RESEARCH ARTICLE

Presurgical evaluation of bony implant sites using panoramic radiography and cone beam computed tomography—influence of medical education

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Objectives: The aim of this study was to compare the subjective quality rating of panoramic radiography (PAN) and CBCT in the planning of dental implant procedures by clinicians with different educational backgrounds.

Methods: Radiographic images (PAN and CBCT) of 42 patients were examined as follows: the maxillary (MX) anterior region of patients, the MX posterior region of 16 patients and the mandibular (MD) posterior region of 16 patients. These sites were used for planning of dental implant insertion. Data sets were analyzed by examiners with different training backgrounds: three general practitioners (GP), three oral surgeons (OS) and three maxillofacial surgeons (MS). A standardized questionnaire in a standardized setting was answered by participants.

Results: The majority of participants rated an additional CBCT as “required” (14.0%) or “reasonable” (56.1%). These ratings depended strongly on the area of interest (MX anterior region: 31.1 and 58.9%; MX posterior region: 14.6 and 62.5%; and MD posterior region: 2.8% and 47.9%). MS classified CBCT as required more often than GP and OS (23.8 vs 10.3 and 7.9%; $p < 0.001$). With the additional information of CBCT, “therapy affecting” ratings were stated high in all groups.

Conclusions: Especially in the anterior and posterior MX, significant subjective benefits for an additional CBCT were seen for planning of dental implant procedures. Participants with fundamental medical education asked for CBCT more often. The results indicate that an improved education in three-dimensional dental radiology is necessary.

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Introduction

Next to clinical examination, radiographic assessment is one of the most important diagnostic tools in dentistry.¹

It is of importance to reveal more clinically relevant details that cannot otherwise be identified.^{2,3} Panoramic radiographies (PAN) are common and easy to obtain but may not answer all related clinical questions. This is due to the underlying technique and distortion factors associated with it. Aside from being a two-dimensional

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imaging technique, variations in patient curvature of jaws and imaging position could propagate dimensional errors. In addition, PAN may not show fine anatomic details. Three-dimensional (3D) imaging of anatomic structures is useful in cases of inflammation, trauma, bone pathologies and neoplastic diseases. It also became an important element in dental implantology.^{4,5} However, 3D radiography involves higher radiation doses to be applied. For certain indications, CBCT offers an alternative to conventional CT with about 10–50% less radiation exposure.⁶ Deman *et al*⁷ reported an applied radiation dose—normalized to 100 mAs and measured for a large-field of view (FOV)—of 11.4 mGy/100 mAs in dental CBCT. This value is two times lower than the observed value in a multislice CT scan with about 20.7 mGy/100 mAs for the same FOV. Nonetheless, CBCT still yields higher radiation doses than conventional dental radiography techniques.^{7–10} Compared with PAN, the effective dose in CBCT is about 4–27 times higher.^{7,9,10}

There are only a few publications addressing the additional benefit of CBCT in surgical planning of implant procedures.^{11–15} In a clinical survey on 108 patients with 365 dental implants, Guerrero *et al*¹¹ concluded that CBCT for implant planning results in a higher degree of prediction, especially for implant length, when compared with PAN only. Similarly, Fortin *et al*¹³ stated that the use of PAN in the maxilla leads to a pre-operative overestimation for sinus augmentation, which may be avoided by 3D planning. Others, on the other hand, found a weak evidence that availability of CBCT reduces bone perforations and increases the rate of safe implant placement in the anterior edentulous mandible.¹²

An attempt for a systematic review on the importance of CBCT in dental implant procedures was not possible owing to the high number of variables in this specific indication of implant placement.¹⁵ Even so, a high number of dentists, oral surgeons (OS) as well as maxillofacial surgeons (MS) have access to CBCT and use it routinely mainly for dental implant procedures.^{16,17}

Therefore, the aim of this study was to evaluate the use of PAN and CBCT for bony dental implant site evaluation correlated to practitioner professional training.

