RESEARCH ARTICLE

Audit of a 5-year radiographic protocol for assessment of mandibular third molars before surgical intervention

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Objectives: To perform an audit of a three-step protocol for radiographic examination of mandibular third molars before surgery.

Methods: 1769 teeth underwent surgery. A standardized three-step radiographic protocol was followed: (1) panoramic imaging (PAN), (2) stereoscanography (SCAN) and (3) CBCT. If there was overprojection between the tooth and the canal in PAN, SCAN was performed. If the tooth was determined to be in close contact with the canal in SCAN, CBCT was performed. Close contact between the tooth and the canal was assessed in all images, and patient-reported sensory disturbances from the alveolar inferior nerve were recorded after surgery. The relation between the final radiographic examination and sensory disturbances was determined. Logistic regression analysis tested whether signs for a close contact in PAN/SCAN could predict no bony separation between the tooth and canal in CBCT.

Results: 46% of teeth underwent PAN, 31% underwent SCAN and 23% underwent CBCT as the final examination. 21% underwent all three radiographic examinations. 53/76% of teeth with close relation to the canal in PAN/SCAN showed no bony separation in CBCT; if there was close relation in PAN/SCAN, there was 1.6/4.3 times higher probability that no bony separation existed in CBCT. 16 cases of sensory disturbances were recorded: 4 operations were based on PAN, 8 on SCAN and 4 on CBCT.

Conclusions: The radiographic protocol was in general followed. SCAN was superior to PAN in predicting no bony separation between the tooth and the canal in CBCT, and there was no relation between sensory disturbances and radiographic method.

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Introduction

Before surgical intervention of mandibular third molars, a radiographic examination is performed to assess the position of the third molar in relation to the neighbouring tooth and other anatomical structures, particularly, the relation to the mandibular canal, and additionally, to assess number and morphology of the roots and related pathology. Thereby, the radiographic image should help

the surgeon to state a diagnosis and establish a proper treatment plan. For years, panoramic imaging (PAN) has been the first-choice method for radiographic examination of mandibular third molars,¹ and if signs of an intimate relationship between the third molar and the mandibular canal are present in the PAN, representing an increased risk for sensory disturbances to the alveolar inferior nerve (IAN) during treatment, further radiographic examination may be indicated. Three-dimensional (3D) imaging, primarily CBCT, has therefore been

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suggested to assess the relation between the third molar and the mandibular canal prior to surgical intervention.²⁻⁴ Recently, guidelines for the use of CBCT have been published.⁵ These guidelines conclude that “*where conventional radiographs suggest a direct inter-relationship between a mandibular third molar and the mandibular canal, and when a decision to perform surgical removal has been made, CBCT may be indicated.*” The guidelines indicate that a conventional radiographic method should precede CBCT. As also concluded in the report, the guidelines are extracted based on studies with a rather low level of evidence. Therefore, more research is needed on the efficacy of CBCT.

Only one study is available in the literature that has suggested a protocol for the radiographic examination of mandibular third molars.² In this protocol, PAN and/or intraoral imaging was the first-choice radiographic method and sufficient in the majority of cases when there was no overprojection between the roots of the third molar and the mandibular canal. A posterior–anterior open-mouth projection was a supplement to the initial examination if the relation between the third molar and the mandibular canal was unclear. Moreover, CBCT or low-dose CT was used when the above-mentioned examinations were still not adequate. By this suggested protocol, PAN was sufficient in approximately 50% of the cases and, in approximately 20% of the cases, the third molar received a 3D examination before surgical removal. By this protocol, it seems that no permanent sensory disturbances to the IAN were observed.² Although following the SEDENTEXCT guidelines,⁵ the protocol has not been validated or compared with other protocols, and therefore the evidence for its efficacy is sparse.

The aim of this study was to perform an audit for a different step-wise radiographic protocol using PAN, stereoscanography (SCAN) and CBCT for pre-operative assessment of mandibular third molars. The detailed aims were (1) to evaluate how often each radiographic method was used as the final examination, (2) to evaluate the associations between the two conventional two-dimensional radiographic methods and CBCT in determining the relation between the third molar and the mandibular canal, (3) to assess if signs of a close contact in PAN and SCAN were able to predict no bony separation between the tooth and canal as seen in the CBCT images, and (4) to assess if there was a relationship between sensory disturbances in relation to the IAN and the final radiographic method.

