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Localization of impacted maxillary canines and root resorption of neighbouring teeth: a study assessing the diagnostic value of panoramic radiographs in two groups of observers

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SUMMARY

OBJECTIVES: To assess the diagnostic value of panoramic views (2D) of patients with impacted maxillary canines by a group of trained orthodontists and oral surgeons, and to quantify the subjective need and reasons for further three-dimensional (3D) imaging.

MATERIALS AND METHODS: The study comprises 60 patients with panoramic radiographs (2D) and cone beam computed tomography (CBCT) scans (3D), and a total of 72 impacted canines. Data from a standardized questionnaire were compared within (intragroup) and between (intergroup) a group of orthodontists and oral surgeons to assess possible correlations and differences. Furthermore, the questionnaire data were compared with the findings from the CBCT scans to estimate the correlation within and between the two specialties. Finally, the need and reasons for further 3D imaging was analysed for both groups.

RESULTS: When comparing questionnaire data with the analysis of the respective CBCT scans, orthodontists showed probability (Pr) values ranging from 0.443 to 0.943. Oral surgeons exhibited Pr values from 0.191 to 0.946. Statistically significant differences were found for the labiopalatal location of the impacted maxillary canine ($P = 0.04$), indicating a higher correlation in the orthodontist group. The most frequent reason mentioned for the further need of 3D analysis was the labiopalatal location of the impacted canines. Oral surgeons were more in favour of performing further 3D imaging ($P = 0.04$).

CONCLUSIONS: Orthodontists were more likely to diagnose the exact labiopalatal position of impacted maxillary canines when using panoramic views only. Generally, oral surgeons more often indicated the need for further 3D imaging.

Introduction

With a prevalence of 1–3 per cent, the maxillary canine is the second most frequently impacted permanent tooth after third molars (Preda *et al.*, 1997; Chaushu *et al.*, 1999; Mason *et al.*, 2001; Walker *et al.*, 2005). The maxillary canine is both functionally and aesthetically of great importance (Dewel, 1949). Of all teeth, the maxillary permanent canine has the longest period of development, as well as the longest eruption path starting from its point of formation, lateral to the piriform fossa, into occlusion, which may explain the high incidence for deviation and retention of the maxillary canines (Dewel, 1949). When permanent teeth fail to erupt spontaneously, an interdisciplinary treatment planning approach comprising orthodontists, oral surgeons, dentomaxillofacial radiologists, and prosthodontics is ideally required.

Early detection as well as exact localization of an impacted maxillary canine is important to avoid complications such as root resorption of neighbouring teeth, ankylosis of the affected canine, or the formation of cystic lesions (Ericson and Kurol, 1987; Ericson and Kurol, 1988; Ericson and Kurol, 2000; Liu *et al.*, 2008). Incisor root resorption is a well-recognized complication of impacted canines. Palatally and labially displaced canines can cause root resorption of the adjacent teeth (Rimes *et al.*, 1997; Jung *et al.*, 2012; Lai *et al.*, 2013). Accurate knowledge of the three-dimensional (3D) location of the impacted canine and detection of root resorption on adjacent teeth have an impact on the orthodontic treatment planning by influencing the decision whether the canine should be aligned or surgically removed (Bjerklin and Ericson, 2006; Becker *et al.*, 2010).

Recent studies have compared the diagnostic accuracy for the location of impacted maxillary canines and the detection of root resorption of neighbouring teeth by means of two-dimensional (2D) and 3D radiographs (Alqerban *et al.*, 2009, 2011; Haney *et al.*, 2010; Botticelli *et al.*, 2011; Wriedt *et al.*, 2012; Lai *et al.*, 2013). Some of the studies have a small sample size, are performed using dried skulls or lack information regarding inter-rater reliability of the radiographic image analysis. Owing to the higher radiation dose applied, especially to children and adolescents when using cone beam computed tomography (CBCT) imaging, this technique requires a clear indication and benefit for the patient strictly adhering to ALARA (as low as reasonably achievable) principles in medicine (Claus *et al.*, 2012). There is no data in the literature comparing analysis and interpretation of impacted maxillary canines by experienced orthodontists and oral surgeons using 2D images, and to identify the (subjective) need for further 3D imaging within and between these specialties. Therefore, the aim of the present study was to assess the analysis and interpretation of panoramic views (2D) of patients with impacted maxillary canines by a group of trained orthodontists and oral surgeons and to quantify the subjective need and reasons for further 3D imaging within and between the two specialties.

