

# Mandibular canal-related parameters interpreted in panoramic images and CBCT of mandibular third molars as risk factors to predict sensory disturbances of the inferior alveolar nerve

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**Abstract.** The aim of this study was to determine whether cone beam computed tomography (CBCT) before mandibular third molar removal can improve the risk assessment for neurosensory disturbances of the inferior alveolar nerve (IAN) compared to panoramic radiography (PAN). One hundred and six mandibular third molars examined by PAN and CBCT were removed. A temporary sensory disturbance of the IAN was present in 20 cases; a permanent disturbance was found in one case. Three blinded observers assessed radiographic risk factors in PAN and CBCT images. Positive (PPV) and negative (NPV) predictive values and positive (LR+) and negative (LR–) likelihood ratios were calculated for all parameters for all observers. Inter-observer reproducibility was expressed as both the percentage accordance and the kappa-statistic. Generally, the PPV and LR + were the same for PAN and CBCT, and there was good inter-observer reproducibility. The highest PPV and LR + for PAN were found when part of the roots were positioned inferior to the lower white border line of the canal, and for CBCT when the canal was positioned between the roots of the tooth. In conclusion, parameters assessed in PAN and CBCT are not reliable risk factors for neurosensory disturbances of the IAN, and CBCT appears not to improve the risk assessment.

**Key words:** third molar; radiography; cone beam computed tomography; panoramic imaging.

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A recent meta-analysis concluded that the assessment of cone beam computed tomography (CBCT) images prior to the removal of a mandibular third molar neither reduces morbidity, e.g. the number of postoperative sensory disturbances of the inferior alveolar nerve (IAN)<sup>1</sup>, nor results in a shorter operation time<sup>2</sup>. In randomized controlled clinical trials comparing panoramic imaging and CBCT as the radiographic method used before surgery, sensory disturbances of the IAN were observed in both groups, and there was no significant difference between the groups<sup>3-7</sup>. It could be speculated though, that there are signs in both panoramic images and CBCT that could serve as risk factors able to predict which patients will experience a sensory disturbance of the IAN after removal of a mandibular third molar.

With regard to panoramic radiography, seven signs indicating a close relationship between the third molar and the IAN, suggested by Rood and Shehab<sup>8</sup>, have been discussed as risk factors for sensory disturbance of the IAN. It has been concluded in reviews that three of these signs, i.e. interruption of the white border line of the canal, darkening of the third molar roots, and change in course of the canal, are more valid predictors of a close relationship between the roots of the tooth and the IAN than the other four, but that these signs are also associated with false-positive findings<sup>9,10</sup>. However, the outcome variable was the patient's sensation of IAN impairment in only three of these studies<sup>8,11,12</sup>. In a retrospective case-control study<sup>11</sup>, the reported positive predictive values (PPV) of these three risk factors seen in panoramic images ranged from 0.25 to 0.34, with a prevalence of 16% of documented IAN injury manifested by complaints of sensory disturbances after third molar removal. In a prospective clinical study<sup>8</sup>, PPVs ranged from 0.14 to 0.33, with a prevalence of IAN injury of 3% at 7-10 days postoperative. The third study found a PPV of 0.03 for any of the radiographic risk factors suggested by Rood and Shehab<sup>12</sup>; the prevalence of experienced postoperative sensory disturbance of the IAN at 7 days after removal of the third molar was 3.5%<sup>12</sup>.

Only one study assessing postoperative sensory disturbance has obtained results for risk factors seen in panoramic images and CBCT of the same patient group, but information on how the sensory disturbances were defined or measured is absent<sup>13</sup>. The prevalence of a temporary sensory disturbance at 1 week postoperative was reported to be 5.4% among 280 patients, and it was found that if the

mandibular canal was positioned between the roots of the third molar, or there was no bony separation between the third molar and the mandibular canal seen in CBCT, the PPVs were 0.47 for each radiographic risk factor. Furthermore, if a combination of darkening of the roots and interruption of the white border line of the canal was present in the panoramic image, the PPV was 0.53<sup>13</sup>.

