

The radiographic localization of impacted maxillary canines: a comparison of methods

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SUMMARY This study compared two different radiographic techniques for localization of impacted maxillary canines: vertical parallax (from a panoramic and a maxillary anterior occlusal radiograph) and magnification (from a single panoramic radiograph). The radiographs and the information regarding the impacted canines were obtained retrospectively from records of patients treated in the Day Stay Unit of the Eastman Dental Hospital. The two different radiographic techniques were tested blind and compared for localization of the impacted canine by six examiners. The 'gold standard' used for the radiographic comparisons was the true position of the canine as recorded at operation.

The results showed a wide variation between the six examiners in the prediction of the canine position with the two different techniques. Localization with vertical parallax was more successful overall than with magnification, although the difference failed to reach significance. Seventy-six per cent of the impacted canines could be successfully located with vertical parallax and 66 per cent with magnification. Further analysis showed that, while almost 90 per cent of the palatally impacted canines could be correctly detected with both techniques, less than half of the buccal canines could be detected with parallax and only one in 10 buccal canines could be detected with magnification. If a canine is suspected to be buccally placed from its appearance on a panoramic film and cannot be palpated, further views are justified.

Introduction

An impacted tooth is one 'whose eruption is considerably delayed, and for which there is clinical or radiographic evidence that further eruption may not take place' (Thilander and Jakobsson, 1968). Maxillary canines are the most frequently impacted teeth after the third molars with a prevalence ranging from 0.92 per cent (Dachi and Howell, 1961) to 2.56 per cent (McKay, 1978), depending on the population examined.

The diagnosis of an impacted maxillary canine is based on both clinical and radiographic examination. The following clinical signs may be indicative of canine impaction:

- (1) delayed eruption of the permanent canine or prolonged retention of the primary canine (Thilander and Jakobsson, 1968);
- (2) absence of a normal labial canine bulge or presence of a palatal bulge in the canine region;
- (3) delayed eruption, distal tipping, or migration of the permanent lateral incisor;
- (4) loss of vitality and increased mobility of the permanent incisors (Kettle, 1958).

Many radiographic methods have been proposed. Two have special interest since they utilize the radiographs that are most commonly taken in orthodontic assessment.

Parallax

This was first introduced by Clark (1909). It involves two radiographs taken at different horizontal angles with the same vertical angulation. Due to parallax, the more distant

object appears to travel in the same direction as the tube shift and the object closer to the tube appears to move in the opposite direction [the so called Same Lingual Opposite Buccal (SLOB) rule; this could equally be remembered as Buccal Opposite Palatal Same (BOPS)]. The parallax technique may also be applied when the radiographs are taken at a different vertical angulations (vertical parallax). Various combinations have been used based on the technique of parallax:

- (1) two intra-oral periapical radiographs taken at different horizontal angles (Clark, 1909).
- (2) one maxillary anterior occlusal and one maxillary lateral occlusal (Southall and Gravely, 1989).
- (3) one periapical and one maxillary anterior occlusal radiograph (vertical parallax; Rayne, 1969).
- (4) one panoramic and one maxillary anterior occlusal radiograph (vertical parallax; Keur, 1986).

Although the tube for the panoramic radiograph is actually positioned behind the patient's head with a vertical angle of -7 degrees, in order to explain the shift technique it may be considered to be in front of the head at an angle of $+7$ degrees. Since the maxillary occlusal is taken at a vertical angle in the range of 60 – 65 degrees, there is an effective difference ranging from 53 – 58 degrees between the two films as shown in Figure 1 (Jacobs, 1994).

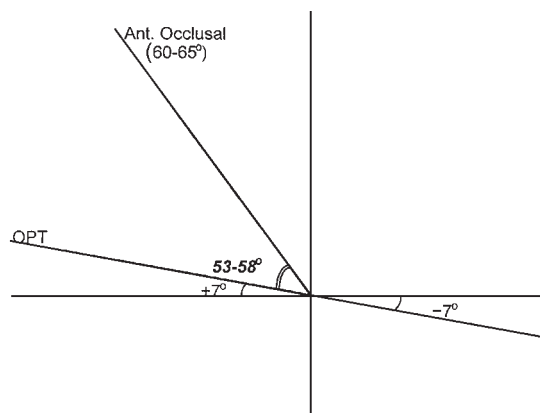


Figure 1 Vertical angulation between the orthopantomogram and the maxillary anterior occlusal.

