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Does CBCT scans alter surgical treatment plans? Comparison of preoperative surgical diagnosis using panoramic versus cone-beam CT images

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Does CBCT scans alter surgical treatment plans ? Comparison of preoperative surgical diagnosis using panoramic versus cone-beam CT images

Summary

Purpose: The aim of this study was to evaluate retrospectively if (1) 3D imaging resulted in significantly more surgically relevant information and if (2) 3D diagnostic imaging information had a significant impact on the decision process in six different classes of surgical indications.

Material and Methods: Records of all patients who had undergone both panoramic x-ray and CBCT imaging due to surgical indications between January 2008 and December 2012, were selected from existing patient documentations. In February 2013, all surgically relevant evaluations and diagnoses of both conventional panoramic radiographs and CBCT scans were retrieved from the patients charts. It was recorded whether (1) 3D imaging presented additional surgically relevant information and (2) if the final decision of surgical therapy had been based on 2D or 3D imaging.

Results: A total of 253 patients with both panoramic x-ray and CBCT analysis were eligible for the study. Significantly more surgically relevant information was seen in cases of implant dentistry, maxillary sinus diagnosis and in oral and maxillofacial traumatology. However, surgical strategies had not been influenced to any significant extent by 3D imaging.

Conclusion: Within the limitations of this study it may be concluded that CBCT imaging results in significantly more surgically relevant information in implant dentistry, maxillary sinus diagnosis and oral and maxillofacial surgery. However, 3D diagnosis had only a minor impact on surgical therapies based on 2D panoramic radiographies. Further studies are necessary to define indications for CBCT in detail.

Key words: Cone beam CT, oral and maxillofacial surgery

Does CBCT scans alter surgical treatment plans ? Comparison of preoperative surgical diagnosis using panoramic versus cone-beam CT images

Introduction

Recent literature has pointed out that panoramic and intraoral radiographies are still the basic imaging methods in dentistry, allowing two dimensional (2D) imaging of oral hard tissues (Suomalainen et al., 2015). Panoramic radiographs show a single image of the maxilla, mandible, teeth, temporo-mandibular joints and maxillary sinuses. During exposure, the x-ray source and detector rotate synchronously around the patient producing a curved surface tomography. However, due to the tomographic nature of the technique, only structures located within the tomographic plane are well delineated and those in front or behind that plane are blurred (Lurie, 2004) which may result in limited diagnostic information.

To overcome these shortcomings, cone beam CT (CBCT) devices were introduced in dento-maxillofacial imaging in the late 1990s (Arai et al., 1999, Mozzo et al., 1998). During x-ray exposure, a series of planar projection images of the field of view (FOV) are generated. When the basis projection images have been acquired, the CBCT unit reconstructs the primary projection frames to provide standard viewing displays of coronal, sagittal and axial images similar to the MSCT data display (Scarfe and Farman, 2008).

At present, there is an ongoing discussion on clinical indications of 2D vs. 3D technique. With respect to implant dentistry, it was concluded that no additional imaging is required for implant placement if the clinical assessment of implant sites indicates that there is sufficient bone width and the conventional radiographic examination reveals the relevant anatomical boundaries and adequate bone height and space (Harris et al., 2012). Nevertheless, additional information in the third dimension may be of value in implant dentistry. In preoperative diagnosis and planning based on two-dimensional (2D) imaging, dental implants may be placed in areas with a potential risk of damage to vital structures. Thus, restricting preoperative diagnosis to 2D images in dental implant practice can potentially cause implant failures (Guerrero et al., 2014). Moreover, it was stated that three-dimensional evaluation of the sinus with CBCT was significantly more reliable in detecting pathology than panoramic imaging (Tadinada et al., 2015). Similarly, there is an ongoing discussion in other indications.

To enhance clarity in the discussion, evidence-based guidelines for the use of CBCT in dental and maxillofacial radiology were prepared by several institutions such as the European Commission guidelines (European Commission, 2012). However, there is little information whether 3D diagnosis results in alteration of surgical treatment plans based on 2D imaging. It was shown recently that CBCT imaging of suspected mandibular fractures resulted in a change in the treatment plan in 9.5 % (Kaeppler et al., 2013). At present, it is unclear if similar percentages may be found when 2D information is compared to 3D diagnosis in other surgical indications.