No study has focused on the predictive values of radiographic risk factors for sensory disturbances in panoramic images and CBCT of the same group of patients with a well-defined method for measuring sensory disturbances of the IAN as the outcome. The aim of this study was to determine whether the examination of CBCT images before removal of the mandibular third molar can improve the risk assessment for neurosensory disturbances of the IAN compared to panoramic radiography.

## Materials and methods

### Patients

One hundred and six mandibular third molars (59 left side and 47 right side) in 34 male and 72 female patients (mean age 29 years, range 19-56 years) were included in this study. The study was performed as part of a recent randomized controlled clinical trial with patients who had a panoramic examination and a CBCT before removal of a mandibular third molar<sup>6</sup>. The patients were referred to the study clinic from their general dentist to have a mandibular third molar removed.

Clinical and panoramic radiograph examinations were performed in the study clinic before the patient was included in the study. Patients had to meet two inclusion criteria: (1) superimposition of the roots of the third molar on the mandibular canal in the panoramic image; and (2) a neurosensory test performed on the side to be operated on, as well as on the contralateral side, using a Semmes-Weinstein monofilament set consisting of numbers 1.65, 2.36, 2.44, 2.81, and 3.61, with application in four locations within the area of innervation of the IAN<sup>6</sup>. The patients marked their perception of the filament pressure on a visual analogue scale (VAS) ranging from 0 (normal sensation) to 100 mm (totally numb)<sup>6</sup>. Patients were included if they scored zero on the VAS for both sides, which was also related to a positive sensation of the pressure from the thinnest filament. One third molar was included for each patient. After inclusion, the patients underwent a CBCT examination in the study clinic.

### Radiographic examinations

The panoramic radiography and CBCT examinations were performed using a Scana 3D unit (Soredex, Helsinki, Finland). Panoramic radiography was performed using a full adult projection, and the CBCT examination was performed with a 6 × 6 cm field of view and 0.13-mm voxel resolution. OnDemand software (Cybermed Inc., Irvine, CA, USA) was used for the evaluation of the CBCT examinations and the full volumes were assessed.

### Radiographic assessment

Three observers with over 10 years of experience with CBCT assessed the images on high-quality monitors in a room with dimmed light. First, the panoramic images were examined for possible risk factors for postoperative sensory disturbance, as follows (with the 'increased risk' category stated first in the brackets): the cranio-caudal relationship between the roots of the third molar and the mandibular canal (roots inferior to the lower white border line of the canal/roots between the white border lines of the canal); interruption of the white border lines of the canal (yes/no); position of the canal over the roots (canal in the middle or the upper third of the root complex/canal in the apical third of the root complex); darkening of the roots in the area of superimposition (yes/no); narrowing of the canal lumen over the roots (yes/no); and change in course of the canal over the roots (yes/no). The same parameters (except for darkening of the roots and interruption of the white border lines of the canal) were assessed in the CBCT volumes, in addition to the buccolingual relationship between the roots of the third molar and the mandibular canal (canal between the roots/roots buccal to the canal/roots lingual to the canal/roots and canal at the same level); canal positioned in a root flex (yes/no); and bony separation between the roots of the third molar and the mandibular canal (no/yes).

### Postoperative test of sensory disturbance

The third molars were removed by one of two dentomaxillofacial surgeons in another clinic (the operating clinic) using a standard surgical approach. One week postoperatively, the patients had the sutures removed in the study clinic and the neurosensory test was repeated on both sides. A sensory disturbance of the IAN

was registered if there was a difference in perception of the filament pressure between the operated and the control side. All patients who were found to have a sensory disturbance also subjectively perceived a sensory deficit. The dentist performing the tests was not aware of which side was the operated side (although in some cases it was obvious because of swelling of the cheek).

Twenty-one patients (19.8%) experienced a sensory disturbance of the IAN the week after surgery. All patients were seen on a monthly basis until the sensory disturbance had recovered based on the patient's subjective perception. One of the patients (0.9%) was found to have a permanent sensory disturbance lasting more than 6 months.