- (5) one panoramic radiograph alone when a Panorex machine is used (Turk and Katzenell, 1970).

Magnification

This technique is based on the principle of 'image size distortion'; that is for a given 'focal spot'–film distance, objects further away from the image receptor (film) will be depicted more magnified than objects closer to the film (Figure 2; Goaz and White, 1982). Two methods can be used with this technique.

Status-x radiography (Ostrowsky, 1976). This involves a special tube inserted in the patient's mouth and a film held around the face by the patient. The hollow anode provides nearly a point source of radiation and, therefore, the laws of central projection apply—the object closer to the source is magnified.

Panoramic radiography (Wolf and Matilla, 1979; Fox *et al.*, 1995). The principle of image distortion can be applied in panoramic radiography. If a canine is relatively magnified in comparison to the adjacent teeth in the arch or the contralateral canine, it will be located closer to the tube, i.e. palatally, and if it is relatively diminished it will be located further away from the tube, i.e. labially. This method is most effective when the canine is not rotated, not in contact with the incisor root and the latter is not tipped

Other methods reported in the radiographic localization of the impacted canine are the vertex occlusal radiograph (Hitchin, 1951), image sharpness, and relationship of the canine cusp tip with the lateral incisor root in the panoramic radiograph. The 'right angle' technique involves two films taken at right angles to each other so that the canine can be located in three dimensions, e.g. lateral skull and postero-anterior cephalogram (Broadway and Gould, 1960), or lateral skull and panoramic radiograph (Coupland, 1987). Tomography, e.g. polytomography (Ericson and Kurol, 1987), and computer tomography (Ericson and Kurol, 1988) are especially useful in cases of root resorption of the adjacent teeth.

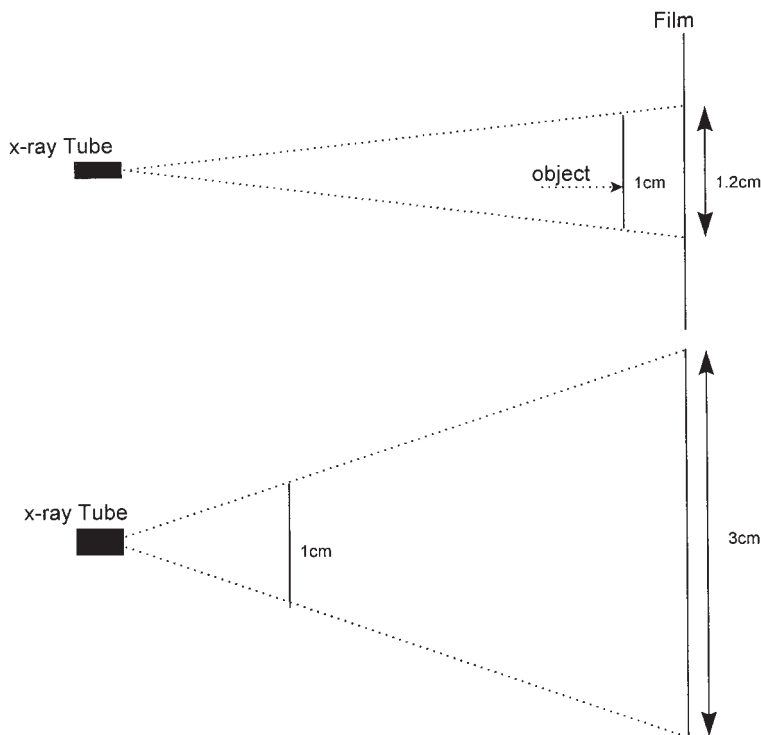


Figure 2 Increasing the distance between the object and the film increases the magnification.