Therefore, the aim of the present study was to evaluate if (1) 3D imaging resulted in significantly more surgically relevant information and if (2) 3D diagnostic imaging information had a significant impact on the decision process of the clinician working with the images, according to level three of the efficacy of new medical imaging techniques (i. e.; diagnostic thinking efficacy), in six clinical indication groups (Fryback and Thornbury, 1991).

Materials and Methods

Study sample. In February 2013, the records of all patients who had undergone both panoramic x-ray and CBCT imaging due to surgical indications between January 2008 and December 2012, were eligible from existing patient documentations of the Department of Oral and Maxillofacial Surgery of this University. In all cases, 2D imaging was performed as radiographic first line diagnosis. Patients with uncertain clinical and/or radiological findings had undergone in addition CBCT. Accordingly, inclusion criteria for this study were an existing preoperative conventional panoramic radiograph and a CBCT scan from the same patient, and data about the intended surgical procedure, based on 2D information, and the definitive procedure based on CBCT diagnosis. Institutional Review Board approved this study.

Image acquisition. Panoramic radiographs were performed with Orthoralix 8500 (Soredex, Helsinki, Finland). For each patient, individual exposure settings had been documented in the patients charts and ranged from 60–80 kV and 4–10 mA. The scan time was 12 s. Panoramic film cassettes had a size of 15 x 30 cm and contained a high-speed intensifying screen (Lanex Regular, Kodak, Rochester, USA). In all cases, Kodak T-MAT G films were used (PAN/TMG15) and the Kodak GBX-2 as dark-room light. Panoramic films had been automatically processed in a Kodak RP X-Omat M5 processor (Eastman- Kodak). The automixer provided a specific gravity of the developer (1.081 to 1.091 gcm^{-3}). Water temperature ranged from 21°-27°C.

CBCT scans were acquired with a Galileos CBCT unit (Sirona Dental Systems Inc., Bensheim, Hessen, Germany) with a maximum resolution mode (voxel size) of 150 µm. The fixed field of view size of 15 cm resulted in a spherical scan volume of 15x15 cm. Scan parameters ranged between 10 – 42 mA tube current at 85 kV tube voltage. The exposure time ranged between 2 and 6 seconds, the scan time was 14 s. The X-ray detector for the unit was a 9 inch (23 cm) image intensifier and a charge-couple device camera.

Diagnostic regimen. Between January 2008 and December 2012, all conventional panoramic radiographs and all CBCT scans had been diagnosed by two experienced clinicians (one oral surgeon, one oral and maxillofacial surgeon). Conventional PAN were analyzed with the aid of a magnifying glass (HRP, 4x; Heine Optotechnik, Herrsching, Germany) and calipers, if measurements were indicated (Züricher Modell; Dental- Liga, Zürich, Switzerland) on a backlit screen in a darkened room. CBCT images were presented on a computer with screen size 1680 x 1050 (Intel HD Graphics 3000 384 MB). The same computer software was used for all CBCT scans (Galaxis®, Sirona Dental Systems). Digital images were analyzed in all cases using the full facilities of the Galileos viewer software. All images were presented in full volume size and with the option to change all possible setting options (adjusting of contrast, scrolling through volume). Prior to the evaluation and diagnosing process, an introduction about the applications and features of the Galileos viewer software was given to both observers.

Comparison of PAN/CBCT Diagnosis. In February 2013, a radiological experienced dentist (CW) retrieved all surgically relevant evaluations and diagnoses of both conventional panoramic radiographs and CBCT scans from the patients charts. Moreover, the investigator re-evaluated all images with respect to the documented surgically relevant diagnosis. It was recorded whether (1) 3D imaging provided additional surgically relevant information and (2) if the final decision of surgical therapies had been based on 2D or 3D imaging. Radiographic findings were defined as “surgically relevant information” if radiographic anatomy and/or pathology provided more details. Therefore, full access to conventional x-ray and digital CBCT evaluation was provided (see Diagnostic regimen).