#### Data analysis

Data were registered in Excel (Microsoft Office 2010, Microsoft Corp., Redmond, WA, USA) and imported into SPSS version 13.0 software (SPSS Inc., Chicago, IL, USA). For each observer, the canal-related registrations from the panoramic and CBCT images were related to the presence of a sensory disturbance of the IAN using descriptive statistics. In addition, the PPVs for radiographic markers assumed to be risk factors for a sensory disturbance of the IAN were calculated, as follows: the number of teeth that truly experienced a sensory disturbance divided by the number of teeth interpreted to have a risk factor, i.e. true-positives/(true-positives + false-positives). The negative predictive values (NPVs) were also calculated, as follows: the number of teeth that truly did not experience a sensory disturbance divided by the number of teeth without an assumed risk factor, i.e. true-negatives/(true-negatives + false-negatives). Moreover, the positive likelihood ratio ( $LR+ = \text{sensitivity}/(1 - \text{specificity})$ ) for radiographic markers was calculated to assess the odds that a sensory disturbance actually existed if a given radiographic marker was observed. Subsequently, the negative likelihood ratio ( $LR- = (1 - \text{sensitivity})/\text{specificity}$ ) was calculated. The predictive values and likelihood ratios were calculated for all canal-related parameters observed in both image modalities by all observers (for a few variables, it was not meaningful to calculate the NPV and LR-). In addition, PPV, NPV, LR+, and LR- values were calculated in cases with more than one risk factor. Finally, reproducibility among the observers was calculated and expressed

pairwise as the percentage accordance and the kappa-statistic.

#### Results

The relationships between image findings and the presence and absence of a sensory disturbance of the IAN are presented in [Tables 1 and 2](#). The PPVs and NPVs in general were almost the same for the findings in panoramic images and CBCT, for each observer and among observers, although 'canal between roots' observed in CBCT images obtained the highest PPVs for a sensory disturbance. Moreover, the NPVs were in general much higher than the PPVs for both modalities. The LR- were in general lower than the LR+ for both modalities, and the LR+ were in general higher for findings in CBCT images than in panoramic images.

For panoramic images, the highest PPVs were obtained for 'roots of the third molar positioned inferior to the lower border of the mandibular canal', with PPVs ranging from 0.31 to 0.33 among the observers. This means that around one third of the patients who were assessed as having a high risk of a sensory disturbance of the IAN based on an inferior position of the roots of the third molar, truly experienced a sensory disturbance. The same parameter also obtained the highest LR+ (range 1.8–2.1), meaning that the relative risk of having a sensory disturbance of the IAN is doubled if the roots of the third molars are positioned inferior to the lower white border line of the canal in a panoramic image. Interruption of the white border lines of the canal, darkening of the roots, change in the course of the canal, and narrowing of the lumen of the canal obtained lower PPVs of around 0.2 and LR+ of around 1. The NPVs for panoramic images ranged from 0.79 to 0.87, meaning that in the absence of a risk factor assessed in panoramic images, four out of five did not experience a sensory disturbance of the IAN. As shown in [Table 3](#), a combination of two risk factor signs seen in panoramic images did not increase the predictive values or the likelihood ratios.

For CBCT, the highest PPVs were obtained for 'canal positioned between the roots of the third molar', with PPVs ranging from 0.44 to 0.50 among the observers. This means that around half of the patients who were assessed as having a risk of a sensory disturbance of the IAN based on the canal being positioned between the roots of the third molar, truly experienced a sensory disturbance. For all observers, 'canal between the roots' observed in CBCT also obtained the highest

LR+ (range 3–4.1), meaning that if the CBCT examination revealed that the mandibular canal was positioned between the roots, there was a 3–4.1 times higher risk that the patient would actually experience a sensory disturbance of the IAN after removal of the third molar than for other root–canal positions. However, this sign was present in only 11–18% of the patients depending on the observer. For the parameter 'no bony separation between the roots of the third molar and the mandibular canal', all three observers obtained a PPV of 0.25, meaning that one quarter of the cases with this radiographic sign experienced a sensory disturbance of the IAN; additionally the LR+ were all 1.3. A superior position of the roots of the third molar in relation to the upper border of the mandibular canal obtained NPVs of 0.92–0.96, meaning that almost all cases (but not 100%) without a suspicion that a sensory disturbance would occur, actually did not perceive any disturbance. A combination of signs observed in CBCT did not increase the predictive values or the likelihood ratios ([Table 3](#)).