Radiographic localization of the impacted canine is very important, especially if surgical treatment is to be undertaken. For many cases, radiography is the only means of accurately determining the position of the unerupted canine. The fact that so many radiographic localization techniques exist shows that none of them is ideal. A study on the radiographic prescribing habits of orthodontists and oral surgeons showed that 78 per cent used more than two radiographs and 23 per cent used four or more (Southall and Gravely, 1987). It may be possible that clinicians use the technique with which they are most familiar at the cost of an increased dose of radiation to the patient (Southall and Gravely, 1987). An increase in the level of dental radiography by a factor of six between 1957 and 1977 has been reported (Kendall *et al.*, 1981).

Clinicians should be encouraged to evaluate the radiographic methods currently in use in terms of the dose levels to which the patients

are exposed. If it can be shown that a single radiographic technique provides the same information as other techniques that require a higher radiation exposure, the justification for the use of those with higher exposure must be questioned (Southall and Gravely, 1987).

The panoramic radiograph is widely used in general practice and is the first choice radiograph for orthodontic patients (Southall and Gravely, 1987). Use of the maximum amount of information that can be obtained from such a radiograph would help reduce unnecessary radiation exposure to patients.

The current study was undertaken in order to assess the validity of two different radiographic techniques in the localization of the impacted canine: vertical parallax (from a panoramic and anterior maxillary occlusal radiograph) and magnification (from a single panoramic radiograph). The null hypothesis tested was that there was no difference between the two techniques.

Materials and methods

The study consisted of a retrospective analysis of the records of 100 patients who had undergone surgical treatment of unerupted canines in the Day Stay Unit of the Eastman Dental Institute, London.

The following criteria were used in order to select the sample:

1. For every patient included there should be one panoramic and one maxillary anterior occlusal radiograph of acceptable diagnostic quality (e.g. no distortions on the panoramic film due to incorrect patient positioning).
2. If a patient had gross distortion of the dental arches due to a cleft palate they were excluded.
3. Ideally, the radiographs should have been taken on the same day, shortly before the operation. If the two radiographs were taken more than 6 months apart or active orthodontic treatment had taken place between the two radiographic examinations, the patient was excluded.
4. A surgical diagnosis of the position of the impacted canine should be clearly stated in the operation records otherwise the patient was excluded.

Radiographic examinations

The estimated position of the canines with the two different radiographic techniques was recorded for six examiners: a consultant maxillofacial surgeon (A), a consultant orthodontist (B), a consultant in paediatric dentistry (C), a junior member of staff (senior house officer) (D), and two MSc postgraduate students (E and F). One postgraduate (the person responsible for the study) assessed the whole sample, whilst the rest examined a sub-sample of 40 patients. The examinations were standardized: the radiographs were studied on the same conventional X-ray illuminator (Kodak Coldlight Illuminator series 2, Ostsiern Scharnhhausen, Germany). Black card templates were used in order to eliminate the peripheral light from the X-ray viewer and the names, hospital numbers, and dates of birth on the radiographs were hidden. All radiographs were taken at the Department of Radiography,

Eastman Dental Hospital. The maxillary anterior occlusal radiographs were taken using a Philips X-ray machine (50–65 KV and 7.5 mA; Philips Medical Systems, London UK) using an intra-oral film (Kodak E-speed Plus). The panoramic radiographs were taken by either Planmeca 2002CC-Proline (66 KV and 8 mA; Planmeca, Helsinki, Finland) or Siemens Orthopantomograph 5 (65–70 KV and 15 mA; Siemens AG, Munich, Germany) using an extra-oral film AGFA HT-U (green sensitive; AGFA-Gaevert, Antwerp, Belgium).

Each of the examiners examined the radiographs on two separate occasions using the two different techniques. The familiarity of each examiner with the techniques was obtained with a questionnaire, since this could be helpful in explaining differences in accuracy between the two techniques. At the first examination, the canines were localized with vertical parallax from the panoramic and the anterior occlusal radiographs. An example is given in Figure 3a,b: the impacted right maxillary canine has moved upwards ('with the tube') from the orthopantomogram to the anterior occlusal radiograph and therefore is localized palatally. At the second examination (1 month later), the localization of the same canines was undertaken with the magnification method by the panoramic radiographs only. For example, in the previous orthopantomogram (Figure 3a), the impacted canine is horizontally magnified with comparison to the contralateral erupted canine and is therefore localized palatally. The following guidelines were given prior to the examination if the examiners were unfamiliar with the magnification technique (Fox *et al.*, 1995).

