RESEARCH ARTICLE

Radiographic methods used before removal of mandibular third molars among randomly selected general dental clinics

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Objectives: To assess radiographic methods and diagnostically sufficient images used before removal of mandibular third molars among randomly selected general dental clinics. Furthermore, to assess factors predisposing for an additional radiographic examination.

Methods: 2 observers visited 18 randomly selected clinics in Denmark and studied patient files, including radiographs of patients who had their mandibular third molar(s) removed. The radiographic unit and type of receptor were registered. A diagnostically sufficient image was defined as the whole tooth and mandibular canal were displayed in the radiograph (yes/no). Overprojection between the tooth and mandibular canal (yes/no) and patient-reported inferior alveolar nerve sensory disturbances (yes/no) were recorded. Regression analyses tested if overprojection between the third molar and the mandibular canal and an insufficient intraoral image predisposed for additional radiographic examination(s).

Results: 1500 mandibular third molars had been removed; 1090 had intraoral, 468 had panoramic and 67 had CBCT examination. 1000 teeth were removed after an intraoral examination alone, 433 after panoramic examination and 67 after CBCT examination. 90 teeth had an additional examination after intraoral. Overprojection between the tooth and mandibular canal was a significant factor ($p < 0.001$, odds ratio = 3.56) for an additional examination. 63.7% of the intraoral images were sufficient and 36.3% were insufficient, with no significant difference between images performed with phosphor plates and solid-state sensors ($p = 0.6$). An insufficient image predisposed for an additional examination ($p = 0.008$, odds ratio = 1.8) but was only performed in 11% of the cases.

Conclusions: Most mandibular third molars were removed based on an intraoral examination although 36.3% were insufficient.

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Introduction

Performing a radiographic image before deciding to remove a mandibular third molar is considered good clinical practice because it helps the surgeon to establish a treatment plan. Ideally, the image should display the whole tooth and the surrounding bone in addition to related anatomical structures.¹ Findings in the radiograph may indicate complications during

removal of the tooth, e.g. the risk of a post-operative sensory disturbance to the inferior alveolar nerve (IAN). Furthermore, it could help to select the adequate surgical technique and to establish the foundation of the patient's informed consent. Sensory disturbances in the innervation area of the IAN have been reported to vary between 0.4% and 6%² and constitute a serious complication.

Guidelines for the use of CBCT scanning for radiographic examination of mandibular third molars before

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surgical intervention have suggested that CBCT can be used in cases where the conventional image displays a close interrelation between the third molar and the mandibular canal, but it was also concluded that the evidence for the use of CBCT is sparse.³ Recently, a review on radiographic examination of mandibular third molars reported that there is little evidence that CBCT will change either the treatment or the post-operative patient outcome.² Moreover, it has been documented that the use of CBCT is connected with higher costs and radiation to the patient than conventional methods.^{4–8} Currently, no exact protocol of the radiographic examination of mandibular third molars exists, and therefore no strict guidelines for general practitioners (GPs) to follow have been advocated.²

Before guidelines are issued, it may be of interest to know which radiographic protocols are actually used in practices, where removal of third molars is performed. There seems to be only one study that has assessed how GPs use CBCT, or other radiographic methods, in private dental clinics.⁹ This was a questionnaire study conducted among the registered CBCT clinics in Norway. Most frequently, CBCT was used for implant treatment planning and localization of impacted teeth; however, no prevalence, particularly, for mandibular third molars was reported.⁹ Questionnaire studies are prone to be associated with various types of errors,¹⁰ and to our knowledge, no observational, epidemiological studies have been conducted, where GPs' offices have been visited and patient files including images read systematically to obtain information on the use of radiographic methods for a specific diagnostic task in dentistry.

Therefore, the aims were to assess radiographic methods and diagnostically sufficient images used before removal of mandibular third molars in an epidemiological study among randomly selected general dental clinics, and furthermore, to assess factors predisposing for an additional radiographic examination.