Methods and materials

Patients

During a 5-year period (2008–12), a total of 2846 fully or semi-impacted mandibular third molars (in 2270 patients) were referred from the Section of Oral and Maxillofacial Surgery and Oral Pathology, Department

of Dentistry, Aarhus University, Aarhus, Denmark, to the Section of Oral Radiology, Department of Dentistry, Aarhus University, to undergo a radiographic examination. 1769 teeth (in 1259 patients) underwent surgical intervention; 38% were performed by oral and maxillofacial surgeons and 62% by undergraduate dental students. The presence of patient-reported sensory disturbances in the innervation area of the IAN was recorded in the patient's file. A permanent sensory disturbance was defined to be present if the symptoms had lasted more than 1 year after surgery.

Radiographic examination

A standardized three-step radiographic protocol before surgery was defined: (1) PAN, (2) SCAN and (3) CBCT examination. The PAN or, in some cases, a sufficient periapical image was always available at the initial clinical examination, and only teeth with an indication for surgical intervention or cases where additional radiographic findings were needed to determine indication for surgical intervention were considered for further radiographic examination.

The three-step protocol was as follows: Step 1: PAN [Cranex Tome[®] unit (Soredex, Helsinki, Finland) together with a storage phosphor plate image receptor (Digora[®] image plate and PCT scanner; Soredex)/conventional film (Agfa-Gevaert N.V. HT-G in a cassette with Kodak Lanex[™] Regular screens; Kodak, Rochester, NY, machine developing) or a ProMax[®] unit (Planmeca, Helsinki, Finland) with a charge-coupled device-based image receptor]. If the roots/tooth overprojected the mandibular canal in PAN (and similarly in the periapical image) and/or if the roots were blurred and/or if pathology was present, which could not be sufficiently assessed in PAN and was decisive for surgical intervention, the patient was referred to Step 2: SCAN [Scanora[®] unit (Soredex) with Digora phosphor plate image receptor/conventional film]. SCAN consisted of a series of four images (stereoscopic multiview), which displayed the third molar in one orthogonal and one distoecentric projection and two projections cranial to these. In both directions, the tube-shift angle was 4°. This technique allows for viewing with stereopsis in addition to the tube-shift technique the coronal relation between the tooth and the mandibular canal.⁶ If the mandibular third molar was interpreted to be in close contact with the mandibular canal in SCAN and/or if the roots were blurred and/or if pathology was present, which could not be sufficiently assessed in SCAN, and was decisive for surgical intervention, the patient was further referred to Step 3: CBCT [NewTom 3G[®] (QR SRL, Verona, Italy) or Scanora 3D (Soredex); in the NewTom scanner, a 6-inch field of view was used and in the Scanora 3D, a 6 × 6-cm field of view].

Radiographic assessment

The PAN and SCAN images were exported from their dedicated software and viewed in general software (DigiView[™] picture archiving and communication system; Erik Gotfredsen, Royal Dental College, Aarhus,

Denmark) with possibilities to use zoom function and image enhancement, including brightness, contrast and gamma curve functions.⁷ The CBCT volumetric data sets were reconstructed to display two-dimensional image sections (NewTom 3G: 0.2-mm sections; Scanora 3D: 0.13-mm sections) in three planes: axial, sagittal and coronal, and were viewed in their dedicated software (NewTom 3G: NNT, QR SRL; Scanora 3D: OnDemand®, Cypermed Inc., Irvine, CA). The initial PAN images were interpreted for further referral (*i.e.* tooth overprojecting the mandibular canal) by the surgeon, and subsequent SCAN and CBCT images were interpreted consecutively in the daily radiology clinic by one of three oral radiologists. Written radiographic reports were made of these images, including an assessment of the position of the tooth in relation to the adjacent teeth, number and morphology of the roots, presence of pathology in relation to the third molar and adjacent teeth as well as the relationship between the roots of the third molar and the mandibular canal.

For the analysis of the association between the PAN/SCAN methods and CBCT in determining a close relation between the third molar and the mandibular canal, one of two oral radiologists interpreted all PAN images again according to well-established criteria for a close relation between these structures: close contact was defined when at least one of the following three signs was seen in the image: (1) interruption of the radiopaque borders of the mandibular canal, (2) narrowing of the lumen of the mandibular canal and (3) changes in the course of the mandibular canal. In SCAN, it was recorded if the third molar was located buccally, lingually or in close contact to the canal. In the CBCT sections, it was recorded if the third molar was located buccally, lingually or on top of the canal and, furthermore, if there was no bony separation (indicating direct contact) between the third molar and the canal.

Data treatment

Data were analysed using SPSS® 13.0 (SPSS Inc., Chicago, IL). Descriptive statistics calculated the number of operated third molars based on each of the three radiographic methods as the final method and the number of sensory disturbances to the IAN associated with each final radiographic method. Logistic regression analysis with no bony separation observed in the CBCT sections (yes/no) as the outcome variable was performed to evaluate whether the signs of a close contact between the tooth and the canal in PAN and SCAN predicted no bony separation as seen in CBCT.