The impacted canine will be classified as:

- | | |
|------------------|--|
| (A) Buccal: | Where relative diminution of the crown has occurred in the horizontal plane, compared with adjacent teeth lying in the arch. |
| (B) In the arch: | Where the canine has the same degree of horizontal magnification as adjacent erupted teeth. |
| (C) Palatal: | Where relative magnification of the crown has occurred in the horizontal plane compared with adjacent teeth lying in the arch. |

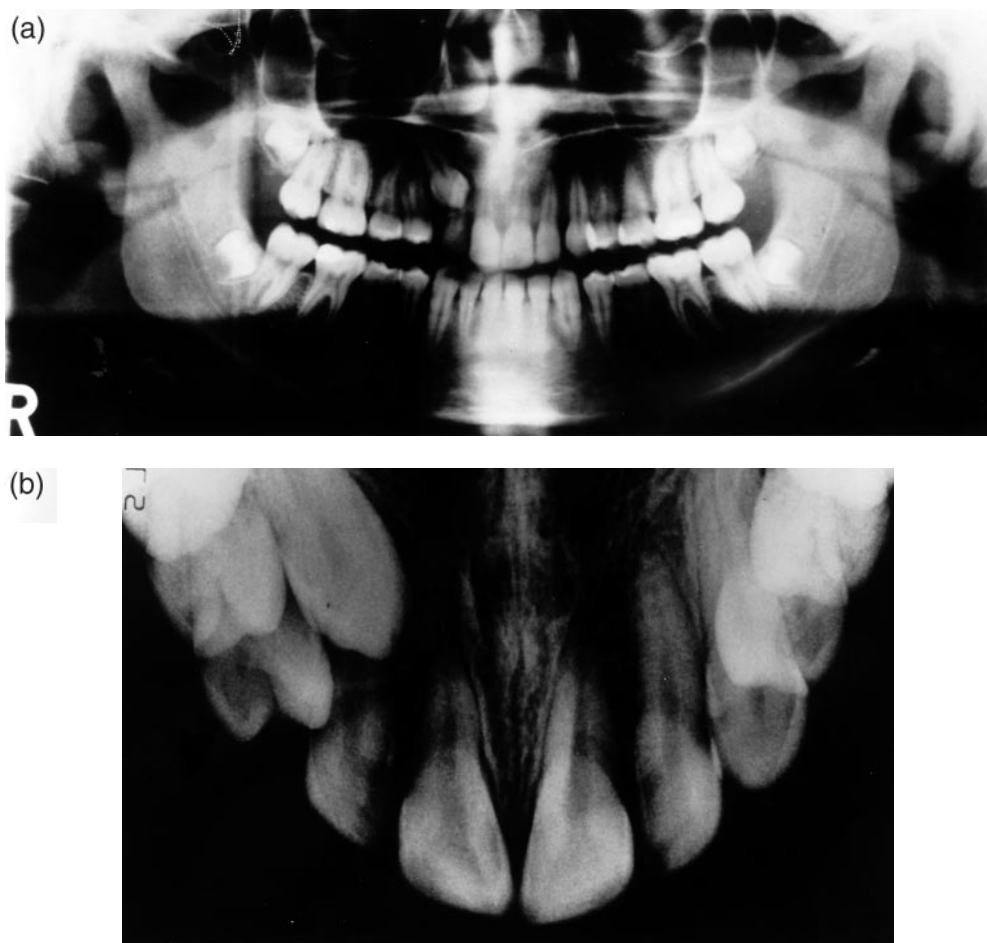


Figure 3 (a) Orthopantomogram showing an impacted right maxillary canine. (b) Maxillary anterior occlusal radiograph of the same patient as 3(a).

In case of unilateral impaction the comparisons should be carried out with the contralateral normally occluded canine.