In general, the reproducibility expressed as the percentage accordance or as the kappa value was similar for the three observer pairs. Furthermore, the reproducibility was in general higher for the panoramic images than for CBCT, except for the course of the canal. For panoramic images, the reproducibility was highest for the cranio-caudal relationship, with percentage accordance ranging from 91.5% to 92.5% and kappa values ranging from 0.76 to 0.77 among the observer pairs. The lowest percentage accordance among the observers was found for assessing the 'canal position over the roots', which ranged from 64.4% to 71.7%, and the lowest kappa values were found for 'canal lumen', which ranged from 0.08 to 0.16 among observer pairs. For CBCT the general reproducibility among observer pairs was highest for 'bony separation', with percentage accordance ranging from 88.7% to 90.6% and kappa values ranging from 0.74 to 0.79. The highest percentage accordance was found for 'canal course' (92.5–98.0%), and the lowest percentage accordance was found for 'canal position' (56.6–69.8%).

#### Discussion

In this study, some 'classical signs' of a close relationship between the third molar and the mandibular canal seen in panoramic radiographs were evaluated. The PPVs were in general not high.

Table 1. Relationships between panoramic radiography image findings and the presence ('Yes',  $n = 21$ ) and absence ('No',  $n = 85$ ) of a sensory disturbance of the IAN for each observer, with the predictive values (PPV, NPV) and likelihood ratios (LR+, LR-) in parentheses.

Panoramic parameter	Sensory disturbance					
	Observer 1		Observer 2		Observer 3	
	Yes (PPV; LR+)	No (NPV; LR-)	Yes (PPV; LR+)	No (NPV; LR-)	Yes (PPV; LR+)	No (NPV; LR-)
Cranio-caudal relationship						
Inferior to canal	7 (0.32; 1.8)	15	8 (0.31; 1.8)	18	9 (0.33; 2.1)	18
Between canal borders	14 (0.17; 0.82)	70 (-)	13 (0.16; 0.79)	67 (-)	12 (0.15; 0.72)	67 (-)
Interruption of the canal borders						
Yes	13 (0.19; 1.0)	55	11 (0.19; 1.0)	46	15 (0.21; 1.1)	55
No	8	30 (0.79; 1.1)	10	39 (0.80; 1.0)	6	30 (0.83; 0.83)
Canal position						
Middle/upper part	8 (0.35; 2.1)	15	11 (0.24; 1.3)	35	14 (0.26; 1.4)	40
Apical part	13	70 (0.84; 0.76)	10	50; (0.83; 0.81)	7	45 (0.87; 0.62)
Darkening of roots						
Yes	4 (0.21; 1.1)	15	1 (0.10; 0.46)	9	3 (0.21; 1.1)	11
No	17	70 (0.81; 1.0)	20	76 (0.79; 1.1)	18	74 (0.80; 0.99)
Canal lumen						
Narrowing	0 (-)	5	4 (0.24; 1.3)	13	3 (0.14; 0.67)	18
No narrowing	21	80 (0.79)	17	72 (0.81; 0.95)	18	67 (0.79; 1.1)
Canal course						
Change	4 (0.25; 1.4)	12	3 (0.30; 1.8)	7	3 (0.25; 1.3)	9
No change	17	73 (0.81; 0.92)	18	78 (0.81; 0.94)	18	76 (0.81; 0.97)

LR-, negative likelihood ratio; LR+, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value. (-): not meaningful for calculating the number.

