Radiographic evaluation of implant sites: decision-making criteria on the necessity for cross-section imaging for treatment planning in implant dentistry

Report of 868 consecutively treated cases and literature review

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Aim. The aim of this study was to investigate in which clinical situations CT cross-section imaging or standard X-ray examinations should be utilized for dental implant planning and to provide guidelines for the correct use of ionizing radiation in implant dentistry.
Methods. The study included 868 partially and totally edentulous patients who had consecutively received 2604 implants. Patients who presented sufficient width (recorded clinically) and height (recorded on the panoramic radiographs) were classified as *safe patients* and underwent a standard implant insertion procedure. Patients who presented a narrow alveolar ridge at the clinical examination and/or insufficient height measured with the panoramic radiograph were classified as *unsafe patients* and underwent a CT to assess the necessity of bone augmentation procedures. Intraoperative observations, change of treatment plan and outcome data were evaluated.
Results. Cumulative survival rate of implants was, totally, 97.3%. In 91.3% of cases within the group of safe patients, implants were placed according to panoramic radiographs and clinical evaluation. In 8.7% of the cases, implant diameter or length were changed during surgery. In 37% of the cases within the group of unsafe patients, after CT examination, residual bone was judged sufficient to receive implants. In the left 67% cases, implants were placed after bone grafting procedure.
Conclusion. In standard cases, clinical examination and panoramic radiography can be considered appropriate tools to evaluate the bone status prior the implant insertion. Considering the high levels of radiations and adjunctive costs, CT is an additional tool to be reserved for the planning of complex cases.

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Implant therapy has become, nowadays, commonly used in dental practice as it represents a reliable and predictable procedure to restore a correct balance between jaws avoiding the discomfort caused by removable prosthesis. In addition to clinical examination, radiological exams provide images on the existing bone structure being an important part of the pre-implantological evaluation. In any case, a strong clinical indication and a low dosage of radiation should be the main guidelines in selecting the pre-implantological imaging.[1] The aspect of exposure to radiation must be decided according to the internationally recognized principle of ALARA (As Low As Reasonably Achievable). All radiation exposure for medical purposes must be justified in advance under consideration of the specific objectives of the exposure and the special characteristics of the person affected.[2] Panoramic and endo-oral radiographs can be considered as the basic images in this context.[3-5] However, the necessity of cross-sectional images is being discussed increasingly at scientific meetings and their demand is augmenting as more clinicians use of integrated instruments when planning dental implants

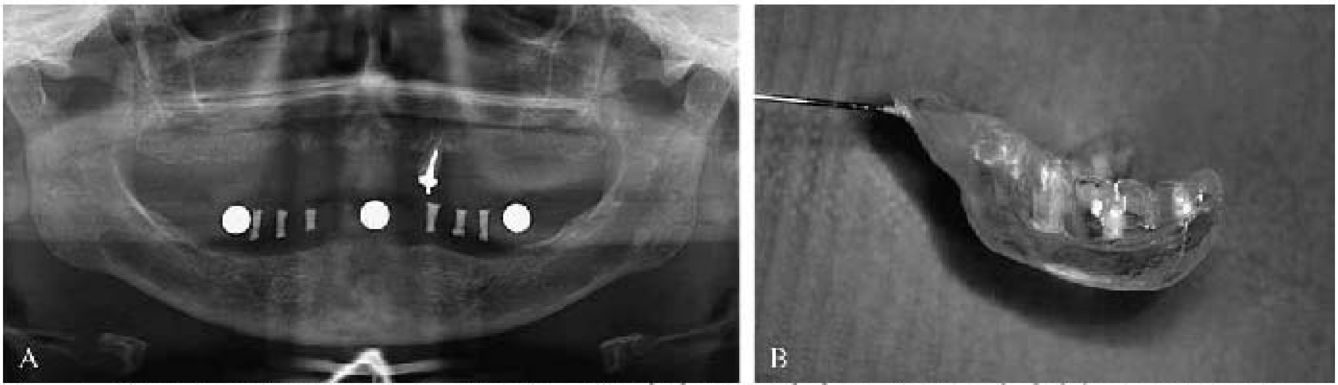

Figure 1.—Digital panoramic radiograph was taken using a resin-made radiographic stents with one or more stainless-steel balls and gutta-percha points.

