeply with distance from the central plane of the image layer on the side towards the rotation center of the beam. On the side towards the film the magnification factor decreases, but this decrease is more gradual than the increase on the opposite side". Therefore, it was difficult to differentiate labial and central canine impactions on the basis of CII values.

Overall, the results for the CII and CCI values for canines in the different zones and sectors did not reach statistical significance ($P > 0.05$). This meant that there was no explicit range of values of CII and CCI lying in a particular zone or sector. Thus evaluation by zone or sector had no effect on the CII and CCI values of impacted canines. These findings were not in concurrence with those of the study by Chaushu et al. (11) who concluded that, "By imposing vertical restriction, 100% accuracy could be achieved for all of those canines that overlapped the middle and coronal zones of the adjacent teeth". Since there was only one labially impacted canine in the apical zone, we applied the Mann-Whitney *U*-test after excluding the apical zone; CII and CCI in the middle and coronal zones also did not show any statistically significant difference ($P > 0.05$).

Our results therefore did not corroborate the findings of Chaushu et al. (11) who found that "the magnification of palatal canines in the middle zone was higher than the magnification of palatal canines in the coronal zone. Most of the palatal teeth were projected more superiorly to the labial teeth; furthermore, the more superior the tooth, the greater its magnification".

The amount of magnification or diminution of the impacted canine is a factor of the distance from the line of the dental arch in which the canine would have been located if it had erupted. Hence, this factor should have more influence on the mesio-distal dimensions of impacted canines than would vertical zones and horizontal sectors. Unfortunately, by this method it is difficult to judge the distance of labially impacted canines from the line of the arch because for these canines there is less diminution. Also, differentiation between labially and centrally impacted canine is difficult. In our study, the CII and CCI values of labially and centrally impacted canines were not significantly different.

The control group had a wide range of c-CII values (0.753-1.33); this may have been the reason for the altered CII and CCI values and could have resulted in improper localization of the impacted canines. For the magnification method to be completely reliable an ideal arch form is necessary, making the CII of labially impacted canines greater than 1 and that of palatally impacted canines less than 1; to achieve this is very difficult.

CCI cannot be considered as a reference in all instances, because bilateral canine impactions occur frequently, meaning that large sets of these samples are not always available. Also, in many of our potential study patients the erupted canines were rotated, a few were ectopically placed, and one was transposed with a premolar, the widest mesio-distal dimension of which was not reliable.

Since there was an overlap of the ranges of CII values of various canine impactions, a precise cut-off point could not be determined. A value of 1.16 was considered to give a hint as to the locations of impacted maxillary canines. A palatally impacted canine could be reliably localized if its CII was higher than, or equal to, 1.16 in 77% of our samples. No distinction can be made between labial and central canine impactions. In a previous study the cut-off point was 1.15 (11).

In our study, the variability in readings by the two examiners and the differences between the readings made by the first examiner on separate occasions were not significant ($P > 0.05$). Hence, we consider our measurements to be reliable.

Wolf and Mattila in 1979 pointed out that the reliability of the magnification method is questionable. The labio-palatal position of approximately 90% of all impactions can be determined accurately. The greatest accuracy was achieved with palatally located teeth, for which the magnification is largest. However, the accuracy of this method decreased significantly when these teeth were positioned at the level of the dental arch, or buccal to it (15). Our findings were in accordance with theirs.

A prior study by Fox et al. (13) in 1995 demonstrated that correct prediction of palatal, unerupted, maxillary canine crowns using differential magnifications on dental panoramic radiographs is possible in about 4 out of 5 cases.

Previous studies (3,11,13) have shown that the accuracy of diagnosis of labio-palatally impacted maxillary canines on the basis of magnification in panoramic radiographs is 80% to 90%. Our findings were similar.

Since many cases were excluded from our study, the locations of only those impacted canines for which the labial view projection was apparent on a panoramic radiograph could be predicted by the differential magnification method.

In conclusion, correct prediction of palatal canine impactions by using differential magnification on a dental panoramic radiograph is possible in about 80% of cases. Vertical and horizontal restrictions have no value in recognition of the labiolingual positions of impacted maxillary canines. The panoramic radiograph cannot be used as the sole radiograph in the reliable localization of impacted maxillary canines; it can be used only as an adjunct to other, established methods.

Although the narrow image layer in the anterior region is a disadvantage of panoramic radiographs, the resulting distortion can prove to be a blessing in disguise if a method can be established to reliably localize impacted maxillary canines by using a single panoramic radiograph. Further studies should be conducted with larger sample sizes. Similar principles could be tested for localizing impacted mandibular canines.

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