To enable statistical evaluation, all cases were assigned according to the classification of indications which had been published by the German Society for Oral and Maxillofacial Surgery (Hassfeld, 2008). Due to the fact that not all eight original indications were represented among the 253 cases, only six groups were used (Class A – F, Table 1).

Classes A – F might include almost countless sub-indications. To provide statistically relevant subgroups, each pair of imaging was assigned to one of the following indications: In Class A (Implant Surgery) it was intended to evaluate if CBCT analyses had a major impact on the need of augmentation in the vertical dimension or on implant length. Moreover, comparison of treatment planned based on 2D or 3D diagnosis should show in Classes B, C and D, if there was a difference of total amounts of diagnostic biopsies, surgical revisions, and osteotomies. Comparison of both modes of imaging in Class E should reveal if CBCT had had an impact on the rate of conservatively vs. surgically treated fractures of the mandible. Lastly, it should be found out if 3D imaging in other indications (Class F) had resulted in an alteration of surgical therapies.

Data processing and statistical analysis. Panoramic radiographs and CBCT were compared due to the primary (surgically relevant information) and secondary outcome parameter (definitive surgical therapy). For the latter, panoramic radiography and CBCT findings were compared with the actually applied surgical procedure. Table 2 provides counts and percentages of surgically relevant findings based on 2D and 3D imaging. Moreover, the number of surgical decisions based on either panoramic radiographs or on CBCT imaging is reported with counts and percentages in Table 2. The statistical significance of difference in proportion was tested by the Chi-square test. The site was treated as a random factor. A p-value ≤ 0.05 was considered to indicate statistical significance. Statistical analysis was performed using the commercial computer program SPSS (Statistical Package for Social Sciences) for Windows (version 20, SPSS Inc. Chicago, Illinois, USA).

Results

Study sample. Between January 2008 and December 2012, a total of 255 patients underwent both panoramic x-ray and CBCT analysis due to surgical indications. Because of artifacts, two images (one panoramic x-ray, one CBCT) in two patients could not be diagnosed (0.78%). Accordingly, 253 patients were eligible for the study. Among these patients, there were 120 women and 133 men, with a mean age 48.8 years (range 9–88 years). Sixty-seven percent of patients were more than 40 years of age, 31% were between 21 and 40 years old and only 2% were less than 20 years old. Distribution of imaging may be seen from Table 2. CBCT scans were mostly indicated in Class C (diagnosis of the dento-alveolar complex, n = 64, 25.3%) whereas lowest number of 3D images were attributable to Class B (Maxillary Sinus, n = 23, 9.1%).

Comparison of PAN/CBCT surgically relevant information and surgical procedure. It may be seen from Table 1 that surgically relevant information, based on panoramic radiography or CBCT, was not equally distributed in classes A – F. In class A (Implant Surgery), the difference was highly significant between both modes of imaging ($p < 0.001$). Accordingly, in 86.9% of all cases 3D diagnosis provided significantly more surgically relevant information as compared to 2D diagnosis. All of the 61 pairs of imaging were related to evaluation of the vertical bony dimension before implant surgery. However, CBCT analyses had a no major impact on the need of augmentation in the vertical dimension including the posterior region of the maxilla. Moreover, there was no change in implant lengths following CBCT.

Similarly, three-dimensional imaging of the maxillary sinus (Class B) presented statistically significant more surgically relevant information (82.6%) as compared to preoperative 2D diagnosis ($p < 0.001$). However, in this Class, only 1 of 23 cases (4.3%) underwent surgery in a modified form. In this case, a formerly intended revision of the sinus was replaced by a less invasive endoscopic treatment.

In contrast, 3D imaging did not provide significantly more surgically relevant diagnostic information as compared to 2D diagnosis, neither in Class C (Dentoalveolar Comlex) ($p = 0.48$) (Figure 1 a-c) nor in Class D (Bony Pathology and Anomalies of Structures) ($p = 0.79$). Accordingly, CBCT imaging had no significant impact on definite surgery, neither in Class C ($p < 0.001$) nor in Class D ($p < 0.001$). Especially, extraction of impacted inferior third molars and biopsy of bony pathologies did neither change indication for surgery nor access strategy.