Materials and methods

Patients

The present study was retrospective in design regarding patient selection and included only patients that had received panoramic radiographs and CBCT scans (field of view: 4 × 4, 6 × 6 or 8 × 8 cm; 3D Accuitomo XYZ Slice View Tomograph, Morita Corp., Kyoto, Japan). Between January 2009 and December 2010, a total of 60 patients fulfilled these inclusion criteria. All patients had been referred to the Section of Dental Radiology and Stomatology at the Department of Oral Surgery and Stomatology, University of Bern, for further diagnostic 3D imaging of impacted/ectopically erupting maxillary canines (uni- or bilateral) with or without suspicion of resorption of neighbouring teeth. Patients with a known cleft palate were excluded from further analysis. Owing to the retrospective nature of the study, it was exempt from formal approval by the ethical committee of the State of Bern.

Panoramic view analysis

The panoramic views assessed in the present study had been performed by the referring dentists. The devices and operating parameters used for these panoramic views differed, but images were only accepted when available in a digital format (300 dpi and higher) for this study. Ten experienced specialists participated in the evaluation of the panoramic radiographs: five orthodontists and five oral surgeons. All observers were blinded to the analysis of the CBCT scans. Panoramic images were analysed using a Dell 380 Precision workstation (Dell SA, Geneva, Switzerland) and a 19 inch Eizo Flexscan monitor with a resolution of 1280 × 1024 pixels (Eizo Nanao AG, Wädenswil, Switzerland). A standardized questionnaire to mark with a cross was used to assess the following parameters for all panoramic views:

1. Labiopalatal location of the crown of the impacted canine in relation to the neighbouring teeth classified in labial, median, or palatal position;
2. Root resorption on central/lateral incisors, first, and/or second premolars (yes/no);
3. If root resorption was suspected, the degree of resorption was graded according to the classification based on clinical and computed tomography (CT) data by Ericson and Kurol (2000) for each tooth separately into no resorption, slight resorption (resorption up to half of the dentine thickness), moderate resorption (resorption of the dentine midway to the pulp or more, the pulp lining being unbroken), and severe resorption (resorption reaches the pulp);
4. Follicle size as measured from the crown of the impacted canine to the border of the follicle: less than 3 mm for normal or greater than 3 mm for enlarged follicles (Ericson *et al.*, 2002);
5. The necessity of further 3D investigations (yes/no). If yes, for which of the following reasons primarily?
   - Evaluation of the labiopalatal location of the impacted canine;
   - Evaluation of the incidence of root resorption on adjacent teeth;
   - Evaluation of the follicle of the impacted canine.

The questionnaire data were then compared within the two specialties (intragroup) and between the two specialties (intergroup) to assess possible correlations and differences for the analysed parameters using panoramic views. Furthermore, the findings from the CBCT scans were compared with the questionnaire data based on 2D imaging to estimate the correlation of the data within and between the two specialties. Finally, the need for further 3D imaging was analysed for the two groups based on the use of panoramic radiographs.

CBCT imaging and analysis

For all CBCT scans, a basic voxel size of 0.08 mm was used for evaluation. The operating parameters were set at 5.0 mA and 80 kV, and the exposure time was 17.5 seconds. The data were reconstructed in slices and examined slice by slice in all three dimensions (sagittal, coronal and axial) on 1:1 scaled images using a software program (i-Dixel, Morita Corp., Kyoto, Japan). All CBCT scans were evaluated for the following parameters by one experienced orthodontist not involved in the analysis of the panoramic views: 1. labiopalatal location of the impacted maxillary canine, 2. incidence and degree of root resorption on adjacent teeth, and 3. size of the dental follicle of the impacted maxillary canine in mm measured at the widest area of the follicle perpendicular to the crown on coronal and axial CBCT slices (distance greater than 3 mm considered to be an enlarged follicle, Ericson *et al.*, 2002).