Methods and materials

This was a retrospective observational, epidemiological study where 2 observers (with extensive expertise in oral radiographic interpretation) visited 18 GPs' clinics in Denmark (DK) during a 3-year period from October 2011 to June 2014. The clinics were randomly selected from the five administrative regions of DK; the demographic parameters are listed in Table 1. Patient records including radiographs from patients, who had surgical intervention of one or two mandibular third molars, were included. These data were collected from the patients' records. The data were organized in Epi-Data v. 3.1 (The EpiData Association; Odense, DK). Data on economic issues and radiation exposure estimates to the patient have been reported in a recent article.⁵ In comparison with that study, one more clinic was included in the present study.

Selection of general practitioner clinics

The inclusion criteria for the participating GPs were: (1) clinics that offered patients surgical removal of a mandibular third molar and (2) GPs who had implemented one of two dental software systems, "DentalSuite[®]" (Vallensbæk, DK) or "AlDente[®]" (Hørning, DK), since both systems facilitate the possibility of extracting data anonymously about the number of patients and the number and type of radiographs and treatments. Exclusion criteria for GP clinics were: (1) status as specialist clinic based on referrals from other dentists and (2) GP clinics where surgical removal of the lower third molar was referred to other clinics. The GPs were randomly chosen from lists provided by the software companies. Information about the study was sent to 20 selected GPs. One clinic declined participation, and one clinic did not answer.

Recordings in general practitioner clinics

The type of radiographic unit(s) and type of receptor(s) available were recorded in each clinic. The records of patients, who had at least one mandibular third molar removed, were extracted by the two observers, and the following parameters were recorded: (1) sex (male/female), (2) age (years), (3) type of radiographic image(s) available before surgery (intraoral image, panoramic image, CBCT), (4) type of intervention (full tooth removal/coronectomy) and (5) patient-reported presence of a permanent sensory disturbance in the innervation area of the IAN recorded post-operatively.

The two observers viewed the radiographic images and assessed if the image was sufficient. A sufficient image was defined as an image in which the whole tooth and the course of the mandibular canal over the root(s) were displayed in the image. Furthermore, overprojection between the mandibular third molar and the mandibular canal was recorded in the images (yes/no).

Data treatment

The number of operated third molars, number of images with overprojection between the tooth and the mandibular canal, and number of sufficient *vs* insufficient images were calculated for each clinic. The most recent radiograph taken of the third molar in question prior to surgery was defined as the base type image for surgical intervention.

Logistic regression analysis was performed to analyze if the type of digital receptor influenced image diagnostic quality in intraoral images (SPSS[®] v. 13.0; IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). Likewise by logistic regression, it was analyzed whether an overprojection between the tooth and the mandibular canal in the intraoral image had an impact on performing an additional radiographic examination. Logistic regression was also used to determine whether an insufficient intraoral image predisposed for performing an additional radiographic examination.

Table 1 Number of clinics visited in each administrative region of Denmark with number of working dentists and their age range in years, radiographic equipment used for each modality available in the clinic, number of removed teeth and the mean age of the operated patients (pts)