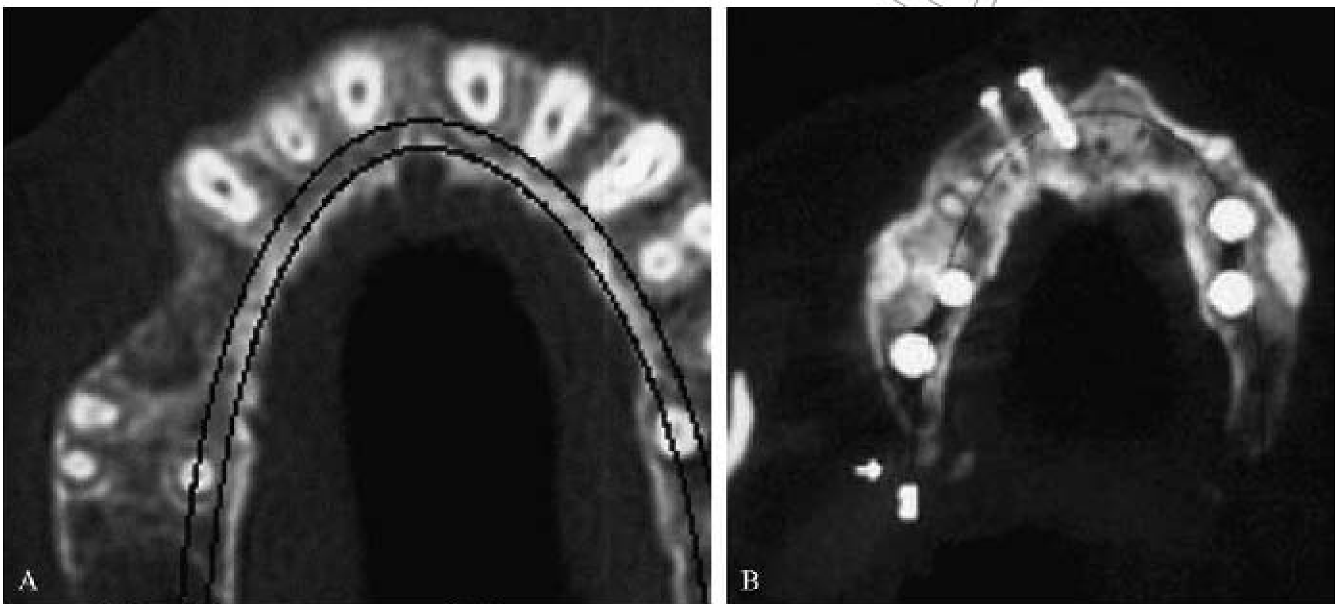

Figure 2.—CT-images were needed to assess the possibility of placing implants with standard procedures or alternatively.

placement.[4, 6-8] In dental implantology, we are currently seeing increasing opportunities to improve diagnostic precision by use of computed tomography (CT) even if its great benefits must be weighed against the increased radiation damage risk. Unfortunately, this risk is not as widely recognized as it should be and both clinicians and patients tend to lack a clear understanding of the radiation doses involved in CT studies, which are higher than those used in other common x-ray studies.

The objective of this study was to investigate the indications to the use of CT cross-section imaging or standard X-ray examinations for dental implant planning and provide guidelines for the correct use of ionizing radiation in implant dentistry.