Statistical analysis

Summary statistics were calculated for all assessed parameters. To assess intra- and inter-rater agreement, unweighted Kappa values were calculated by the method of Fleiss (1971) and Conger (1980). To analyse the reproducibility of the diagnostic procedure, all observers had to evaluate and answer the questionnaire twice of a total of 30 randomly selected panoramic radiographs. To evaluate the consistencies of the answers to the questionnaires (methodological error) within the same group and between the two groups of specialists and to analyse agreement between 2D and 3D radiographic findings, a logistic regression model with mixed effects was used. The resulting value shows the average probability (Pr) for the same answers. All statistical analyses were performed with the internet-based R software package (Version 2.12.1 http:www.r-project.org).

Results

Patients

Of the 60 patients with CBCT scans and panoramic radiographs enrolled in the present study, 18 (30 per cent) were male and 42 (70 per cent) were female with a mean age of 17.3 years (8.7–70.2 years). Overall, these patients had 72 impacted canines referred for further analysis and treatment. Bilateral impaction was present in 12 patients (20 per cent). Among these 72 impacted canines, 34 were located on the right side (47.2 per cent).

Panoramic view analysis

The observers judged the impacted canine most often to be located in a palatal position (49.5 per cent). Root resorptions were most often diagnosed for lateral incisors (13.4 per cent), and rarely for second premolars (1.3 per cent). For further details see also Table 1.

The analysis of the data from the questionnaire within the orthodontist group exhibited Kappa values ranging from 0.081 for assessment of the grade of root resorption on the second premolar to 0.487 for estimation of a possible root resorption for the lateral incisor (Table 2). Oral surgeons exhibited Kappa values ranging from 0.095 for assessment of the labiopalatal location of the impacted canines to 0.517 for estimation of the follicle size. When comparing the two groups, statistically significant differences for the Kappa values were found for the assessment of the labiopalatal location of the impacted maxillary canines ($P = 0.03$).

The average probability values (Pr) for the experts in the two groups to repeat the same answers to the questionnaire twice ranged from 0.77 to 1 (Table 3). There were no statistically significant differences between the groups regarding consistency of the answers with P values ranging from 0.227 to 0.998.

CBCT imaging and analysis

In 32 cases, the impacted canine was located in a palatal (44.4 per cent), in 29 in a buccal (40.3 per cent), and in 11 in median position (15.3 per cent; see also Table 1). Out of the 60 included patients, 30 showed root resorption (with a total of 38 teeth involved), and 30 patients showed no root resorption on adjacent teeth. Root resorption on adjacent teeth occurred mostly on the lateral ipsilateral incisor (I2: 25 teeth = 65.8 per cent of all teeth with resorption/34.7 per cent of all I2 included). Of all 38 adjacent teeth showing root resorption on the CBCT scan, 18 were graded slight (47.4 per cent), 4 moderate (10.5 per cent), and 16 severe (42.1 per cent). The dental follicle was considered to be enlarged in 48 out of 72 cases included (66.7 per cent).

CBCT versus panoramic view analysis

The comparison of the data from the questionnaires with the analysis of the respective CBCT sections within the orthodontist group exhibited Pr values ranging from 0.443 for assessment of the labiopalatal location of the impacted canines to 0.943 for detection of a root resorption on the second premolar (Table 4). Oral surgeons exhibited Pr values ranging from 0.191 for assessment of the labiopalatal location of the

Table 1 Labiopalatal location, root resorption of adjacent teeth, and follicle size of the impacted canines as judged by the observers (orthodontists and oral surgeons) and as diagnosed using cone beam computed tomography (CBCT) scans.