Region	Clinic	n dentists (age range, years)	Equipment			n removed teeth	Mean age, pts (age range, years)
			Intra	Pan	CBCT		
Capital	1	6 (38–65)	DIGORA® PSP (SOREDEX, Helsinki, Finland)	Scanora3D (SOREDEX)	Scanora3D	180	31.9 (17–78)
	2	5 (26–44)	DIGORA PSP	–	–	173	33.6 (12–81)
	3	3 (46–47)	DIGORA PSP	Cranex (SOREDEX)	–	73	32.7 (19–80)
	4	7 (27–39)	DIGORA PSP	Promax3D (Planmeca)	Promax3D	65	28.7 (18–57)
Zealand	5	4 (30–62)	VistaScan PSP (Dürr Dental, Bietigheim-Bissingen, Germany)	Promax2D (Planmeca)	–	71	34.4 (17–79)
	6	3 (31–49)	Dixi CMOS sensor (Planmeca, Hatfild, PA)	Promax2D	–	121	37.4 (17–81)
Mid Jutland	7	3 (32–48)	VixWin CCD sensor (Gendex, Helsinki, Finland)	–	–	44	33.4 (19–76)
	8	5 (28–55)	VistaScan PSP	–	–	57	29.9 (18–65)
	9	3 (40–65)	Visualix CCD sensor (Gendex)	–	–	30	27.2 (19–40)
	10	5 (29–65)	DIGORA PSP	–	–	126	32.3 (18–87)
Southern Denmark	11	7 (29–70)	DIGORA PSP	Scanora3D	Scanora3D	88	28.4 (14–66)
	12	2 (50–52)	VistaScan PSP	Art plus (AJAT, Espoo, Finland)	–	80	30.4 (17–80)
	13	6 (32–60)	DIGORA PSP	Promax3D	Promax3D	79	33.9 (12–85)
	14			Cranex	–		
	15	1 (67)	DIGORA PSP	Cranex	–	25	36.5 (21–72)
	16	2 (39–51)	DIGORA PSP	EPX-Impla (Ewoo, Yongin, South Korea)	EPX-Impla	130	33.3 (17–87)
Northern Jutland	17	4 (32–63)	Sidexis CCD sensor (Sirona Dental, Wals bei Salzburg, Austria)	–	–	52	34.1 (21–95)
	18	3 (33–65)	DIGORA PSP	–	–	106	35.0 (18–70)

CCD, charge-coupled device; CMOS, complementary metal oxide silicon; Intra, intraoral image; PAN, panoramic image; PSP, photostimulable storage phosphor system.

Results

Type of equipment and number of surgical interventions

The type of radiographic equipment available in each GP clinic can be seen in Table 1. All clinics had a dental X-ray unit, 11 clinics had in addition the possibility of performing a panoramic examination and 5 clinics had a CBCT unit. All CBCT units also had the possibility for panoramic imaging, thus this may be the same unit although listed as two modalities in the table. The majority of intraoral images were obtained by a photostimulable storage phosphor plate system (PSP), and DIGORA® PSP (SOREDEX, Helsinki, Finland) was the preferred receptor. Four clinics used intraoral solid-state sensors from manufacturers. In every administrative region, both younger and older GPs were involved.

1500 mandibular third molars (784 right side, 716 left side; mean patient age 32.7 years (range 12.0–95.0 years) in 1403 patients (740 females and 663 males) had undergone surgical intervention). 1460 molars were fully removed and 40 had coronectomies. 588 (39.2%) molars were operated in clinics that only had dental units available, 370 (24.7%) teeth were operated in clinics that in addition were able to perform panoramic

imaging and 542 (36.1%) teeth were operated in clinics that also had CBCT. Two mandibular third molars had been referred for a CBCT examination in another clinic, and one third molar had been referred for a panoramic examination.

Radiographic modality before intervention

In total 1090 intraoral images, 468 panoramic images and 67 CBCT volumes were assessed. From Figure 1, it can be seen that 1000 (66.7%) mandibular third molars underwent surgery on the basis of an intraoral image, 433 (28.9%) underwent surgery on the basis of a panoramic image and 67 (4.5%) underwent surgery on the basis of a CBCT. 97 (6.5%) mandibular third molars had 2 radiographic examinations before surgery, and 14 (0.9%) molars underwent an intraoral, a panoramic and a CBCT examination before surgery. In 75 (16.0%) cases, the patients underwent an intraoral examination before the panoramic examination.

In the clinics that had panoramic equipment there was large variation (28.8%–94.5%) in how much this equipment was used before mandibular third molar removal. Among clinics that had CBCT, between 1% and 31% of the third molars had been removed on the basis of a CBCT examination before surgery.

Figure 1 Distribution of radiographic modality before surgical intervention. Intra, intraoral image; PAN, panoramic image.