Material and methods

This study was conducted over a period of four years (from May 2005 to May 2008) and a treatment of

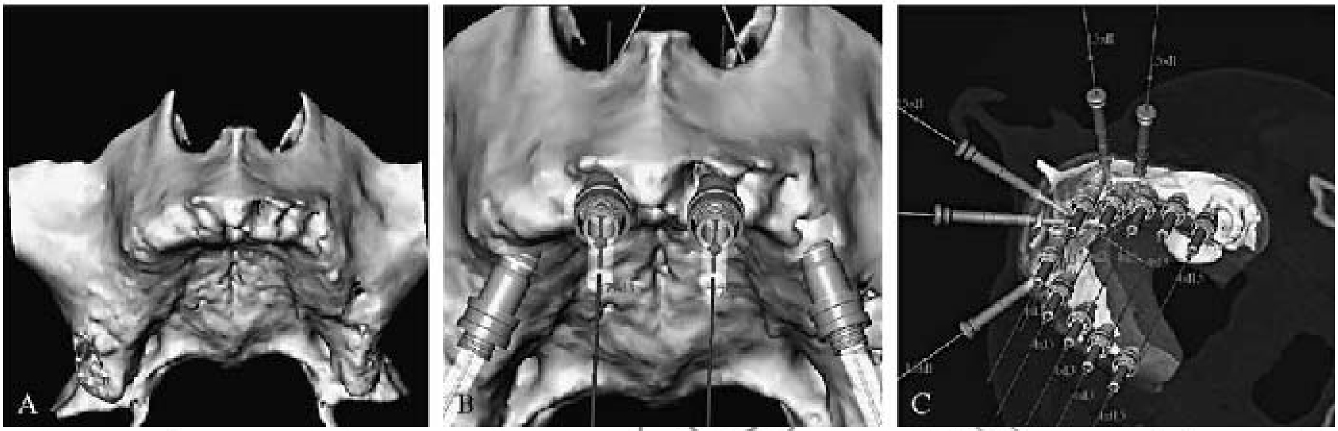

Figure 3.—Digital CT-images, saved in a DICOM 3 format, Procera® Software planning program (Nobel Biocare AB, Gothenburg, Sweden).

Figure 4.—Panoramic radiograph for post-operative control taken immediately after surgery and at 3,6,12 months after surgery.

868 patients (526 women and 342 men), whose average age was 53 years old. The surgeon performed the initial clinical examination of the potential implant sites in the patients. The width of the alveolar ridges was assessed by manual examination and a digital panoramic radiograph was taken using a resin-made radiographic stents with one or more stainless-steel balls and gutta-percha points (Figure 1). Measurements were performed on the panoramic radiograph. Measures were taken from the top of the alveolar crest to the mandibular canal, in the mandible, and to maxillary sinus or nose in the maxilla. A graduated implant scale from the implant manufacturer was used to determine the length of the implant to insert. 8mm-bone height for the maxillary sites and 12 mm-bone height for the posterior mandible were considered sufficient. Patients who presented sufficient width (recorded clinically) and height (recorded on the panoramic radiographs) were classified as *safe patients* (group 1) and underwent a standard implant insertion with no need to additional radiographic examination. Patients who presented a narrow alveolar ridge at the clinical examination and/or insufficient height, measured on the panoramic radiograph, were classified as *unsafe patients* (group 2). In these second cases, CT-images were obtained to assess the possibility of placing implants with standard procedures or, alternatively, if bone augmentation procedures were essential prior to implant placement (Figure 2).

Panoramic and the majority of tomographic exams were undertaken using the Cranex Tome unit (Soredex, Helsinki, Finland), with a magnifying factor of 1.5. The exposure values were 60-73 kV, 8-10 mA and 15-19 s for panoramic images, and 60-73 kV, 1-6.4

mA and 46 s for cross-sectional images. A 15 X 30 cm film cassette was used with a medium or a regular Lanex intensifying screen for the tomogram and panoramic exams, respectively, and a Kodak Tmat G film (Eastman Kodak Company). All radiographic films were developed using the same automatic processor (AT-2000 XR; Air Techniques, MD, USA). A series of four cross-sectional images (spiral tomography) of 4mm layer thickness for each region of interest was taken using the Dental Tomo software by the Cranex Tome Soredex unit. Thirty-seven fully edentulous patients, who had already digital CT-images, saved in a DICOM3 format, were evaluated processing images with Procera® Software planning program (Nobel Biocare AB, Gothenburg, Sweden). This assessment was made in order to study the possibility of placing implants in residual bone, via flap-less surgery, avoiding bone graft procedures (Figure 3).