	Orthodontists	Oral surgeons	Overall	CBCT (%)
	Median/range (%)	Median/range (%)	Median/range (%)	
Labiopalatal location of the impacted maxillary canine	Labial: 26.73 (18.31–50.00) Median: 12.87 (5.00–29.52) Palatal: 57.33 (42.86–73.24)	Labial: 21.74 (10.68–40.00) Median: 42.86 (6.67–63.16) Palatal: 45.63 (0.00–60.87)	Labial: 26.03 (10.68–50.00) Median: 17.36 (5.00–63.16) Palatal: 49.48 (0.00–73.24)	Labial: 40.32 Median: 15.29 Palatal: 44.38
Root resorption on central incisor (I1)	Yes: 3.06 (0.00–7.14) No: 96.94 (92.86–100.00)	Yes: 3.04 (2.04–6.12) No: 96.94 (93.88–97.96)	Yes: 3.05 (0.00–7.14) No: 96.94 (92.86–100.00)	Yes: 6.94 No: 93.06
Root resorption on lateral incisor (I2)	Yes: 12.50 (7.14–17.86) No: 87.50 (82.14–92.86)	Yes: 16.07 (6.25–33.93) No: 83.93 (66.07–93.75)	Yes: 13.39 (6.25–33.93) No: 86.61 (66.07–93.75)	Yes: 34.72 No: 65.23
Root resorption on first premolar (PM1)	Yes: 6.122 (3.06–11.22) No: 93.88 (88.78–96.94)	Yes: 8.16 (3.06–31.63) No: 91.84 (68.37–96.94)	Yes: 7.14 (3.06–31.63) No: 92.86 (68.37–96.94)	Yes: 9.72 No: 90.28
Root resorption on second premolar (PM2)	Yes: 0.89 (0.00–6.25) No: 99.11 (93.75–100.00)	Yes: 2.68 (0.00–8.04) No: 97.32 (91.96–100.00)	Yes: 1.34 (0.00–8.04) No: 98.66 (91.96–100.00)	Yes: 1.34 No: 98.61
Follicle size	<3mm: 68.57 (53.33–78.10) >3mm: 31.43 (21.90–46.67)	<3mm: 67.62 (50.48–80.95) >3mm: 32.38 (19.05–49.52)	<3mm: 68.10 (50.48–80.95) >3mm: 31.90 (19.05–49.52)	<3mm: 32.28 >3mm: 66.72

Table 2 Intragroup and intergroup agreement of orthodontists and oral surgeons.

	Orthodontists (Kappa)	Oral Surgeons (Kappa)	Overall (Kappa)	Ortho versus Surg (*P* values)
Labiopalatal location of the impacted maxillary canine	0.24	0.095	0.135	**0.03**
Root resorption on central incisor (I1)	0.275	0.181	0.222	0.76
Root resorption on lateral incisor (I2)	0.487	0.371	0.468	1.00
Root resorption on first premolar (PM1)	0.432	0.38	0.419	0.83
Root resorption on second premolar (PM2)	0.179	0.135	0.148	0.27
Grade of resorption on I1	0.171	0.112	0.146	0.60
Grade of resorption on I2	0.355	0.284	0.362	0.65
Grade of resorption on PM1	0.279	0.269	0.279	1.00
Grade of resorption on PM2	0.081	0.117	0.119	0.27
Follicle size >3mm	0.426	0.517	0.452	0.57
Further 3D analysis required (yes/no)	0.324	0.101	0.173	0.13

Kappa values: no agreement, <0; slight, 0–0.2; fair, 0.21–0.40; moderate, 0.41–0.60; substantial, 0.61–0.80; almost perfect, 0.81–1 (Landis and Koch, 1977). Ortho, Orthodontists; Surg, Oral Surgeons.
Bold value = statistically significant difference.

Table 3 Methodological error for orthodontists, oral surgeons, and between both groups.

	Orthodontists (Pr values)	Oral Surgeons (Pr values)	Overall (Pr values)	Ortho versus Surg (*P* values)
Labiopalatal location of the impacted maxillary canine	0.7712918	0.7829957	0.7772133	0.803
Root resorption on central incisor (I1)	0.9875006	0.975001	0.9812494	0.419
Root resorption on lateral incisor (I2)	1	0.9834308	0.9961725	0.997
Root resorption on first premolar (PM1)	0.9277815	0.916667	0.92222	0.694
Root resorption on second premolar (PM2)	0.9889039	1	0.994444	0.998
Grade of resorption on I1	0.9875006	0.975001	0.9812494	0.419
Grade of resorption on I2	0.9882734	0.9764132	0.9834308	0.443
Grade of resorption on PM1	0.916667	0.8777829	0.897219	0.227
Grade of resorption on PM2	0.9774453	0.9944423	0.9861114	0.273
Follicle size >3mm	0.8663425	0.9061324	0.8880822	0.488
Further 3D analysis required (yes/no)	0.9060984	0.8826119	0.8949752	0.486