Interruption of the white border lines of the canal obtained PPVs of 0.19–0.21 and darkening of the roots obtained PPVs of 0.10–0.21, values that are lower than those reported in a recent study, in which a PPV of 0.53 was found for both signs<sup>13</sup>. On the other hand, these values are comparable to those found in older studies, in which the PPVs were in the range of 0.14–0.25 for 'interruption of the white border lines of the canal' and 0.17–0.32 for 'darkening of the roots'<sup>8,11</sup>. Combining the two signs did not change the prediction efficacy in the present study, nor in the previously published one<sup>13</sup>. The PPV for 'roots of the third molar positioned inferior to the lower white border line of the canal' was around 0.32 in the present study, and the odds of having a sensory disturbance of the IAN, if this sign was present, were almost doubled. In general, the predictive values of radiographic risk factors seen in panoramic images were interpreted as poor, which has also been concluded in former reviews<sup>9,10</sup>, and one could speculate that CBCT would improve the prediction of a postoperative sensory disturbance of the IAN.

In this study, the PPV for the sign 'no bony separation between the third molar and the mandibular canal' was 0.25, which means that 75% of the patients in this study did not perceive any sensory disturbance even though the sign was observed in the CBCT. The odds of having a postoperative sensory disturbance of the IAN if there was no bony separation between the third molar and the mandibular canal seen in the CBCT were 1.3 times higher. So the relative risk was 1.3 in this study of 106 patients with this sign, which seems without clinical relevance. Furthermore, it was observed that if the sign was not present, there was still a risk of sensory disturbance, since the NPVs were 0.89–0.93, meaning that approximately 10% of the patients with bony separation between the tooth and mandibular canal seen in CBCT would still experience a sensory disturbance. Other studies have found higher PPVs for the same risk factor (0.47–1), but the conclusion may be that the sign cannot be trusted, since the NPVs were extremely low in these studies<sup>13,14</sup>. One previous study demonstrated that the sign 'no bony separation between third molar and canal' was present in the CBCT images of two out of four patients who experienced a permanent IAN injury; however bone was clearly present in the remaining two<sup>15</sup>. In summary, the sign 'no bony separation between the mandibular third molar and the mandibular canal' may

Table 2. Relationships between CBCT image findings and the presence ('Yes',  $n = 21$ ) and absence ('No',  $n = 85$ ) of a sensory disturbance of the IAN for each observer, with the predictive values (PPV, NPV) and likelihood ratios (LR+, LR-) in parentheses.

CBCT parameter	Sensory disturbance					
	Observer 1		Observer 2		Observer 3	
	Yes (PPV; LR+)	No (NPV; LR-)	Yes (PPV; LR+)	No (NPV; LR-)	Yes (PPV; LR+)	No (NPV; LR-)
Cranio-caudal relationship						
Inferior to canal	9 (0.28; 1.6)	23	11 (0.35; 2.2)	20	11 (0.31; 1.8)	25
Between canal borders	11 (0.21; 1.1)	41	9 (0.16; 0.8)	46	9 (0.16; 0.8)	48
Superior	1	21 (0.96; 0.20)	1	19 (0.95; 0.22)	1	12 (0.92; 0.36)
Buccolingual relationship						
Canal between roots	7 (0.44; 3)	9	9 (0.45; 3.0)	11	6 (0.50; 4.1)	6
Buccal to canal	9 (0.29; 1.7)	22	8 (0.28; 1.5)	21	8 (0.28; 1.5)	21
Lingual to canal	4 (0.09; 0.39)	42	4 (0.09; 0.39)	42	4 (0.11; 0.48)	34
Same level	1 (0.08; 0.36)	12	0	11	3 (0.11; 0.50)	24
Canal position						
Middle/upper part	7 (0.33; 2.1)	14	10 (0.48; 1.9)	21	10 (0.25; 1.4)	30
Apical part	13 (0.21; 1.1)	50	10 (0.18; 0.91)	45	10 (0.19; 0.94)	43
Superior	1	21 (0.96; 0.20)	1	19 (0.95; 1.1)	1	12 (0.92; 1.1)
Canal in a root flex						
Yes	1 (0.25; 1.3)	3	2 (0.5; 1.9)	4	0 (-)	7
No	20	82 (0.80; 0.99)	19	81 (0.81; 0.95)	21	78 (0.79)
Bony separation						
No	17 (0.25; 1.3)	52	17 (0.25; 1.3)	52	19 (0.25; 1.3)	58
Yes	4	33 (0.89; 0.49)	4	33 (0.89; 0.49)	2	27 (0.93; 0.31)
Canal lumen						
Narrowing	11 (0.24; 1.3)	34	14 (0.29; 1.6)	35	17 (0.30; 1.4)	49
No narrowing	10	51 (0.84; 0.49)	7	50 (0.88; 0.56)	4	36 (0.90; 0.45)
Canal course						
Change	1 (0.50; 2.5)	2	0 (-)	1	2 (0.40; 1.6)	5
No change	20	83 (0.81; 0.97)	21	84 (0.8)	19	80 (0.81; 0.97)