From Figure 1, it can be seen that 90 mandibular third molars underwent an additional radiographic examination, panoramic, CBCT or both, after an initial intraoral examination. Logistic regression analysis showed that overprojection between the tooth and the mandibular canal as observed in the intraoral image [$p < 0.001$, odds ratio (OR): 3.56, confidence interval: 1.98–6.38] was a determining factor for performing an additional radiographic examination. An additional examination was thus performed three-and-a-half times more often when there was overprojection in the intraoral image.

Diagnostically sufficient images

Of the 1090 assessed intraoral images, 694 (63.7%) were judged sufficient, meaning that the third molar and its relation to the mandibular canal were fully displayed in the image. By contrast, 396 (36.3%) intraoral images were insufficient. The distribution was almost similar in the five administrative regions of DK (Capital 32%, Zealand 28%, Mid Jutland 29%, Southern DK 47% and Northern DK 44%).

In 44 cases (11.1%) of the insufficient intraoral images, additional radiographic examination(s) were performed: 32 patients underwent additional panoramic imaging; 4 patients underwent CBCT; and 8 patients underwent both (Table 2). Logistic regression analysis showed that there was nearly twice the chance that the GP would perform an additional examination if the

intraoral image was deemed insufficient ($p = 0.008$, OR: 1.8, confidence interval: 1.16–2.78). However, still 352 mandibular third molars were removed on the basis of an insufficient intraoral image, which equals 35.2% of all teeth removed on the basis of an intraoral image. In fact, 158 of these cases were operated in a clinic where panoramic imaging was available but not used. Five of the panoramic images were judged to be insufficient, because it was not possible to interpret the mandibular canal in the image, and in none of these cases an additional radiographic examination was performed. One CBCT was insufficient, because the field of view was positioned too low and, consequently, only the root tips of the third molar were included in the volume, and furthermore, it was not possible to visualize the mandibular canal. No other image was available. To sum up, the majority of third molars had sufficient pre-operative radiographs performed, but 358 (23.9%) mandibular third molars were removed on the basis on an insufficient image.

There was no statistically significant difference between the number of diagnostically sufficient intraoral images obtained with PSPs and solid-state sensors; neither between all intraoral images ($p = 0.6$) nor between intraoral images performed in a clinic, in which there was a panoramic unit available ($p = 0.8$). Examples of insufficient intraoral images are shown in Figure 2.

Post-surgical complications

Three permanent sensory disturbances to the IAN (0.2% of full tooth removals) were reported in the patients' records. One of these was caused by a removal where the pre-operative radiograph was a sufficient intraoral image showing overprojection between the tooth and mandibular canal. The operation was performed in a clinic where only intraoral imaging was available. The second was caused by a removal where the pre-operative radiographs were a sufficient intraoral image and a sufficient panoramic image, both showing overprojection between the third molar and the mandibular canal. The third permanent sensory disturbance to the IAN was caused by a removal where CBCT was performed pre-operatively and interpreted with no bony separation between the third molar and the mandibular canal.

Discussion

The study had an epidemiological, retrospective design. The information obtained from the patients' records was the retrospective part, whereas the recordings of the radiographic method and image quality were prospective and performed *in situ*, distinguishing this study from questionnaire or interview studies. The clinics were evenly distributed according to the population in the five administrative regions of DK.⁵ The random selection of clinics represents the best epidemiological design to secure that sex, age, experience and other demographic variables of the included dentists are representative of all

Table 2 Distribution of additional radiographic examinations in relation to quality of the intraoral image

Type of additional radiographic examination	Sufficient intraoral image (n = 694)	Insufficient intraoral image (n = 396)
Panoramic examination	29	32
CBCT examination	11	4
Panoramic + CBCT examination	6	8
Total	46	44

Danish dental practices. In this way, the results are representative and reproducible.