Probability (Pr): 0 = no agreement; close to 0 = small chance for agreement; 0.5 = there is a 50/50 chance; close to 1 = strong chance; 1 = agreement will almost definitely occur. Ortho, Orthodontists; Surg, Oral Surgeons.

impacted canines to 0.946 for detection of a root resorption on the second premolar. When comparing the two groups, a statistically significant difference was only found in the assessment of the labiopalatal location of the impacted maxillary canines ($P = 0.04$), indicating a higher correlation between evaluation of the panoramic views by orthodontists and the actual location of the impacted canines in the 3D scans compared with the respective data from oral surgeons.

Evaluation of the necessity of further 3D investigations

Further evaluation of the labiopalatal location of the impacted maxillary canines was the factor most often indicated as a reason for use of further 3D radiographic imaging (569 out of 880 questionnaire responses). To further assess the size of the follicle was only indicated 74 times as a reason to perform a 3D scan of the region of interest (Table 5). For all three factors potentially influencing the decision to perform additional 3D radiographic imaging, oral surgeons were statistically significantly more in favour of 3D imaging than orthodontists (*P* values ranging from 0.03 to 0.04).

Discussion

Patients with impacted maxillary permanent canines require interdisciplinary treatment planning, including diagnosis of the exact location of the impacted canine. Furthermore, the incidence of root resorption on adjacent teeth, incisors, and premolars should be diagnosed initially. Previous studies have shown that both parameters have a great influence on the treatment plan for orthodontists and oral surgeons alike (Bjerklin and Ericson, 2006; Haney *et al.*, 2010; Alqerban *et al.*, 2011).

Localization of impacted canines and root resorption of adjacent teeth has been reported to be more difficult to diagnose on panoramic radiographs compared with 3D imaging (Alqerban *et al.*, 2009, 2011). Data from analysis and interpretation of panoramic radiographs have shown great variation from images based on CBCT scans (Botticelli *et al.*,

Table 4 Agreement between three-dimensional and two-dimensional radiographic findings within and between both groups of specialists.

	Orthodontists (Pr values)	Oral Surgeons (Pr values)	Overall (Pr values)	Ortho versus Surg (*P* values)
Labiopalatal location of the impacted maxillary canine	0.4429249	0.1905562	0.2915640	**0.04**
Root resorption on central incisor (I1)	0.7734683	0.7489838	0.7612237	0.37
Root resorption on lateral incisor (I2)	0.9387738	0.9285682	0.9336712	0.52
Root resorption on first premolar (PM1)	0.8275697	0.8101369	0.8190345	0.52
Root resorption on second premolar (PM2)	0.9428571	0.9464286	0.9446428	0.79
Grade of resorption on I1	0.7612237	0.7346998	0.7479597	0.34
Grade of resorption on I2	0.9387738	0.9285682	0.9336712	0.52
Grade of resorption on PM1	0.7743624	0.7577751	0.7661951	0.62
Grade of resorption on PM2	0.9392859	0.9392891	0.9392834	1.00
Follicle size >3mm	0.5196848	0.5418146	0.5211798	0.64

Probability (Pr): 0 = no agreement; close to 0 = small chance for agreement; 0.5 = there is a 50/50 chance; close to 1 = strong chance; 1 = agreement will almost definitely occur. Ortho, Orthodontists; Surg, Oral Surgeons.
Bold value = statistically significant difference.

Table 5 Factors influencing the decision for further 3D imaging.

	Orthodontists (yes/no)	Oral Surgeons (yes/no)	Overall (yes/no)	Ortho versus Surg (*P* values)
Labiopalatal location of the impacted maxillary canine	232/208	337/103	569/311	**0.04**
Root resorption on adjacent teeth	175/265	259/181	434/446	**0.04**
Size of follicle of the impacted maxillary canine	4/431	70/365	74/796	**0.03**

Ortho, Orthodontists; Surg, Oral Surgeons.
Bold values = statistically significant differences.