CBCT, cone beam computed tomography; LR-, negative likelihood ratio; LR+, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value. (-): not meaningful for calculating the number.

not outperform the signs in panoramic images 'interruption of the white border lines of the canal', 'darkening of the roots', and 'change in course of the canal', and none of these signs can be interpreted as a reliable risk factor to predict a postoperative sensory disturbance of the IAN.

Other signs such as 'narrowing of the canal lumen' and 'the canal situated in a root flex' seen in the CBCT image were found not to be valid risk factors. On the other hand, when the mandibular canal was positioned between the roots of the third molar in the CBCT image, the observers obtained the highest PPVs (0.44–0.50), and the odds of having a sensory disturbance, if this sign was present, were three to four times higher than when the sign was not present. The sign was, however, only present in 11–18% of the cases depending on the observer, and in six to nine cases, it was related to a sensory disturbance. A similar result was found in a previous study, since the PPV was 0.47 for the same sign<sup>13</sup>. It may therefore seem of little value to perform a CBCT merely to seek this specific radiographic sign. A combination of two radiographic signs seen in the CBCT image changed neither the predictive values nor the likelihood ratios.

In this prospective study, the prevalence of a temporary disturbance of the IAN was 19.8%, which is relatively high. The method for measuring disturbances was well-defined as the difference between the patient's perceptions of sensation on the operated side versus the non-operated side when measured with the thinnest fibres at 1 week after the operation. This is a highly subtle method as opposed to those used in previous studies, in which the method for measuring a sensory disturbance has been described less thoroughly, or not at all. Differences in measurement methods may explain differences in the frequency of disturbances to the IAN between studies. It is moreover well known that PPVs are highly dependent on the prevalence of the disease, in this case a sensory disturbance, and this will also explain differences between studies. To compare differences in predictive values between methods, it is therefore of the utmost importance that the two methods have been applied to the same patient group. The present study is novel in directly comparing the presence of classical radiographic 'risk signs' in panoramic and CBCT

Table 3. Relationships between combinations of panoramic radiography image findings and combinations of CBCT image findings and the presence ('Yes',  $n=21$ ) and absence ('No',  $n=85$ ) of a sensory disturbance of the IAN for each observer, with the predictive values (PPV, NPV) and likelihood ratios (LR+, LR-) in parentheses.

Parameters	Sensory disturbance					
	Observer 1		Observer 2		Observer 3	
	Yes (PPV; LR+)	No (NPV; LR-)	Yes (PPV; LR+)	No (NPV; LR-)	Yes (PPV; LR+)	No (NPV; LR-)
Panoramic images						
Canal position + interruption						
Yes	2 (0.14; 0.68)	12	4 (0.15; 0.70)	23	9 (0.24; 1.3)	29
No	19	73 (0.79; 1.1)	17	62 (0.79; 1.1)	12	56 (0.82; 0.86)
Canal position + darkening						
Yes	1 (0.20; 1.0)	4	0 (-)	6	1 (0.20; 1.0)	4
No	20	81 (0.80; 1.0)	21	79 (0.79)	20	81 (0.80; 1.0)
Darkening + interruption						
Yes	4 (0.27; 1.5)	11	1 (0.17; 0.83)	5	3 (0.25; 0.24)	9
No	17	74 (0.81; 0.93)	20	80 (0.80; 1.0)	18	76 (0.81; 2.1)
CBCT						
No bony separation + narrowing						
Yes	11 (0.25; 1.3)	34	14 (0.29; 1.6)	35	16 (0.25; 1.3)	49
No	10	51 (0.84; 0.8)	7	50 (0.88; 0.56)	5	36 (0.88; 0.57)
No bony separation + canal between roots						
Yes	5 (0.36; 2.2)	9	7 (0.39; 2.5)	11	6 (0.5; 4.1)	6
No	16	76 (0.83; 0.85)	14	74 (0.84; 0.77)	15	79 (0.84; 0.76)

LR-, negative likelihood ratio; LR+, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value. (-): not meaningful for calculating the number.

images of the same patient group with a well-defined method for testing sensory disturbances to the IAN, and as such this study adds new important information.