Methods and materials

Patients and examiners

This non-interventional retrospective study was carried out at the Departments of Oral, Maxillofacial and Plastic Surgery of the University Medical Centres of the Universities of Mainz and Rostock, Germany. Patients who were referred for pre-operative planning of dental implant procedures between January 2008 and December 2010 were screened retrospectively. For inclusion in the study, a pre-operative PAN as well as a small-FOV CBCT of the region of interest

(1–2 implant sites) had to be available. This study, on anonymous radiographic images, was performed in accordance with the current version of the Declaration of Helsinki. A total of 42 subjects, 29 female and 13 male patients, were included in the study between the ages of 19 and 91 years (average age 51 years). There were 10 cases of the maxillary (MX) anterior region, 16 cases of the MX posterior region and 16 cases of the mandibular (MD) posterior region. No suitable cases of the MD anterior region were available.

PANs were generated by Orthophos XG Plus (Sirona Dental Systems GmbH, Bensheim, Germany). Sectional CBCTs were generated by KaVo 3D eXam[®] (KaVo Dental GmbH, Biberach, Germany) and Accutomo Morita (J. Morita Mfg Corp., Kyoto, Japan). Nine dental professionals, with different training backgrounds of medical education, participated in the study. Participants were three general practitioners (GP), three OS and three MS. Each participant had the same examination setup using a beamer and a 2 × 3-m screen. Questionnaires were then answered by each participant (Figures 1 and 2), with a questionnaire for PAN (two questions) and CBCT (one question).

In Germany, general dental practitioners usually study dentistry without any further formal dental and/or medical education programme. For OS, they undergo an additional oral surgery training for at least 3 years. MS are required to study dentistry as well as medicine and to undergo a specific surgical and medical training for at least 5 years. For using CBCT, completion of a structured course consisting of at least two classroom-based trainings (each for one day) together with 25 documented CBCT cases and a written examination is required.

All participants had undergone this education and had used CBCT on a daily basis, but with different indications depending on their speciality.

Questionnaire

The first question for PAN was focused on the radiologic quality in the clinical area of interest with four answers to choose from (1 = good visibility and can be assessed/evaluated; 2 = adequate visibility but cannot be assessed/evaluated; 3 = no adequate visibility/not recognizable; and 4 = no visibility/not recognizable). The second question was for a further need of additional CBCT scans. Three answers were given (1 = required; 2 = reasonable; and 3 = not required).

For CBCT, the question focused on the quality of the area of interest related to PAN. The examiner had to choose between four possible answers (1 = shows additional information; 2 = is very useful; 3 = is affecting therapy; and 4 = is absolutely required).

Participant calibration was not carried out in order to avoid preparation for this study to represent clinical decisions of each participant.⁵ In addition, no further training using PAN and CBCT next to their prior experience was provided. This decision was based on the

objective of the study to examine differences between the groups with different medical education.

Statistics

Considering the retrospective design of the study, no power analysis was conducted. All results were expressed as number of cases, arithmetic means $\pm$ standard deviation or as incidence value (%). To assess homogeneity within each group, E-coefficients of inhomogeneity were calculated. For comparison of groups, one-way ANOVA with Tukey's simultaneous *post hoc* tests were conducted and descriptive *p*-values of tests were reported. A *p*-value of <0.05 was termed significant. Analyses were performed with SPSS® v. 20.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL).

Results

The analysis focused on three different aspects—implant site evaluation using PAN, using PAN and CBCT as well as the corresponding influence of professional education.

Implant site evaluation using panoramic radiography

The rating of PAN differed by the areas of interest (Table 1). In total, results showed a high number of “good visibility and can be assessed/evaluated” (31.5%) and “adequate visibility but cannot be assessed/evaluated” (41.5%) ratings, whereas lower ratings were found for “no adequate visibility/not recognizable” (24.1%) and “no visibility/not recognizable” (2.9%). Especially in the MD posterior area, a significant number of sufficient ratings (good and adequate visibility *vs* no adequate visibility and no visibility) was stated (88.9 *vs* 11.1%; $p < 0.001$) (Table 1).

In Question 2, an additional CBCT was significantly more often “required” (14.0%) and “reasonable” (56.1%) *vs* “not required” (29.9%; $p < 0.001$) for all areas. For the MX posterior region, examiner found CBCT to be “required” in 14.6% and “reasonable” in 62.5% *vs* “not required” in 22.9% of the cases ($p = 0.001$). For the MX anterior region 31.1% of the cases CBCT were rated as “required” respectively 58.9% as “reasonable” *vs*

“not required” at 10% of all cases ($p = 0.001$). For the MX posterior and the anterior region, an additional CBCT was seen significantly more often to be at least a reasonable option for implant planning (Table 2).