Since no solid guidelines for a radiographic protocol exist for dental practitioners before removal of a mandibular third molar, it was the aim of this study to assess which radiographic methods were used by GPs, and the consequences of this. It was not surprising that most of the third molars were removed on the basis of an intraoral image, since the majority of Danish GPs only have a dental X-ray unit in their offices. Extremely few patients were referred to other clinics for a more advanced radiographic examination not available in the patient's clinic. Even when a panoramic or CBCT unit was available, the vast majority of the dentists used, or started with, an intraoral examination. This is in accordance with European guidelines for CBCT that a two-dimensional examination should precede a three-dimensional examination, and CBCT can be performed when the two-dimensional image shows an intimate relation between the roots of the third molar and the mandibular canal.³

Criteria for a sufficient intraoral image have been described to be fulfilled, if the tooth and apices of the roots are imaged in a periapical radiograph with at least 2 mm of surrounding alveolar bone.¹ Following these recommendations, it is expected that a sufficient radiographic examination of a mandibular third molar displays the whole tooth and the course of the mandibular canal adjacent to the roots/tooth in the image, and this was the criteria in the present study. This is, however, not always an easy task with intraoral radiography. Results from a previous study showed that in approximately 25% of the cases, it was impossible to obtain a sufficient intraoral image of a mandibular third molar even after a retake.¹¹ In the present study, >36% of the intraoral images were not sufficient by these criteria, and no additional

radiographic examination was performed in 89% of these cases. There was a tendency (OR: 1.8) that an insufficient image led to further examination; however, this occurred in only 11%.

Because of the fact that positioning the receptor in the back of the mouth is uncomfortable for the patient, often leading to insufficient images, panoramic imaging has been advocated by some to be the first choice method for pre-operative assessment of third molars.¹² 11 clinics had the possibility for a panoramic examination, and the GPs in these clinics could have chosen to use panoramic radiography as the initial examination or as a re-examination in case of an insufficient intraoral image, which most probably would have reduced the number of insufficient images before surgery to 19%. Since no interview with the GPs was performed, it can only be speculated why this was not performed. Speculations could include patient payment (panoramic examination is more expensive than intraoral examination) and the dentist's time. It may also be considered that criteria for an insufficient image as defined by the observers in this study were not the same as those used by GPs in the clinics. The GPs may not believe that a higher risk of subsequent patient morbidity is related to not-fully-displayed structures in the image, and in fact, the results of the present study could accord with this.

When a solid-state sensor is used, there may be an even higher risk for performing an insufficient image than PSPs.¹¹ In our study, there was no significant difference between the diagnostic quality of images performed using a solid-state sensor compared with PSPs. However, being retrospective, it was not possible to estimate, *e.g.* the number of retakes that had been deleted, before a final radiographic image was accepted and saved in the file. The results may indicate

Figure 2 Examples of insufficient intraoral images. (a) Only the crown of the third molar is displayed in the image; (b) the distal root tip is not displayed in the image and the mandibular canal cannot be interpreted.

though that GPs learn to operate a sensor as well as a PSP plate over time.

67 third molars (4.5%) were removed on the basis of a CBCT examination. From the clinics hosting CBCT equipment, some used it quite often and some rather seldom for third molar examination. It may be assumed that third molars were evenly distributed according to tooth impaction state, root morphology and intimate relation to the mandibular canal among general dental clinics in DK; moreover, that one clinic in the study did not treat more “difficult” molars than others since specialist clinics were excluded. Thus, one could speculate that some of the clinics having CBCT used it more frequently because it was available and needed to be depreciated,^{4,5} whereas others would stick to conventional equipment for other reasons, *e.g.* because they were still insecure with CBCT or because they had the opinion that CBCT examination does not provide enough benefit for the patient before removal of a third molar. The absence of evidence-based national guidelines could make the decisions in the private practices confusing, inconsistent and arbitrary.