A total of 2604 implants were placed and intraoperative situation was recorded pointing out whether the planned therapy was changed during surgery according to unexpected anatomical findings or any other complication. For post-operative control, a panoramic radiograph was taken immediately after surgery (see the legend) (Figure 4).

Results

Totally, 1140 implants were inserted in 564 patient of group 1 and 1464 in 244 patient of group 2 (Table I).

Only 18 implants failed in group 1 and 52 implants in group 2 with a cumulative survival rate of 98.4% in group 1 and 96.4% in group 2 (mean cumulative survival rate=97.3%) (Table I). Intra-operative complications did not occur in any patients.

In all cases of the group 'safe patients' (group 1), intra-operative analysis confirmed the assumptions formulated in accordance with the clinical findings and panoramic radiographs: bone volume was considered sufficient for standard implant placement. The vertical magnification factor determined by the measurements of the steel ball on the panoramic radiographs was very constant at 1:1.42±0.01. In 74 mandibular (10.3%) and 25 maxillary sites (6%) (total 8.7%) of patient belonging to group 1, a slight deviation in width or height was discovered after flap elevation. Implant's diameter or length was, so, adapted to fit the new conditions (Table II).

TABLE I.—*Patient data.*

	Safe (group 1)	Unsafe (group 2)	Total
Number of patients	564	244	868
Radiographic examination	Panoramic radiograph	Spiral Computed Tomography	
No. of implant inserted	1140	1464	2604
Complications	+++++*	++++**	
No of implant failed	18	52	70
Cumulative survival rate	98.4%	96.4%	97.3%

TABLE II.—*Implant data in group 1; *transient paresthesia of the inferior alveolar nerve/564 patients).*

Safe (group 1)	Mandible (%)	Maxilla (%)	Total
No of implants	717	423	1464
No of implant inserted on the base of clinical and panoramic findings	643 (89.7%)	398 (94%)	1041 (91.3%)
No of implant changed in length or diameter during surgery on the base of intra-operative findings	74 (10.3%)	25 (6%)	99 (8.7%)
Failure	10	8	18
Complications- patient (%)	1 (0.17%)*	—	—

TABLE II.—*Implant data of group 2; *graft infection/resorption/244 patients; **acute and /chronic sinusitis/244 patients).*

Unsafe (group 2)	Mandible (%)	Maxilla (%)	Total
No of implants	428	1036	1464
No of implants inserted in a standard way	170 (39.7%)	372 (36%)	542 (37%)
No of implants inserted after bone augmentation procedure (sinus lift, onlay or veener grafts)	258 (60.3%)	664 (64%)	922(63%)
Failure	18	34	52
Complications-patient (%)	10 (4.09)*	6 (2.45%)	

Regarding group 2, in 170 mandibular (39.7%) and 372 maxillary (36%) sites (total 37%), it was suggested to investigate further. With the help of additional tomographic images, it was considered if implants could be placed in residual bone, with no need of additional bone augmentation procedure (Table III). In other 258 mandibular (60.3%) and 664 (64%) maxillary sites (total 67%), implants were placed after bone grafting in order to restore an adequate alveolar ridge volume (Table III).

In only one patient (0.17%) of group 1, transient post-operative altered tactile sensation of the mental nerve emerged after implant placement in the mandible, while no acute or chronic sinusitis was found subsequently implant insertion in the maxilla (Table II). Sensory disturbances were minor, persisted for 3 to 8 weeks and resolved spontaneously.

In group 2, in 10 patient (4.09%) grafts infected and 6 patient (2.45%) were affected by acute or chronic sinusitis (Table III).

Discussion

Pre-implantologic analysis based on clinical and two-dimensional panoramic radiographs is not sufficient to understand the real availability of bone width. For this reason, AAOMR (American Academy of Oral and Maxillofacial Radiology) demands that cross-sectional imaging should be used in the planning of implant placement for certain patients.[6] It's true that there are no reliable clinical methods to get 3-D images of the bone volume. For instance, measuring the thickness of the soft tissues (bone mapping) may not provide reliable results.[9] At the same time, although an experienced surgeon may be able to evaluate the width of residual alveolar crest and decide if standard implant placement is possible or not, muscles and soft tissues might influence the clinical aspect and, hence, the diagnosis.