2011; Wriedt *et al.*, 2012). In the present study, the lowest overall value of correlation between evaluation of panoramic views and CBCT scans was found for the labiopalatal location of the impacted maxillary canines (Pr = 0.292). Regarding this parameter, there was a statistically significant difference between the two specialities, with oral surgeons being less likely to diagnose the location of the canines (labial, median or palatal) correctly. The statistically significant difference for this parameter between orthodontists and oral surgeons was also present when assessing intra- and intergroup agreement of the completed questionnaires. Here, oral surgeons were less likely to agree on the labiopalatal location of the impacted canines seen on panoramic views compared with orthodontists.

That panoramic views are difficult to interpret may be partially due to difficulties in positioning of the patient's head and distortions due to the exposure technique (Graber, 1966; Stramotas *et al.*, 2002; Granlund *et al.*, 2012). Also, the overlapping of anatomic structures has been reported to cause further difficulties in diagnosis (Ericson and Kurol, 2000; Heimisdottir *et al.*, 2005; Alqerban *et al.*, 2011; Botticelli *et al.*, 2011; Wriedt *et al.*, 2012). What could be clearly demonstrated by the present investigation is that the methodology applied to diagnosis is quite reproducible, with Pr values ranging from 0.77 to 1, and no significant differences between the two groups regarding consistency of the answers (*P* values ranging from 0.227 to 0.998).

Previous studies have shown that root resorptions on adjacent teeth due to impacted canines are more clearly visualized using 3D imaging compared with 2D imaging modalities (Ericson and Kurol, 2000; Walker *et al.*, 2005; Botticelli *et al.*, 2011). Generally, 2D imaging tended to underestimate the presence and also the extent of root resorptions, thus demonstrating the superiority of 3D imaging in their early diagnosis. These findings are also corroborated in the present study, where orthodontists and oral surgeons alike did diagnose root resorptions less frequently on panoramic views compared with the actual findings on CBCT scans. The classification of the grade of root resorption as proposed by Ericson and Kurol (Ericson and Kurol, 2000) is based on findings from clinical and CT evaluation. In the present study, this classification was used to assess root resorptions on adjacent teeth due to impacted canines in panoramic views. It has to be taken into account that based on this methodology, the observers in the current study were actually assessing horizontal but not oblique resorptions. This could explain some of the discrepancy of evalutating the presence and grade of root resorptions between 2D and 3D imaging seen in the results (overall Pr values ranging from 0.748 to 0.945).

When comparing the reported data on prevalence of root resorptions using CBCT, the data vary considerably. Lai and co-workers found root resorptions in 25.37 per cent of the lateral incisors, 5.22 per cent of the central incisors, 4.48

per cent of the first premolars, and 0.75 per cent of the second premolars (Lai *et al.*, 2013). In the present evaluation, root resorptions were found in 34.72 per cent of the lateral incisors, 6.94 per cent of the central incisors, 9.72 per cent of the first premolars, and 1.34 per cent of the second premolars. Strbac *et al.* found only 7.7 per cent of the lateral and 2 per cent of the central incisors with root resorptions (Strbac *et al.*, 2013). Premolars were not analysed in this study. A possible reason for this discrepancy may be the selection of the population to be analysed that may already have introduced a considerable bias.

Ericson *et al.* (2002) compared the width of the dental follicle of ectopically erupting canines with the canines that were erupting normally using CT scans. Distances of more than 3 mm were considered to be enlarged. However, they could not confirm that an enlarged follicle exhibited a greater risk of causing root resorption on adjacent teeth. Asymmetric follicles were found more frequently, which can only be illustrated with 3D imaging. Although the visualization of the labiopalatal dimension of the follicle is not possible on panoramic radiographs, diagnosis of an enlarged follicle showed good correlation when comparing data from CBCT scans and panoramic radiographs (overall Pr value of 0.521).