The apparent lack of consideration among the GPs in our study as regards a sufficient image may reflect the fact that injury to the IAN is a rather infrequent post-operative morbidity. Only three post-operative sensory disturbances to the IAN were registered in the patients’ records. Sensory disturbances of short duration are traditionally not reported in the patient’s record, and a temporary discomfort to the patient therefore cannot be estimated from our data. This parameter may as well be underestimated, because one could imagine that if the patient did not report any change in sensory feeling, the dentist may not ask the patient or examine for it. On the other hand, a permanent injury to the IAN may substantially decrease life quality, thus we can assume that severe cases were reported. No other morbidity data or data on the surgical procedures etc. were extracted from the patients’ records. The three sensory disturbances occurred after the full removal of the teeth, and in all cases, the base image before removal was of sufficient quality. Since 24% of all the third molars in this study were removed on the basis of an image in which the whole tooth and mandibular canal were not displayed, it may be concluded that sensory disturbances may mainly be influenced by other factors than the pre-operative radiograph, *e.g.* disruption of the IAN during surgery, injection of anesthetics or both.¹³ It is tempting to speculate from our findings that the radiographic method *per se* does not influence the frequency of sensory disturbances to the IAN. The study had an observational design which means that one should be cautious drawing firm conclusions. Surely, GPs should not be encouraged to perform surgery of mandibular third molars without a sufficient radiograph. Even if there is no high evidence available supporting the assumption, that patients will benefit

from a sufficient visualization of the relevant anatomical structures before removal of the third molar, the necessity of sufficient radiographic imaging is anchored in other considerations. Without a sufficient image, it will not be possible to make a correct diagnosis, thereby undermining the foundation of the treatment decision. Furthermore, pathological findings could be missed, exposing the patient to health risks and/or repeated surgery. Additionally, to fulfil the requirements for the necessary informed consent, relevant information including pathology and risks should be based on clinical and radiological findings. On this background, it seems mandatory to perform a sufficient radiographic image of the region before surgical intervention even if an image-derived decrease in morbidity or complication rate cannot be verified.

The huge variation in the use of radiographic modality illustrates the need for a validated radiographic protocol for mandibular third molars. Two protocols have been suggested and described in the literature.^{14,15} CBCT was used in 21% and 23% of the cases, respectively, following these protocols, and it was in general concluded that in most cases a panoramic image would suffice. Very recent evidence from a randomized controlled trial has demonstrated that CBCT is connected with approximately four times the costs for panoramic imaging for treatment planning of mandibular third molars,⁴ and that CBCT will substantially change neither the treatment plan¹⁶ nor the outcome for post-surgical morbidity with regard to days absent from work, pain and neurosensoric disturbances to the IAN.^{4,17–19} Results from these recent studies may be implemented in guidelines in the near future.

In conclusion, most mandibular third molars were removed on the basis of an intraoral image, and panoramic and CBCT examination were not commonly used in GP clinics for this purpose. Almost 24% of all third molars were removed on the basis of a diagnostically insufficient radiograph where the full tooth and mandibular canal were not displayed in the image. Overprojection between the tooth and the mandibular canal as observed in the intraoral image was a predisposing factor for performing an additional radiographic examination. Three post-operative sensory disturbances were reported, all caused by an operation where the pre-operative radiographic image was of sufficient quality. It may be speculated that other factors than the pre-operative radiographic modality affects patient outcome.