With respect to surgically relevant information, CBCT provided significantly more surgically relevant information as compared to 2D imaging in Class E (Oral and Maxillofacial Traumatology); i.e. 78.9 % of cases ($p < 0.001$). However, additional surgically relevant information resulted only in 3 modified therapies (3 mandibular fractures, 7.9%) (Figure 2 a-d). This difference was highly significant ($p < 0.001$) which means that definitive surgery had not been influenced by 3d imaging to any significant extent.

Unexpectedly, CBCT evaluation had no impact at all on either surgically relevant information or on surgical therapy in Class F (other indications such as unclear pain or temporomandibular joint disorder). All of the 38 cases underwent x-ray evaluation to exclude bony pathology of the mandibula. However, none of these cases demonstrated indication for surgical therapy. Accordingly, 2D diagnosis had been sufficient for a total of 23 of the 38 cases.

Discussion

The aim of this study was to evaluate retrospectively if (1) 3D imaging resulted in significantly more surgically relevant information and if (2) 3D diagnostic imaging information had a significant impact on the decision process in six different classes of surgical indications.

Therefore, a sample of 253 pairs of panoramic x-rays and CBCT scans allowed correlation between surgical plans based on 2D diagnosis and comparison with the definite surgical procedures carried out following 3D analysis. Two patients had to be excluded due to artifacts in the images (0.78%) which had been caused by movement of the patient during circuit of the x-ray tube. This is in accordance with the literature because it was stated that no system can prevent motion during scanning completely (Bontempi et al., 2008).

To allow statistically relevant group sizes of indications, all pairs of imaging were assigned to one of six indications (Classes A – F). Accordingly, sample sizes ranged from 23 (Class B) to 64 (Class C). Therefore, it seemed not justified to compare more specific sub groups such as those provided in Table 2.

In Class A (Implant Dentistry), surgically relevant information was statistically more often found in CBCT imaging as compared to 2D diagnosis. However, additional surgically relevant information had no impact at all on surgical procedures (augmentation, implant length). Similarly, a concordance between planning from CBCT and from panoramic radiography of nearly 95% was reported (Baciut et al., 2013). In addition, it was pointed out in a recent study that planning of augmentation requirements based on 2- or 3-dimensional images was, in the majority of the cases, in agreement with the actual surgical procedure

(Dagassan-Berndt et al., 2015). However, CBCT-based implant planning tended to suggest more invasive surgery, whereas planning on panoramic radiography tended to underestimate the degree of invasiveness of surgical procedures. Therefore, it was outlined that the most influencing factor is the observer (Dagassan-Berndt et al., 2015). Accordingly, the surgeon has to be aware that planning more in detail might result in more invasive therapy and it is questionable if the patient will profit from such more invasive procedures. Due to its two dimensional nature, transversal bone width cannot be measured on panoramic radiographs, so this parameter was not evaluated here. With respect to the implant length it was recently shown that guided surgery procedures based on CBCT ought to respect safety distances of 2 mm next to vulnerable structures (D'Haese et al., 2012) which is in the order of conventional planning based on 2D imaging. Therefore, like in the present study, CBCT has not yet shown any superiority in this regard. In accordance with the most recent literature it may be concluded that 2D imaging, especially panoramic radiography, is sufficiently accurate for vertical linear measurements in dental implant treatment planning (Luangchana et al., 2015).

Significantly more surgically relevant information was also seen in Class B (maxillary sinus) which is also in accordance with the literature (Brullmann et al., 2012). The authors stated that basal mucosal wall thickening was more likely in patients with decayed and non-vital teeth compared to patients with sound teeth. Similarly, also in this study, CBCT findings confirmed 2D diagnosis and prevented in one case surgical revision of the sinus because minimally invasive endoscopy was sufficient.