Implant site evaluation using PAN and additional CBCT

Overall, 65.8% of answers indicated the usefulness of an additional CBCT (“shows additional information” in 24.3% of cases and “is very useful” in 41.5% of cases). In 30.2% of cases, the additional CBCT was even rated to be affecting therapy. In 4% of cases, CBCT was “absolutely required”. In the maxilla, high ratings (“affecting therapy” and “is absolutely required”) were found in the anterior (28.9 and 12.2%) and posterior areas (40.3 and 1.4%). In contrast, these high values were not seen in the MD posterior area (20.8 and 1.4%) (Table 3).

Implant site evaluation using PAN and CBCT—influence of professional education

E-coefficients of inhomogeneity were 0.2 in the GP, 0.1 in the OS and 0.3 in the MS group. Therefore, equal distributions of the answers were assumed.

In PAN, a statistical significance was found for the MX anterior region in all examiner groups for ratings of “no adequate visibility/not recognizable” (45.6%) and “no visibility/not recognizable” (10%) when compared with other regions ($p < 0.001$) with a slight variance in OS (Table 1).

Significantly different ratings between MS and OS ($p < 0.001$) and MS *vs* GP ($p < 0.001$) were found when the MD posterior area was evaluated (Table 1).

By reducing the four possible answers to “visibility” and “no visibility”, MS reported significantly more “no visibility” ratings in PAN in comparison with GP ($p < 0.001$). “Visibility” included “good visibility and can be assessed/evaluated” and “adequate visibility but cannot be assessed/evaluated”, whereas “no visibility” included “not adequate visibility/not adequate recognizable” and “no visibility/not recognizable”.

An additional CBCT was rated as “not required” (all area: 29.9%) or “reasonable” (all areas: 56.1%) (Table 2), with a significant difference when examining the subgroups.

In most cases of the MD posterior region, CBCT was seen to be “not required” by GP (62.5%) and OS

Figure 1 Panoramic radiography with an area of interest (maxillary side area) and examples of corresponding images of the respective small-field of view CBCT.

Figure 2 Panoramic radiograph with an area of interest (maxillary anterior region) and examples of corresponding images of the respective small-field of view CBCT.

(68.8%). Nonetheless, significantly less MS rated CBCT to be unnecessary in this area (16.7%; $p < 0.001$). Moreover, “absolutely required” ratings were seen significantly more often by the MS (4%) and GP groups (7.9%) than the OS group (0%; $p < 0.0001$) in the MD posterior region.

In the MX anterior area, the GP group rated CBCT to be significantly more “affecting therapy” (40.0%) and “absolutely required” (26.7%) in comparison with OS (23.3 and 0%; $p < 0.001$) and MS (23.3 and 10%; $p = 0.013$).

The evaluation of the MX posterior area showed similar results in the groups of GP (45.8 and 4.2%) and MS (45.8 and 0%) vs the OS group (45.8 and 4.2%; $p = 0.005$). A significantly higher number of “affecting therapy” (45.8%) and “absolutely required” ratings (4.2%) was seen in GP than in OS (29.2 and 0%; $p < 0.001$). In the MD posterior area, it was found that

there was a significantly higher number of “affecting therapy” (47.9%) and “absolutely required” (4.2%) in MS vs GP (8.3 and 0%; $p < 0.001$) and OS (6.2 and 0%; $p < 0.001$).

Discussion

According to the subjective rating of examiners with different professional trainings and medical education, PAN seems less likely to display the MX anterior and posterior areas for planning of dental implants when compared with the MD posterior area. A high demand for additional 3D imaging (CBCT) was seen, based on an initial PAN examination.

A significantly higher number of answers as “not adequately recognizable” and “not recognizable” were observed in the MX anterior region when using PAN.