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References

- Hellén-Halme K, Johansson PM, Håkansson J, Petersson A. Image quality of digital and film radiographs in applications sent to the Dental Insurance Office in Sweden for treatment approval. *Swed Dent J* 2004; **28**: 77–84.
- Matzen LH, Wenzel A. Efficacy of CBCT for assessment of impacted mandibular third molars: a review—based on a hierarchical model of evidence. *Dentomaxillofac Radiol* 2015; **44**: 20140189. doi: <http://dx.doi.org/10.1259/dmfr.20140189>
- SEDENTEXCT Project. *Radiation protection no 172: cone beam CT for dental and maxillofacial radiology*. Luxembourg: European Commission Directorate-General for Energy; 2012.
- Petersen LB, Olsen KR, Christensen J, Wenzel A. Image and surgery-related costs comparing cone beam CT and panoramic imaging before removal of impacted mandibular third molars. *Dentomaxillofac Radiol* 2014; **43**: 20140001. doi: <http://dx.doi.org/10.1259/dmfr.20140001>
- Petersen LB, Olsen KR, Matzen LH, Vaeth M, Wenzel A. Economic and health implications of routine CBCT examination before surgical removal of the mandibular third molar in the Danish population. *Dentomaxillofac Radiol* 2015; **44**: 20140406. doi: <http://dx.doi.org/10.1259/dmfr.20140406>
- Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. *Dentomaxillofac Radiol* 2006; **35**: 219–26. doi: <http://dx.doi.org/10.1259/dmfr/14340323>
- Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. *Dentomaxillofac Radiol* 2003; **32**: 229–34. doi: <http://dx.doi.org/10.1259/dmfr/26310390>
- Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008; **106**: 106–14. doi: <http://dx.doi.org/10.1016/j.tripleo.2008.03.018>
- Hol C, Hellén-Halme K, Torgersen G, Nilsson M, Møystad A. How do dentists use CBCT in dental clinics? A Norwegian nationwide survey. *Acta Odontol Scand* 2015; **73**: 195–201. doi: <http://dx.doi.org/10.3109/00016357.2014.979866>
- Shelley AM, Brunton P, Horner K. Questionnaire surveys of dentists on radiology. *Dentomaxillofac Radiol* 2012; **41**: 267–75. doi: <http://dx.doi.org/10.1259/dmfr/58627082>
- Matzen LH, Christensen J, Wenzel A. Patient discomfort and retakes in periapical examination of mandibular third molars using digital receptors and film. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **107**: 566–72. doi: <http://dx.doi.org/10.1016/j.tripleo.2008.10.002>
- Horner K, Eaton K. *Selection criteria for dental radiology*. London, UK: Faculty of General Dental Practice (UK). The Royal College of Surgeons of England; 2013.
- Renton T, Adey-Viscuso D, Meechan JG, Yilmaz Z. Trigeminal nerve injuries in relation to the local anaesthesia in mandibular injections. *Br Dent J* 2010; **209**: E15. doi: <http://dx.doi.org/10.1038/sj.bdj.2010.978>
- Flygare L, Ohman A. Preoperative imaging procedures for lower wisdom teeth removal. *Clin Oral Investig* 2008; **12**: 291–302. doi: <http://dx.doi.org/10.1007/s00784-008-0200-1>
- Matzen LH, Schou S, Christensen J, Hintze H, Wenzel A. Audit of a 5-year radiographic protocol for assessment of mandibular third molars before surgical intervention. *Dentomaxillofac Radiol* 2014; **43**: 20140172. doi: <http://dx.doi.org/10.1259/dmfr.20140172>
- Matzen LH, Christensen J, Hintze H, Schou S, Wenzel A. Influence of cone beam CT on treatment plan before surgical intervention of mandibular third molars and impact of radiographic factors on deciding on coronectomy vs surgical removal. *Dentomaxillofac Radiol* 2013; **42**: 98870341. doi: <http://dx.doi.org/10.1259/dmfr/98870341>
- Guerrero ME, Botetano R, Beltran J, Horner K, Jacobs R. Can preoperative imaging help to predict postoperative outcome after wisdom tooth removal? A randomized controlled trial using panoramic radiography versus cone-beam CT. *Clin Oral Investig* 2014; **18**: 335–42. doi: <http://dx.doi.org/10.1007/s00784-013-0971-x>
- Petersen LB, Vaeth M, Wenzel A. Neurosensoric disturbances after surgical removal of the mandibular third molar based on either panoramic imaging or cone beam CT scanning: a randomized controlled trial (RCT). *Dentomaxillofac Radiol* 2016; **45**: 20150224. doi: <http://dx.doi.org/10.1259/dmfr.20150224>
- Sanmarti-Garcia G, Valmaseda-Castellón E, Gay-Escoda C. Does computed tomography prevent inferior alveolar nerve injuries caused by lower third molar removal? *J Oral Maxillofac Surg* 2012; **70**: 5–11. doi: <http://dx.doi.org/10.1016/j.joms.2011.03.030>