Each examination was blind, i.e. the examiners did not know the surgical outcome.

Reproducibility studies

One week after each examination a randomly pre-selected sub-sample was re-examined in order to assess intra-examiner variation. This sample was selected from random number tables, and consisted of 40 patients for the whole sample and 16 patients for the smaller sample of 40 patients (40 per cent).

Statistical analysis

The predicted positions of the impacted canines from each radiographic technique were compared with the actual positions found during surgery. The overall percentages of correct diagnosis for each technique were compared with a SND test of statistical significance. The purpose was to determine the extent to which the two methods differed. A Cohen's Kappa statistic was also used in order to compare agreement of each technique with the true position of the canine.

Validity of diagnosis (i.e. correct diagnosis) with either the magnification or parallax technique was expressed as sensitivity for the palatally and

buccally located canines. Sensitivity for the palatally located canine is the probability that a palatally placed canine will be correctly detected with the specific technique.

The above statistical analysis was carried out considering each patient as a single unit and only one canine from each patient was analysed. Therefore, in the case of bilaterally impacted canines the right or the left canine was randomly chosen for analysis. This was undertaken in order to eliminate possible bias from a statistical analysis of variables that were not completely independent, i.e. two impacted canines that belong to the same patient.

Intra-examiner reproducibility for each technique was also tested with a Cohen's Kappa statistic.

Results

The records of 100 patients (71 females, 29 males) with a total of 133 impacted maxillary canines were used for the study. Thirty-three patients had bilaterally impacted canines. Of the 133 canines, 87 (65 per cent) were located palatally, 38 (28 per cent) buccally, and eight (6 per cent) in the line of the arch.

Comparisons between true position and predicted position from the radiographic examinations

The results from the radiographic examinations with the two different techniques were compared with the surgical results by a Cohen's Kappa statistic. The Kappa statistic, between true canine

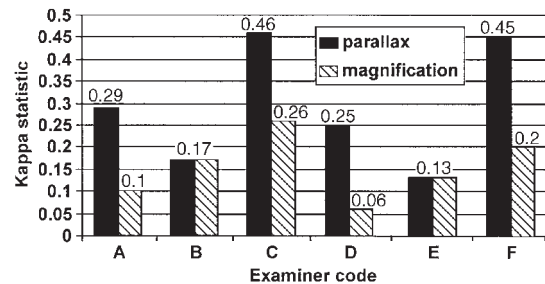


Figure 4 Kappa statistic between true position and position predicted by parallax and magnification for the six examiners.

position and predicted position with parallax, had a range of 0.13 to 0.46 for the six different examiners. Similarly, the Kappa statistic between true position and predicted position with magnification had a lower range of 0.06 to 0.26 for the same examiners (Figure 4).

With regard to the surgery, the 'buccal' and 'in the line of the arch' positions required a buccal flap (for surgical exposure or extraction of the impacted canine). The two positions were therefore combined and new Kappa values were calculated. This resulted in higher Kappa values for most of the examiners for both parallax and magnification (Table 1).

Comparisons between parallax and magnification

From the previously calculated Kappa values, a difference between the parallax and the magnification method was evident. Comparing the percentages of agreement with the two methods for examiner F, derived from Tables 2

Table 1 Kappa values before and after 'buccal' and 'in the arch' positions were combined for parallax and magnification (all examiners).

Examiner code	Parallax Normal Kappa	Parallax Kappa when buccal = arch	Magnification Normal Kappa	Magnification Kappa when buccal = arch
A	0.29	0.41	0.10	0.24
B	0.17	0.48	0.17	0.30
C	0.46	0.51	0.26	0.31
D	0.25	0.32	0.06	0.07
E	0.13	0.33	0.13	0.08
F	0.45	0.50	0.20	0.29

Table 2 A comparison between true canine position and position predicted by parallax for examiner F.

		Position predicted by parallax			
		Arch	Palatal	Buccal	Total
True Position	Arch	2	2	1	5
	Palatal	3	62	4	69
	Buccal	3	11	12	26
	Total	8	75	17	100

Table 3 A comparison between true canine position and position predicted by magnification for examiner F.