Table 1 Tabular summary of the results of the first question of the questionnaire for PAN

Areas of interest (number of cases)	Question: “The clinical area of interest, based on panoramic radiography, shows...?”	GP (n = 3)	OS (n = 3)	MS (n = 3)	p-value
All areas (n = 42)	1 = good visibility and can be assessed/evaluated	48 (38.1%)	51 (40.5%)	20 (15.9%)	<0.001
	2 = adequate visibility but cannot be assessed/evaluated	51 (40.5%)	52 (41.3%)	54 (42.9%)	
	3 = no adequate visibility/not recognizable	22 (17.5%)	19 (15.1%)	50 (39.7%)	
	4 = no visibility/not recognizable	5 (4.0%)	4 (3.2%)	2 (1.6%)	
MX anterior region (n = 10)	1 = good visibility and can be assessed/evaluated	0 (0%)	4 (13.3%)	4 (13.3%)	0.141
	2 = adequate visibility but cannot be assessed/evaluated	11 (36.7%)	11 (36.7%)	10 (33.3%)	
	3 = no adequate visibility/not recognizable	14 (46.7%)	13 (43.3%)	14 (46.7%)	
	4 = no visibility/not recognizable	5 (16.7%)	2 (6.7%)	2 (6.7%)	
MX posterior region (n = 16)	1 = good visibility and can be assessed/evaluated	15 (31.3%)	11 (22.9%)	9 (18.8%)	0.017
	2 = adequate visibility but cannot be assessed/evaluated	26 (54.2%)	29 (60.4%)	18 (37.5%)	
	3 = no adequate visibility/not recognizable	7 (14.6%)	6 (12.5%)	21 (43.8%)	
	4 = no visibility/not recognizable	0 (0%)	2 (4.2%)	0 (0%)	
MD posterior region (n = 16)	1 = good visibility and can be assessed/evaluated	33 (68.8%)	36 (75.0%)	7 (14.6%)	<0.001
	2 = adequate visibility but cannot be assessed/evaluated	14 (29.2%)	12 (25.0%)	26 (54.2%)	
	3 = no adequate visibility/not recognizable	1 (2.1%)	0 (0%)	15 (31.3%)	
	4 = no visibility/not recognizable	0 (0%)	0 (0%)	0 (0%)	

GP, general practitioners; MD, mandibular; MS, maxillofacial surgeons; MX, maxillary; OS, oral surgeons.

Table 2 Tabular summary of the results of the second question of the questionnaire for PAN

Areas of interest (number of cases)	Question: "Is an additional CBCT of the clinical area of interest required?"	GP (n = 3)	OS (n = 3)	MS (n = 3)	p-value
All areas (n = 42)	1 = required	13 (10.3%)	10 (7.9%)	30 (23.8%)	<0.001
	2 = reasonable	74 (58.7%)	63 (50.0%)	75 (59.5%)	
	3 = not required	39 (31.0%)	53 (42.1%)	21 (16.7%)	
MX anterior region (n = 10)	1 = required	11 (36.7%)	8 (26.7%)	9 (30.0%)	0.212
	2 = reasonable	19 (63.3%)	17 (56.7%)	17 (56.7%)	
	3 = not required	0 (0%)	5 (16.7%)	4 (13.3%)	
MX posterior region (n = 16)	1 = required	2 (4.2%)	2 (4.2%)	17 (35.4%)	0.001
	2 = reasonable	37 (77.1%)	31 (64.6%)	22 (45.8%)	
	3 = not required	9 (18.8%)	15 (31.3%)	9 (18.8%)	
MD posterior region (n = 16)	1 = required	0 (0%)	0 (0%)	4 (8.3%)	<0.001
	2 = reasonable	18 (37.5%)	15 (31.3%)	36 (75.0%)	
	3 = not required	30 (62.5%)	33 (68.8%)	8 (16.7%)	

GP, general practitioners; MD, mandibular; MS, maxillofacial surgeons; MX, maxillary; OS, oral surgeons.

Similarly, a higher number of answers indicated that CBCT was "affecting therapy" and "absolutely required" for this area. A potential reason for such finding is the possibility of artefacts in PAN due to the underlying radiographic technique,¹ as well as its nature being two-dimensional radiography.