For the labiopalatal location of the impacted maxillary canine, agreement between the specialties (Kappa value = 0.135) and between 2D and 3D data (Pr value = 0.292) was rather low or limited. In a recent study analysing inter-rater agreement between two experienced orthodontists and an oral surgeon for the labiopalatal location of impacted maxillary canines on CBCT scans, the resulting Kappa value was much higher (0.877; Lai *et al.*, 2013). The reason for this clear discrepancy of data analysing the same outcome parameter is mainly due to the radiographic images used for evaluation in these two studies. In the present study, only 2D images (panoramic views) were judged by the observers, whereas in the study by Lai *et al.* (2013), the observers evaluated CBCT scans.

In the present study, the observers also indicated in 65.7 per cent of the questionnaire responses (569 out of 880) that the need to know the exact labiopalatal location of the impacted maxillary canine was the reason for further use of 3D radiographic imaging. Nevertheless, this finding should be interpreted with some caution. A limitation of this study is that clinical data such as visualization and palpation was not available to the observers, and they had to make a judgement on the 2D images from panoramic views only. The second most frequent reason justifying the need for further diagnostic 3D radiographic imaging was the identification and visualization of possible root resorptions on adjacent teeth, which may have an impact on the treatment plan (overall 434 out of 880 questionnaire repsonses). Interestingly, more oral surgeons than orthodontists stated that an enlarged follicle is an indication for further 3D radiographic imaging (70 responses versus 4). For orthodontists, the enlarged follicle does not seem to justify further 3D imaging. In the orthodontic literature, the enlarged follicle has been reported not to be a risk factor for causing root resorption (Ericson *et al.*, 2002, Lai *et al.*, 2013). However, oral surgeons may have another concern that justifies further 3D radiographic imaging, e.g., the possible development of a cystic lesion in the area of the impacted maxillary canine (dentigerous cyst).

The crucial issue is whether, based on individual judgement by a specialist, single or multiple periapical X-rays or an occlusal radiograph should always be performed initially together with a panoramic view for diagnostics (Clark, 1909; Ericson and Kurol, 1986). Only when questions such as the exact location of the impacted canine or resorption of adjacent teeth still remain unclear after this initial clinical and radiographic evaluation, should adjunctive 3D evaluation be considered. Therefore, routine replacement of current radiographic techniques with 3D imaging must be considered with great care—especially when treating children. To measure the radiation risk for patients, the effective dose is the most widely accepted figure (Martin, 2008; Pauwels *et al.*, 2012). While average effective doses to the children and adolescent phantoms have been reported to be similar to adult doses (Lofthag-Hansen *et al.*, 2011), specific organs in children may receive up to a fourfold increase (thyroid) in dose relative to that of the adolescent. It is therefore imperative that dental 3D examinations (CBCT or CT) on children have to be fully justified over conventional X-ray imaging, and that patient- and equipment-specific dose reduction measures should be used at all times. Besides CBCT imaging, CT has evolved to become faster, more sensitive, more accessible, and adjustable for dental diagnostic tasks (Kyriakou *et al.* 2011; Harris *et al.*, 2012). Newer CT units are capable of scanning the jaws with one swift rotation of the gantry, and reduced dose hard tissue protocols are available today.

Conclusions

On the basis of the data from the present study, the following can be concluded:

- Owing to the limited sample size of observers in each group of specialists (five orthodontists and five oral surgeons), the results have to be interpreted with some caution.
- There was diversity in the answers within the two groups (orthodontists and oral surgeons) when evaluating the labiopalatal location of the impacted maxillary canines, root resorption of neighbouring teeth, and the follicle size with Kappa values ranging from slight to moderate agreement. A statistically significant difference between the two specialist groups was only found for the labiopalatal location of the canine.
- Orthodontists were more likely to diagnose the labiopalatal position of impacted maxillary canines when using panoramic views only.
- The labiopalatal location of the impacted maxillary canine was the most frequent reason justifying further

3D radiographic imaging. Generally, oral surgeons more often indicated the need for further 3D imaging.

- Future studies should evaluate the impact of adjuvant 3D imaging on the treatment plan regarding surgical and orthodontic aspects of the therapy.

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