		Position predicted by magnification			
		Arch	Palatal	Buccal	Total
True Position	Arch	1	4	0	5
	Palatal	6	62	2	70
	Buccal	7	15	3	25
	Total	14	81	5	100

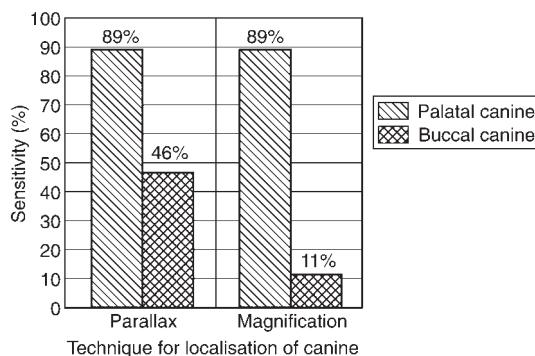
Table 4 Kappa values from the parallax and magnification reproducibility studies, for each examiner.

Examiner code	Kappa value with parallax	Kappa value with magnification
A	0.35	0.81
B	0.67	0.52
C	0.55	0.91
D	0.30	0.82
E	0.49	0.33
F	0.63	0.76

and 3, the SND statistical test had a *P* value $0.05 < P < 0.1$ and the confidence interval of the true difference between the two methods ranged from 0.016 to 20 per cent.

Sensitivity for the palatally or buccally located canine

The sensitivity of both parallax and magnification in the detection of the palatally or

**Figure 5** Sensitivity for the palatal and buccal canine for both parallax and magnification for examiner F.

buccally located canine for examiner F, is shown in Figure 5. Both methods were less sensitive in detecting the buccal canine, especially the magnification.

Reproducibility studies

Intra-examiner reproducibility was assessed with a Kappa statistic for both parallax and magnification, for each examiner (Table 4).

Table 5 shows the familiarity of each examiner with the parallax technique in comparison with their Kappa scores. This could not be carried out for magnification since none of the examiners was familiar with the technique.

Discussion

The sample for the study consisted of patients who had undergone surgery under general anaesthesia for an impacted canine and for whom a panoramic and an upper anterior occlusal radiograph had been taken. Most of the patients had been referred by the Department of Orthodontics at the hospital where the two radiographs are routinely taken for each patient with an impacted canine.

The correct diagnosis of the impacted canine position with the vertical parallax varied quite markedly between the six examiners. The best Kappa score was achieved by the consultant in paediatric dentistry (0.46) and the worst by one MSc student (0.13). Even for the highest scores

Table 5 Relationship between clinical experience and Kappa values for parallax for each examiner.

Examiner code	Clinical experience	Kappa value
A	Never	0.29
B	Always	0.17
C	Sometimes	0.46
D	Sometimes	0.25
E	Often	0.13
F	Never	0.45

the agreement was only 'moderate' and, therefore, not entirely satisfactory.

These results are not in agreement with a study comparing vertical parallax with three other radiographic techniques (Southall and Gravely, 1989). In that study, although the Kappa statistic was not calculated, the percentage of agreement with the true position was 87 per cent. In the current study, the agreement was 76 per cent for examiner F. It should be noted that comparisons between the two studies are not appropriate, since one was a laboratory study where a series of radiographs of a dried skull with a radio-opaque marker placed in different positions, were tested.

The large variation in the Kappa scores between the six examiners could not be explained from the familiarity with the vertical parallax technique. The examiners with the best scores only used the technique 'sometimes', and the examiner who used the technique 'routinely' had the second worse score. This examiner was the consultant orthodontist who, although diagnosing the impacted canine, was not performing the surgery. Nevertheless, when the 'buccal' and 'arch' positions were combined, the same examiner scored very high. This indicates that he was diagnosing many of the buccally positioned canines to be 'in the line of the arch' and *vice versa*. The combination of 'buccal' and 'arch' positions improved the Kappa scores of all examiners, but the agreement was still only 'moderate'.

It should be noted from the above that no conclusions can be extrapolated for the different dental specialties, since the differences may be

due to individual variation, and not necessarily to differences in training and experience.