In summary, according to the findings of this study, the MD posterior area may be less critical for implant planning compared with the MX anterior and MX posterior areas. Although the inferior alveolar nerve can be identified more precisely using CBCT, this is mainly needed in special settings such as dental implantation close to the respective nerve only.^{12,18}

Moreover, the three areas of interest were rated differently by the participants. MS were significantly more in favour of "no adequate visibility" for PAN in the MX and MD posterior areas than other groups. Similarly, they needed the additional CBCT in these regions to be "required" more often. This can be explained as MS, owing to their speciality, have more exposure and training in 3D radiology. Also, it may be hypothesized that these differences are results of lacking knowledge in 3D radiography among GP and OS. As a result, they

tend to rely on PAN only for their diagnosis. Nonetheless, a high number of dentists have access to CBCT and use it routinely.^{16,17}

Using CBCT for pre-operative planning in dental implant surgery provides a clear and informative 3D vision of any individual anatomy. In addition, it helps to overcome pitfalls such as overestimating the need for sinus augmentation in severely resorbed maxillae in PAN,¹³ unexpected greater nasopalatal canal diameter¹⁹ and unusual location of mental foramen or accessory mental foramen.²⁰ CBCT is also necessary in fully guided and digitally integrated implant dentistry.²¹ Therefore, the widely available CBCT offers more precisely examined and diagnosed orofacial structures. However, this depends mainly on the level of clinical radiological knowledge of the orthognathic system, radiographic analytic skills^{16,22} and the anatomic correlation with its surrounding structures.²³

It is of importance to highlight the limitations of this study, where the selection of the patients was based on retrospective nature. There was no power calculation; the cases were heterogeneous, where there might have

Table 3 Tabular summary of the results of the question for CBCT

Areas of interest (number of cases)	Question: "The clinical area of interest, based on the CBCT..."	General dentist (n = 3)	OS (n = 3)	MS (n = 3)	p-value
All areas (n = 42)	1 = shows additional information	31 (24.6%)	50 (39.7%)	11 (8.7%)	<0.001
	2 = is very useful	47 (37.3%)	52 (41.3%)	58 (46.0%)	
	3 = is affecting therapy	38 (30.2%)	24 (19.0%)	52 (41.3%)	
	4 = is absolutely required	10 (7.9%)	0 (0%)	5 (4.0%)	
MX anterior region (n = 10)	1 = shows additional information	1 (3.3%)	3 (10.0%)	2 (6.7%)	<0.001
	2 = is very useful	9 (30.0%)	20 (66.7%)	18 (60.0%)	
	3 = is affecting therapy	12 (40.0%)	7 (23.3%)	7 (23.3%)	
	4 = is absolutely required	8 (26.7%)	0 (0%)	3 (10.0%)	
MX posterior region (n = 16)	1 = shows additional information	6 (12.5%)	16 (33.3%)	9 (18.8%)	0.015
	2 = is very useful	18 (37.5%)	18 (37.5%)	17 (35.4%)	
	3 = is affecting therapy	22 (45.8%)	14 (29.2%)	22 (45.8%)	
	4 = is absolutely required	2 (4.2%)	0 (0%)	0 (0%)	
MD posterior region (n = 16)	1 = shows additional information	24 (50.0%)	31 (64.6%)	0 (0%)	<0.001
	2 = is very useful	20 (41.7%)	14 (29.2%)	23 (47.9%)	
	3 = is affecting therapy	4 (8.3%)	3 (6.2%)	23 (47.9%)	
	4 = is absolutely required	0 (0%)	0 (0%)	2 (4.2%)	

MD, mandibular; MS, maxillofacial surgeons; MX, maxillary; OS, oral surgeons.

been a shift within the selected patients towards more challenging implant cases vs simpler cases with clearer clinical recommendation. Nonetheless, only implant planning cases of 1–2 implants were taken into consideration, as the need for CBCT could be more in cases with larger edentulous spans. In addition, there was no follow-up post-implant placement for the justification of different practitioners' clinical judgment with treatment execution.

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Conclusion

For pre-surgical implant planning procedures, significant subjective benefits of CBCT in addition to PAN for the evaluation of anterior and posterior MX sites were seen. However, these benefits seem to be significantly influenced by the degree of professional training. Therefore, to maximize the benefit of CBCT for all users, an improved education is needed in 3D dental radiology.