Results

The final radiographic examination

The distribution of the radiographic examinations is listed in Table 1. Approximately 46% of the mandibular third molars underwent PAN as the final examination, 31% had a SCAN as the final examination and 23% had a CBCT as the final examination. In a few cases (6.9%),

Table 1 Distribution of radiographic methods

Method	Number of teeth	% of teeth
Periapical alone	2	0.1
PAN alone	819	46.3
SCAN (periapical available)	71	4.0
PAN and SCAN	471	26.6
CBCT (periapical available)	11	0.6
PAN and CBCT	20	1.1
SCAN and CBCT (periapical available)	39	2.2
PAN, SCAN and CBCT	336	19

PAN, panoramic imaging; SCAN, stereoscanography.

a sufficient periapical examination displaying the whole third molar and the mandibular canal was already available from the referring dentist. Therefore, PAN was not performed, but SCAN was then the following examination in 6.2% and CBCT in 0.6% of the cases. In a few cases, CBCT was performed directly after PAN (1.1%). In 21.2% of the cases, all three radiographic examinations had been executed for the same third molar.

Association between PAN/SCAN and CBCT in determining the relation between the third molar and the mandibular canal

In 15 cases, it was impossible to interpret the relation between the third molar and the mandibular canal in PAN. Therefore, only 341 of the 356 that had PAN and CBCT are listed in Table 2. Table 2 shows the association between the findings for the relation between the third molar and the mandibular canal in PAN and no bony separation assessed in CBCT. An agreement was observed in 194 (57%) of the cases. In 92 (53%) of the third molars, which were assessed to have at least one of the signs for a close contact in PAN, no bony separation was seen in CBCT.

In 27 cases, it was impossible to interpret the relation between the third molar and the mandibular canal in either SCAN or CBCT. Therefore, only 348 of 375 that had SCAN and CBCT are listed in Table 3. Table 3 shows the association between the findings for the relation between the third molar and the mandibular canal in SCAN and CBCT. An agreement was observed in 211 (61%) of the cases. In 135 (76%) of the third molars that were assessed to be in close contact to the mandibular canal in SCAN, no bony separation was seen in CBCT.

Prediction of no bony separation between the third molar and the mandibular canal seen in CBCT by signs of a close contact in PAN/SCAN

Table 4 shows the results from the logistic regression analyses of the relation between close contact assessed in PAN/SCAN and no bony separation seen in CBCT. If one (or more) of the three signs for a close contact was assessed in PAN, there was 1.6-times higher probability that no bony separation was seen in the CBCT images than if these signs were not present. If the third molar was assessed to be in close contact to the mandibular canal in SCAN, the probability for no bony separation

Table 2 Association between assessment of signs for close contact in panoramic imaging (PAN) and no bony separation in CBCT

	CBCT—roots in relation to the mandibular canal								
	Bony separation				No bony separation				
PAN	Buccal	Lingual	On both sides	On top	Buccal	Lingual	On both sides	On top	Total
No signs	3	72	0	27	18	14	5	44	183
Interruption	5	29	0	25	30	6	2	31	128
Lumen narrowing	0	3	0	4	2	0	0	12	21
Change in canal course	0	0	0	0	5	0	0	4	9

Agreement between methods is shown in bold.

in the CBCT images was 4.3-times higher than if the third molar was judged not to be in close contact to the mandibular canal. SCAN was therefore more reliable than PAN to predict no bony separation in CBCT images.

Connection between disturbances to the alveolar inferior nerve and the final radiographic method

Coronectomies ($n = 142$) were not included in the categorization of disturbances to the IAN. In 16 cases of the 1627 fully removed third molars (0.98%), sensory disturbances to the IAN were recorded. Ten (0.61%) of the sensory disturbances to the IAN were temporary and six (0.37%) were permanent. 11 of the sensory disturbances to the IAN appeared after an operation was performed by dental students (1.0% of student operations; 6 temporary and 5 permanent) and 5 of the sensory disturbances to the IAN appeared after an operation performed by oral and maxillofacial surgeons (0.94% of surgeon operations; 4 temporary and 1 permanent).