Three observers were included in the present study to assess the inter-observer reproducibility for both panoramic radiographs and CBCT images. The reproducibility was in general high and comparable to other studies. The kappa values among observer pairs for 'no bony separation between the third molar and the mandibular canal' seen in CBCT ranged from 0.74 to 0.79 in the present study, and these numbers are similar to the results reported in other studies including two trained observers (0.75 and 0.78)<sup>16-18</sup>. For 'interruption of the white border lines of the canal' and 'darkening of the roots' seen in panoramic images, the kappa values in the present study were 0.54 and 0.57, and in the two previous studies they were 0.35/0.69 and 0.52/0.87, respectively<sup>16,17</sup>. One study concluded that reproducibility was higher for trained observers than for untrained dental students<sup>18</sup>. Even though the general conclusions from the present study were not overall affected by the observer, it should be borne in mind that observer variation adds to how well predictive values may be trusted in the clinical situation.

It has been speculated that signs in CBCT images may be more predictable than signs in panoramic images<sup>19</sup>, and that this should justify the use of CBCT for establishing a treatment plan, e.g. performing a coronectomy instead of full removal of the third molar. Performing a coronectomy has become a more frequent treatment approach for impacted mandibular third molars with a suspected intimate relationship between the third molar and the IAN in order to avoid postoperative sensory disturbance<sup>20</sup>. It appears that the procedure is safe to perform, with little postoperative morbidity<sup>20-22</sup>. However, this treatment may be more resource-demanding because of the clinical and radiographic follow-ups required to monitor the root complex left in the mandible. Moreover, in a recent study following 200 coronectomy cases, it was found that 3.5% underwent a re-operation, 11.7% had a postoperative infection treated with antibiotics, and two patients suffered from a sensory disturbance of the IAN<sup>21</sup>. Sensory disturbances can therefore not be totally avoided when choosing this treatment approach.

A previous study reported that treatment was changed in 12% of the cases when CBCT was available to the surgeon<sup>23</sup>, and that no bony separation between the

third molar and the mandibular canal seen in the CBCT image was the main reason why treatment was changed from full removal to coronectomy (8% of the changed cases). Moreover, it was found that if the canal lumen was narrowed and/or the canal was positioned in a root flex, there was an even higher risk that treatment would be changed to a coronectomy<sup>23</sup>. Taking the results of the present study and also previous studies into account, one could speculate whether the evidence for this decision-making is actually poor. As such, it is believed that the decision to perform a coronectomy may just as well be taken based on a panoramic image as on a CBCT examination. Moreover, the use of local anaesthesia includes the risk of an injection-related nerve injury causing sensory disturbance of the IAN. This has to be kept in mind, no matter the signs in the preoperative radiograph.

In conclusion, the predictive values expressing the ability of radiographic signs to predict a postoperative sensory disturbance of the IAN are in general relatively poor, both for panoramic radiographs and CBCT images. Although CBCT obtained higher values for some parameters, it is the authors' opinion that these are not robust enough to more accurately predict the risk of complications and thereby to change the patient information when CBCT is available as opposed to merely a panoramic radiograph. It therefore appears that the use of CBCT before removal of a mandibular third molar should be an exception in rare complicated cases.

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### Competing interests

No conflicts of interest.

### Ethical approval

Approval was given by the Committee on Health Research Ethics of the Capital Region in Denmark (Number H-4-2010-052).

### Patient consent

Not required.

### Authors statement

The final manuscripts has been viewed and agreed to submission by all authors

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