In Class C (dento-alveolar complex), 3D imaging did not provide significantly more surgically relevant information. At first look, this is in contrast with the present literature. Early literature on CBCT pointed out that 3D imaging provides more diagnostic information as compared to 2D imaging such as narrow localization of third mandibular molars and the mandibular nerve (Nakagawa et al., 2007). However, one ought to differentiate between "diagnostic information" and "surgically relevant information" which was focused in the present study in the sense of providing more details. Moreover, the present results indicate that more surgically relevant information does not compellingly result in alteration of surgical strategies. This is widely accepted in the literature: The differences between CBCT and panoramic radiography with regards to the identification and length of the mental loop were not found to be statistically significant (Vujanovic-Eskenazi et al., 2015). From another study it was concluded that several risk factors are associated with neurosensory deficits of inferior alveolar nerve after mandibular third molar extraction, such as older age and deeper impaction ($p < .05$) (Kim et al., 2012). Finally, results from a review have shown that existing studies suggest that CBCT did not change patient outcome compared with PAN imaging (Matzen and Wenzel, 2015). Accordingly, it was stated that panoramic radiography examination is sufficient in most cases before removal of mandibular third molars (Matzen and Wenzel, 2015).

Similarly, there was neither no more surgically relevant information in 3D imaging nor a statistically significant impact of CBCT imaging as compared to 2D diagnosis on surgical strategy in Class D. Therefore, in this Class, additional 3D imaging cannot be demanded generally (Schulze, 2013). In contrast, several authors have stated that 3D analysis is superior to 2D imaging with respect to osteomyelitis (Bianchi et al., 2007, Stockmann et al., 2010, Treister et al., 2010). However, this might be explained by the relatively small sample size in this study.

In contrast, again, 3D imaging in oral and maxillofacial traumatology (Class E) showed statistically significant more surgically relevant information as compared to 2D diagnosis. However, only 3 of 38 (7.9 %) cases underwent another form of therapy. Most of these 38 cases were mandibular fractures. This result is also in accordance with the literature: *Kaeppler* et al. (Kaeppler et al., 2013) reported that following CBCT diagnosis, the treatment plan for mandibular fractures was altered for 9.52% of sites. Nevertheless, it is unclear if an altered treatment plan has an impact on the patient`s treatment outcome.

With respect to Class F (Diagnosis of Unclear Pain, Temporomandibular Joint Disorder), there was also no superiority for 3D imaging, neither for diagnosis nor for alteration of surgical interventions. This may be explained by the fact that inflamed soft tissues do not correlate sufficiently with x-ray imaging (Kaeppler et al., 2013). Accordingly, panoramic x-ray diagnosis seems sufficient for those patients at first line. If more information is necessary, magnetic resonance imaging should be discussed.

This study has some limitations. First, patients were recruited from an outpatient setting of a university hospital. Therefore, it cannot be excluded that patients are not representative for the whole population. Second, sample sizes in Classes A – F are relatively small. It cannot be excluded completely that other bigger sample sizes may result in different findings.

Conclusion

Within the limitations of this study it may be concluded that CBCT imaging results in significantly more surgically relevant information in implant dentistry, maxillary sinus diagnosis and oral and maxillofacial surgery. However, 3D diagnosis had only a minor impact on surgical therapies based on 2D panoramic radiographies. Further studies are necessary to define indications for CBCT in detail.