Of the 16 disturbances to the IAN, 4 of the operations were based on PAN as the final examination, 8 operations were based on SCAN and 4 were based on CBCT. Three of the four patients, where the surgical removal was based on PAN alone, ought to have had an additional radiographic examination according to the protocol. By contrast, the patients who perceived a disturbance to the IAN, where the surgical removal was based on SCAN as the final examination, had followed the protocol, which was also the case with the two patients who underwent PAN, SCAN and CBCT, since they showed overprojection between the third molar and the mandibular canal in PAN and were in close contact to the canal in SCAN. Furthermore, in three of four patients, where the surgical removal was based on CBCT, there was no bony separation between the third molar and the mandibular canal.

Discussion

An audit is a systematic examination of data, statements, records, operations and performances for a stated purpose. Quality control programmes in radiology may be implemented in many clinics, predominantly with the aim to reduce the number of retakes and to maintain or improve clinical image quality as recently stated in the guidelines for CBCT.⁵ An audit is, however, more extensive and may be relevant when a defined rationale or procedure has been followed over a time period to assess its outcome.⁸ While hospitals and medical clinics have implemented such quality assurance programmes,⁹ it seems that this has been sparsely performed within dentistry. It may be advocated that dental practices and institutional clinics develop protocols for their clinical and radiographic practice for different diagnostic procedures. Outcome parameters should be defined, and the outcome following the protocol assessed, before any revision of the protocol is performed in order to be able to establish the effect of the changed procedure.

In relation to radiographic protocols of mandibular third molars, only one procedure has been reported for the radiographic examination before surgical intervention.² This protocol stated that a single PAN was sufficient if there was no overprojection between the tooth/roots and the mandibular canal, while in all other cases, the radiographic examination was extended. The results of the Swedish protocol were that 3D scanning had been performed in 20% of the patients who underwent a radiographic examination before surgical intervention, and following their procedure, there were no cases of permanent sensory disturbances to the IAN. In our clinic, a similar type of protocol was defined, and overall, the protocol was followed over the 5-year period in which it was used. In <2% of the cases, the protocol was not followed, and CBCT was, for example, taken

Table 3 Association between assessment of close contact in stereoscanography (SCAN) and no bony separation in CBCT

	CBCT—roots in relation to the mandibular canal								
	Bony separation				No bony separation				
SCAN	Buccal	Lingual	On both sides	On top	Buccal	Lingual	On both sides	On top	Total
Buccal	2	1	0	5	10	0	0	9	27
Lingual	0	74	0	18	2	14	3	13	124
Buccolingual	0	1	0	0	0	0	0	1	2
Close contact	2	29	1	28	46	10	4	75	195

Agreement between methods is shown in bold.

Table 4 Results from the logistic regression analyses with no bony separation between the third molar and the mandibular canal seen in CBCT as the outcome variable

Radiographic method	p-value	Odds ratio	95% confidence interval
PAN			
(No close contact)			
Close contact	<0.050	1.6	1.16–2.36
SCAN			
(No close contact)			
Close contact	<0.001	4.3	2.96–6.34

PAN, panoramic imaging; SCAN, stereoscanography.
Category in brackets served as reference.

after a periapical exposure or PAN without performing SCAN first. In 46% of the cases, there was no need for additional radiography after PAN was available, 31% had SCAN as the final examination and 23% had CBCT as the final examination. A total of 186 of the teeth that had a CBCT were included in a recent research study,⁴ all showing overprojection between the tooth/roots and the mandibular canal in PAN, and these were followed by both SCAN and CBCT owing to the study they were part of. Therefore, it may be that CBCT in some of these cases was performed without a SCAN indication. This is believed to be a minority, and therefore, does not affect the present results. The results from this protocol showed that the frequency of third molars that underwent only PAN as the final examination and of third molars that underwent 3D as the final examination was almost the same as in the protocol suggested by Flygare and Öhman.² In the present study, however, 21% of the patients received three radiographic examinations of the same region before intervention. This may be seen as a rather high radiation burden and, moreover, associated with high costs and resources.^{10,11} In contrast to the previously reported radiographic protocol, we defined the patient-related outcome for our protocol as any sensory disturbance to the IAN recorded after surgery. A permanent disturbance was recorded if this had lasted for more than 1 year, which was the case in six patients. The number of sensory disturbances to the IAN was equally distributed among the operations of oral and maxillofacial surgeons (0.94%) and dental students (1.0%), as has also been shown in a previous study.¹² Of the six permanent sensory disturbances, five appeared after an operation performed by a dental student and one after an operation performed by an oral and maxillofacial surgeon, which indicates a difference between trained and non-trained operators. In the previous study protocol, where no permanent disturbances to the IAN were reported, students were not involved in the operations.²