Referring to the cases reported in this manuscript, whose alveolar ridge was judged having a sufficient width (group 1), this condition was confirmed during implant surgery. In the case of a slight deviation in bone width, it was decided to adapt the diameter of the implant. If the bone width, partly also the lingual undercut, can be estimated sufficiently well by an experienced surgeon, the determination of the implant length should be possible by the measurement of the vertical dimension of the residual ridge in a two-dimensional radiograph only. So, the panoramic radiograph of a correctly positioned patient is an appropriate tool for the measurement of the vertical dimension as the mandibular canal and the mylohyoid line can be detected sufficiently well.[3-5] In the reported case, the vertical magnification factor of the pre-operative panoramic radiograph (determined by measurement of steel ball) was 1:1.42±0.01, according to data shown in literature[3]. The very small standard deviation shows that separate values vary only slightly. Contradictory statements are made about this topic, in literature. It has often been demonstrated that the vertical dimension is quite constant in well-positioned patients and can be considered reliable for clinical activity.[10, 11] Nevertheless, other authors believe that panoramic radiograph is an insufficient tool to determine the vertical bone height because vertical distances are generally underestimated.[12, 13]

Our point of view is close to that of authors who consider that panoramic radiograph provides sufficient and reliable information on vertical bone height. It must be however carefully considered that this requires the exam to be technically correct, which is operator-dependant. Therefore, we are confident that combining a correct panoramic radiograph with experienced clinical evaluation, may be considered the standard method for treatment planning in implant dentistry.[3-5] In patients of group 1, in fact, only 99 out of 1140 sites (8.7%) revealed a change of bone conditions after intra-operative findings with a consequent adaptation of implant diameter or length.

Some authors suggest that cross-sectional tomography is not necessary in cases where bone width appears sufficient from a clinical analysis. In addition, it has to be considered that, differently from panoramic radiograph, spiral or conventional tomography risk to overestimate the vertical bone height.[3, 14, 15] In line with this, it was demonstrated that the magnification factor, in spiral CT scans, is very low and constant if the horizontal ramus of the mandible can be positioned perpendicular to the section plane. In daily clinical work, the exact positioning of the mandible cannot be always achieved. In case the horizontal ramus of the mandible is tilted forward, the cross-sectional image is distorted (enlarged) in its vertical dimension. This vertical distortion and the blurriness of all imaged structures increase with increased tilting of the horizontal ramus of the mandible.[16]

This factor, together with a significantly higher radiation dose, should be considered for the treatment planning of standard cases.

In accordance to the present report, Diniz *et al.*[1] state that in most of standard cases, patients do not get benefits from more extensive imaging techniques. In the majority of cases assessed, actually, the outcome of panoramic radiographs remained unchanged after the tomographic analysis.

On the other hand, in cases with severe bone defects, instead, an analysis employing cross-sectional images is highly recommended.[3, 4, 6-8] Conventional spiral tomography plays an important role in pre-surgical treatment planning, increasing the clinician's self-confidence on the need of additional surgical procedures (bone grafting, sinus lifting etc.).[17]

A further advantage of computed tomography consists in the fact that potential intraoral donor sites for autogenous bone grafts can be shown within the same radiographic imaging process.

The information provided by cross-sectional images can be valuable for detecting the lingual undercuts, which occurs in the posterior or anterior parts of the mandible. While perforations of the nasal fossae and maxillary sinuses don't cause any important complications, perforations of lingual cortical plate, resulting from the injury of larger arteries in the mouth floor, may cause life-threatening bleeding and/or airway obstruction.[18-21]

In these cases, cross-sectional imaging, accurate clinical intraoral pre and intra-operative evaluation, may decrease relevantly the probability of such important complications.[3]

When tomography is indicated, patients and the clinicians may decide whether the risks associated with increased dose of radiations are justified by the advantages of a more accurate diagnosis and a more predictable surgical performance.