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Figure legends

Figure 1 a - c

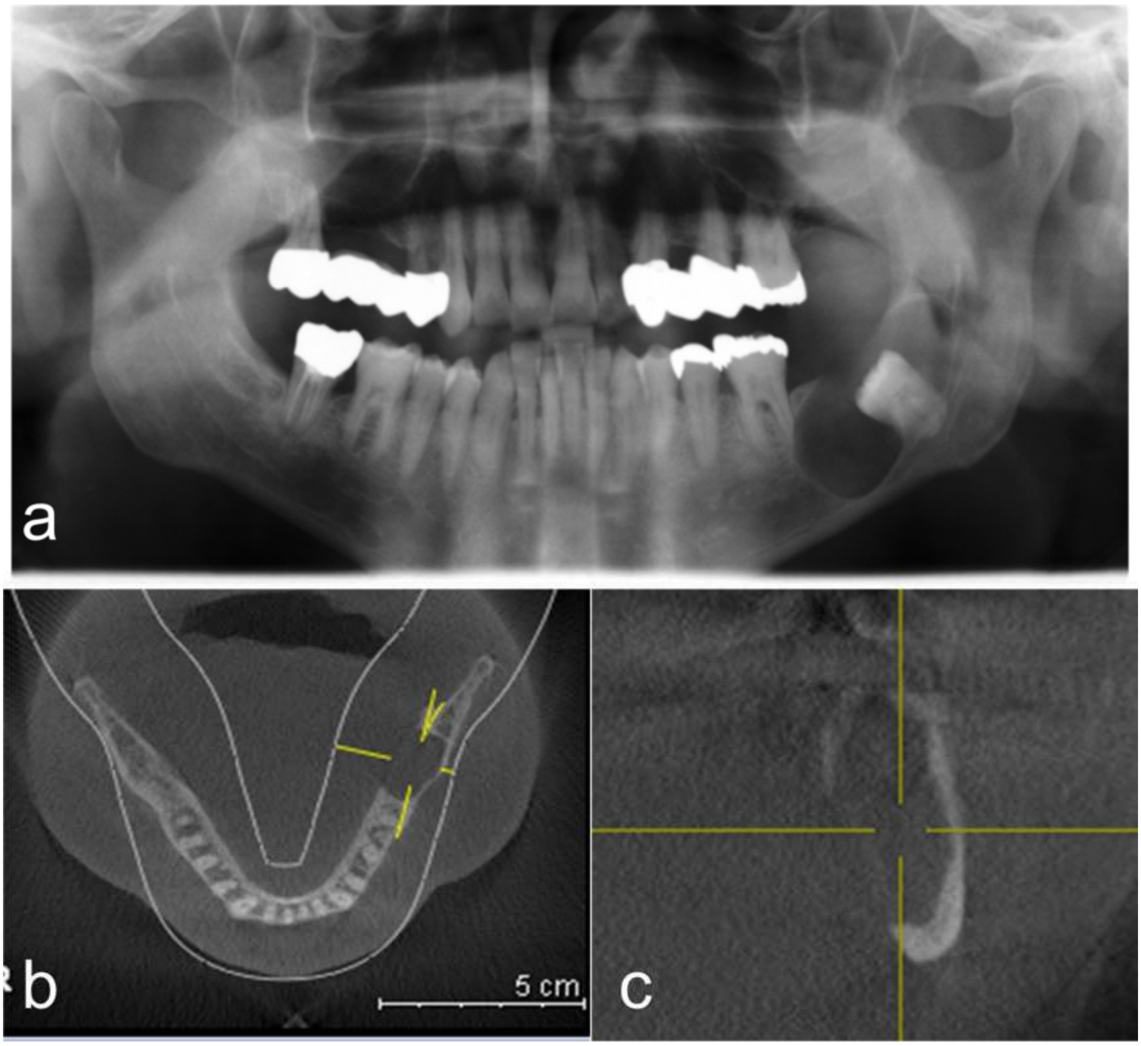
a) Cystic lesion in the left mandible. Risk of artificial fracture during osteotomy seems highly probable.

b, c) Lingual cortical plate completely resorbed in both axial (b) and coronal (c) dimension. Assumption of high risk osteotomy based on 2D diagnosis is confirmed by CBCT.

Figure 2 a - d

a) Subcondylar fractures of the left and right mandible. Conservative treatment was planned due to 2D imaging.