The correct diagnosis with the magnification method also varied between the six examiners and was less accurate than the diagnosis with vertical parallax for most of the examiners. The examiner with the best Kappa score was again the consultant in paediatric dentistry (0.31), and the worst score was the senior house officer (0.06). For two examiners (the consultant maxillofacial surgeon and one MSc student), the Kappa scores were similar for parallax and magnification. Even for the highest scores the agreement was only 'fair' and therefore not satisfactory. The combination of the 'buccal' and 'arch' position resulted in higher Kappa scores for the magnification for almost all examiners, but the agreement was still only 'fair'.

In comparison with two previous investigations, the magnification method was less successful. In an earlier study (Wolf and Matilla, 1979) the percentage of agreement was 88 per cent for the first and 89 per cent for the second examiner. In the present study, the agreement with the magnification method for examiner F was only 66 per cent. However, the 'gold standard' for the previous study was another radiographic technique (similar to the horizontal parallax) and not the true position of the canine, which, in this study, was confirmed at operation. Variations in the sample could also explain differences in agreement; the above study had comparatively more palatally impacted canines for which the magnification has a high sensitivity (89 per cent in the current study). In a later study (Fox *et al.*, 1995) the percentage of agreement was 76 per cent with a Kappa of 0.52, while in the current investigation the results were 66 per cent and 0.2, respectively, for examiner F. Again, the 'gold standard' in the later study was a 'vertex occlusal', which 'have been shown to be unreliable under certain circumstances' (Southall and Gravely, 1987). In addition, in both of the previous studies each impacted canine was considered as a unit with the possibility of introducing bias.

Although the Kappa statistic shows that the magnification method is less accurate than vertical parallax, the difference in agreement did not reach a significant level of $P < 0.05$.

Therefore, to subject a patient to higher radiation exposure (with the inclusion of the anterior occlusal radiograph) may not be justified in the case of a palatally impacted canine, for which the sensitivity is the same with both techniques (89 per cent).

In the study by Fox *et al.* (1995), the sensitivity in the detection of the palatal canine with magnification was also high (82 per cent), while that for the buccal canine was lower (65 per cent). In the current study, the sensitivity for the buccal canine was very low (11 per cent).

Reproducibility studies

For the majority of the examiners, intra-examiner consistency was greater with magnification than with parallax. This was not expected since magnification is considered to be more subjective than parallax, but the fact that the method is easier and simpler may have contributed to a high reproducibility. The senior house officer achieved the highest Kappa score for magnification (0.82) and the consultant orthodontist the highest score for parallax (0.67). In the study by Fox *et al.* (1995), the reproducibility score for magnification was similarly high (0.86). The reproducibility scores for parallax are not satisfactory overall and, although the method is more successful in predicting the true position of the canine, it is far from ideal.

The results are not directly related to the diagnostic ability of the examiners; the overall diagnosis of an impacted canine is also based on clinical observations (i.e. intra-oral observation and palpation). It is encouraging that the buccally impacted canine, which is less successfully detected with the two methods, can often be palpated in the labial sulcus.

Conclusions

The following conclusions can be derived from this study:

- 1 Localization of an impacted canine with vertical parallax was more successful than with magnification, although the difference was not significant ($P > 0.05$).
- 2 There was a wide variation in agreement between true and predicted position from both parallax and magnification between different examiners and dental specialities, not necessarily related to familiarity with the method.
- 3 Seventy-six per cent of the impacted canines could be successfully located with vertical parallax and 66 per cent with magnification. According to Kappa statistic the prediction with parallax can only be classified 'moderate' and with magnification 'fair'.
- 4 Almost 90 per cent of the palatally impacted canines could be correctly detected with parallax and magnification, but only 46 per cent of the buccal canines with parallax and 11 per cent with magnification. Therefore, magnification is only suitable for the detection of palatally impacted canines. If the canine is placed buccally and cannot be palpated, an upper anterior occlusal view is necessary. Since both techniques are unsatisfactory in the localization of a buccal canine, additional views may be justified when a buccally impacted canine is suspected and cannot be palpated.

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