It has been revealed that, in pre-implant evaluation, the use of spiral CT, when compared to conventional CT, reduces the absorbed dose in certain critical structures of the maxillofacial region.[22, 23]

In one in vitro experiment that simulated the combined high-resolution CT examination of the mandible and maxilla, absorbed dose measured at parotid glands reached up to 19 mGy?).[24] On the other hand, the absorbed doses for the parotid glands in conventional panoramic radiography are generally less than 1 mGy, so the difference is 20-fold or greater.[25] Hassfeld *et al.* reported that even if when the dose of CT-scans is reduced by 76%, the absorbed doses exceed those of conventional panoramic radiography by an average factor of 10.[24]

Diederichs *et al.*[25] (case report) reported that spiral CT of the mandible and maxilla may therefore be feasible with a radiation dose of magnitude (80 Kv, 40 mA) similar to that used for conventional panoramic radiography (75 Kv, 8 mA).

Dula *et al.*[26] estimated the hypothetical mortality risk associated with spiral tomography of the maxilla and mandible prior to endosseous implant treatment. The estimation was made using a calculation model recommended by the Committee on the Biological Effects of Ionizing Radiations. Calculations according to the International Commission on Radiological Protection out for comparison did not reveal the decrease of the mortality risk with age and resulted in a higher risk value in comparison to the group of 35-year old individuals (the mortality risk ranged from 31.4×10(-6) for 20-year-old men to 4.8×10(-6) for 65-year-old women when cross-sectional imaging of the complete maxilla was performed.

In dentistry, cone-beam computed tomography (CBCT) technique presents a very promising innovation of tomographic imaging systems and volumetric image reconstruction.

The quality of images offered by this new technique seems to support adequately interventions on head and neck. In fact, it secures low levels of radiation doses enabling multiple intraoperative imaging. Specifically, dose levels are comparable to or less than those emitted by a typical diagnostic CT of the head (2 mSv).[27-29]

Previous work has shown that CT images are affected by a distortion ration from 0% to 6%. This might be due to the alignment of the patient during scanning, to his/her movements, or possibly to the saturation of pixels composing the image. In order to solve the former problem, the use of intraoral stents is recommended to center the patient's head perpendicular to the axis of the implant to be inserted. Nowadays a few software approaches for enhancing implants surgery planning are available in order to obtain exact morphological measurements of the bone and planned teeth.[30-34]

How showed also in few cases in this work, planning programs make it possible to preview suggested implant placement, showing the exact position and depth of the implants before surgery and the fabrication of customized drilling template which allows for implant placement via flap-less surgery and for assessment of a definitive or temporary prosthesis which can be applied immediately after surgery.[34-37]

The concept, with minimally invasive and simplified surgery, reduces the treatment time and post-surgical discomfort.[34-37] Computer guided implant surgery represents a giant step forward in the replacement of teeth with dental implants. With Computerized Tomography (CT) Scan techniques and 3-D imaging, we can now visualize the placement of dental implants in three dimensions. This eliminates the guesswork involved determining what parts of the jawbone offer the best sites for dental implant placement. Computer guided implant surgery provides greater patient satisfaction and simplifies the dental implant treatment process.[34-37]

Conclusions

Panoramic radiograph provides sufficient information on vertical bone height and, combined with a correct clinical evaluation, it can be considered an appropriate tool for the planning of standard treatments in implant dentistry (safe patient). CT should be reserved for the planning of complex cases. Specifically, it is suitable for implant treatment in the direct vicinity of the maxillary sinus and nerves, for multiple implant insertion (unsafe patient) and in cases with probable necessity of bone augmentation before implant placement. It is essential to weigh the absolute risk associated with radiation caused by CT scans against all potential or proven benefits for the patient. A low-dose CT such as Cone- beam CT should be taken into consideration in order to the reduce radiation dose to radiosensitive structures. In addition, the use of planning softwares can improve the planning of implants surgery securing, contemporarily, the patient more accurate, safe and minimally invasive treatments.

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