Two of the cases that experienced a sensory disturbance (temporary) did not show radiographic signs of close contact between the tooth and the canal, since, for one patient, who only underwent PAN, the third molar was positioned superior to the mandibular canal, and for the other patient, the CBCT sections showed bony separation between the tooth and the canal. One of

these two operations was performed by a dental student and the other by an oral and maxillofacial surgeon. This indicates that sensory disturbances may arise from other factors than the contact between the tooth and the IAN, for example, during injection of analgesics. On the other hand, in three cases, a sensory disturbance to the IAN appeared where only PAN, showing overprojection between the tooth and the mandibular canal, was available. These were included in the few cases where additional radiographic examination should have been performed according to the protocol, and it might be possible that findings from further radiographic examinations would have changed the treatment. It is not possible to predict whether or not the sensory disturbance could have been avoided. Furthermore, the hypothesis of a recent study using data from insurance companies in Finland was that the rapid increase in CBCT examinations of mandibular third molars would lower the incidence of permanent injuries to the IAN; however, the authors concluded that the availability of CBCT devices had had no significant effect on the number of IAN injuries.¹³

Several studies have assessed the reliability of PAN for assessment of lower third molars, but the results from these studies are deviating. In a review, it was concluded that three—(1) darkening of the roots, (2) interruption of the radiopaque borders of the canal and (3) diversion of the canal—of the seven signs in PAN for a close contact¹⁴ were more valid than the remaining four.^{15,16} However, the absence of these signs did not indicate that a direct contact did not exist. This is in accordance with the results of the present study in which these signs in the PAN, to some extent, were able to predict no bony separation between the third molar and the mandibular canal in the CBCT examination.

Only a few studies have compared findings from interpretation of SCAN images with findings during and after surgery.^{17–20} One study found no difference between PAN plus eccentric intraoral exposures and SCAN for assessing the relation to the mandibular canal;¹⁸ another study found that SCAN was superior to PAN in determining this relationship,¹⁷ and two studies found that CBCT was superior to SCAN.^{19,20} In most previous studies, one or two oral radiologists performed the radiographic recordings. In our study, one of three experienced radiologists performed the radiographic reports of SCAN and CBCT consecutively as the daily routine. The reproducibility among radiologists for assessing mandibular third molars in CBCT has been reported in a recent study to be high, especially for the assessment of no bony separation between the third molar and the mandibular canal.²¹ There was an association between SCAN and CBCT for predicting no bony separation between the third molar and the mandibular canal, since the odds ratio was 4.3. Thus, SCAN seemed to be able to predict no bony separation as seen in CBCT to a higher degree than could PAN. However, clinics that can perform scanography are limited in number, and this equipment is now-a-days phased out, giving space

to CBCT units. As such, future radiographic protocols will not involve SCAN imaging.

The present study basically follows a cohort of consecutive patients operated over a 5-year period. As such, it is epidemiological in nature and therefore this study provides lower evidence on the efficiency of a radiographic method than, for example, a randomized clinical trial. In a recent prospective clinical study, it was concluded that the treatment plan (full removal/coronectomy) based on PAN and SCAN examinations was changed in 12% of the cases after a CBCT examination was available for the operating surgeon.⁴ On the other hand, recent randomized clinical trials found that there was no significant difference between patient-reported sensory disturbances to the IAN when the operation was based on CBCT compared with merely PAN.^{22,23} More clinical studies are needed to obtain the highest level of evidence when a patient will benefit from a CBCT examination. The results from our study may, however, connect with those from clinical trials, since there was no definite relationship between the radiographic method or signs of close contact in the radiograph and the presence of sensory disturbances to the IAN. Although disturbances to the IAN is seen as the most severe patient complication after removal of a lower third molar, other patient-related outcome variables, such as pain and swelling could also be assessed. Besides, patient-/surgeon-related parameters, for example, operation time, could be relevant. One recent randomized clinical trial showed no

differences in operation time, sickness absence in days, intake of pain relievers and antibiotics between groups of patients randomized to either PAN or CBCT before third molar removal.¹¹

Based on the above speculations on the SCAN method, dose considerations and the results of the present audit, the protocol at our clinic was changed. All patients now undergo PAN examination, and if one of three signs of a close contact is seen and/or if the roots are blurred and/or if pathology is present, which cannot be sufficiently assessed in PAN and is decisive for surgical intervention, a CBCT examination is performed.

In conclusion, the radiographic protocol was in general followed as defined over a 5-year period. SCAN was superior to PAN in predicting no bony separation between the mandibular third molar and the mandibular canal, as seen in CBCT, and three signs for a close contact in PAN were associated with no bony separation in CBCT. Finally, a sensory disturbance to the IAN could not be deduced from the final radiographic method that the operation was based on.

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