b-d) Severe dislocation of the left condyle is clearly visible in the sagittal (b) and coronal (c) dimension. Conservative treatment, based on 2D diagnosis, was changed to surgical therapy due to incliniation of the small fragment, diagnosed in 3D imaging.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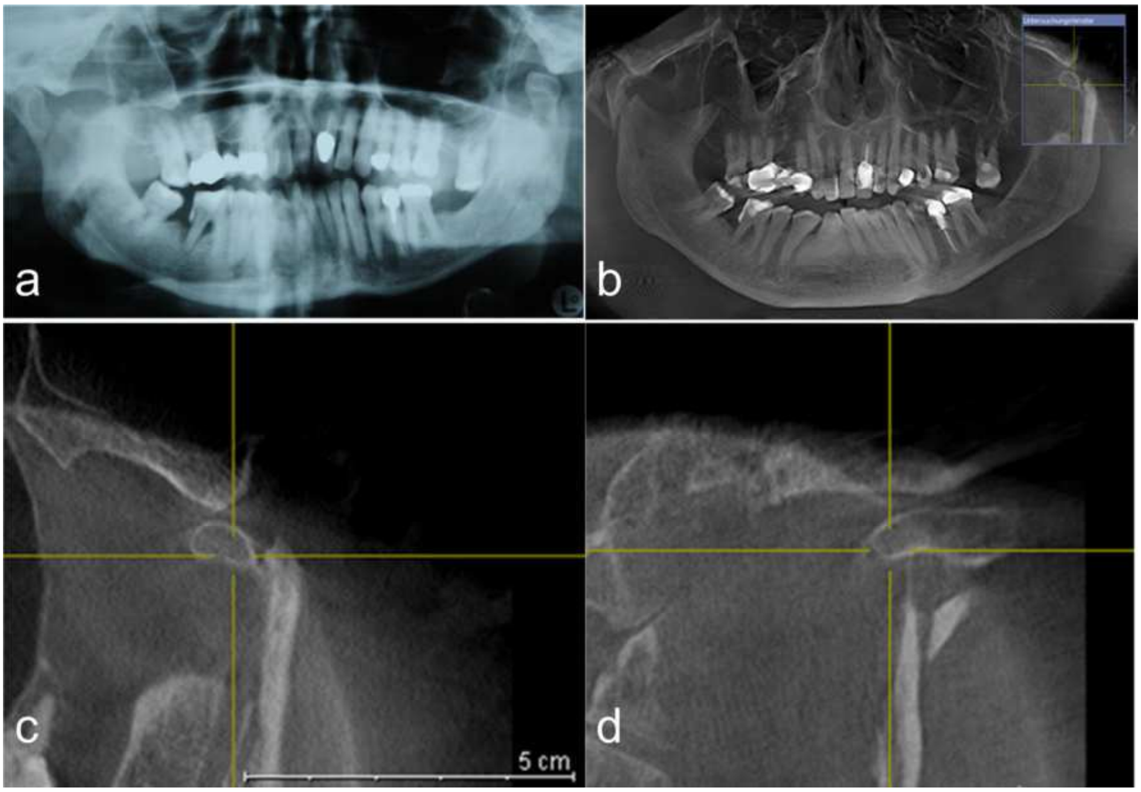

Table 1: Classification of CBCT indications (modified according to (Hassfeld, 2008)).	
Class A	Implant Surgery (Need for Augmentation, Implant Length)
Class B	Maxillary Sinus (Diagnostic Biopsy, Surgical Revision)
Class C	Dentoalveolar Comlex (Osteotomy)
Class D	Bony Pathology and Anomalies of Structures, such as Odontogenic Tumors, Pathology and Structures in Osteitis, Osteomyelitis and Osteoporosis (Diagnostic Biopsy, Surgical Revision, Osteotomy)
Class E	Oral and Maxillofacial Traumatology (Conservative vs. Surgical Treatment of Mandibular Fractures)
Class F	Other Indications (Diagnosis of Unclear Pain, Temporomandibular Joint Disorder)

Table 2. Distribution of surgically relevant information based on either panoramic radiographs (PAN) or on CBCT imaging and alteration of surgical treatment due to CBCT in Class A - F, presented as counts and percentages.

	Surgically Relevant Information in Classes A - F					
	Class A	Class B	Class C	Class D	Class E	Class F
PAN n, (%)	8 (13.1%)	4 (17.4%)	30 (46.9%)	15 (51.7%)	8 (21.1%)	23 (78.9%)
CBCT n, (%)	53 (86.9%)	19 (82.6%)	34 (53.1%)	14 (48.3%)	30 (78.9%)	15 (21.1%)
n (Σ 253)	61	23	64	29	38	38
p	($p < 0.001$)	($p < 0.001$)	($p = 0.48$)	($p = 0.79$)	($p < 0.001$)	($p = 0.07$)
	Alteration of Surgical Treatment due to 3D Imaging					
n, (%)	0 (0%)	1 (4.3%)	1 (1.5%)	0 (0%)	3 (7.9%)	0 (0%)
p	($p < 0.001$)	($p < 0.001$)	($p < 0.001$)	($p < 0.001$)	($p < 0.001$)	($p < 0.001$)