TECHNICAL REPORT

Optimization of cone beam CT exposure for pre-surgical evaluation of the implant site

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Objectives: The aim of this study was to investigate the possibility of reducing patient X-ray dose in the course of implant site evaluation.

Methods: Retrospective practice-based study using a Morita F170 Accuitomo cone beam CT (CBCT) scanner with variable exposure parameters and operating a small cylindrical field of view of 4 cm diameter and 4 cm height. 6 experienced dental surgeons scored the image quality of dental scans on a 5-point scale for adequacy in providing the required information in 2 categories: bone height from alveolar crest to the relevant anatomical structure and bone width.

Results: Lower-dose protocols only marginally affected the preference of the reviewers of the resulting images.

Conclusions: There is potential to reduce patient dose very significantly in CBCT examinations for implant site evaluation.

Dentomaxillofacial Radiology (2012) **41**, 70–74. doi: 10.1259/dmfr/16421849

Keywords: cone beam computed tomography; radiography; radiation dose; dental implant

Introduction

Three dimensional (3D) assessment of the implant site is an essential part of the pre-surgical work-up for any implant patient and is increasingly being provided by cone beam CT (CBCT) imaging. The dose delivered in the course of a CBCT examination is affected by several parameters including exposure time, tube current, the amount of rotation of the gantry around the patient's head and the size of the field of view (FOV).¹ This retrospective practice-based pilot study investigates the possibility of reducing patient X-ray dose in the course of implant site evaluation using one particular apparatus with variable exposure parameters and operating a small cylindrical FOV of 4 × 4 cm and seeks to indicate, within a clinical setting, the relevance and necessity for future study in this important area of dose reduction in this novel imaging medium.

Materials and methods

A Morita F170 Accuitomo (J Morita Corporation, Osaka, Japan) was used to acquire small FOV data

(4 × 4 cm cylinder) for a consecutive series of 68 patients requiring single-unit or short-span implant-supported crown or bridgework in order to identify local bone volume, morphology and anatomical relationships. Imaging was undertaken when justified as part of their clinical and radiological examination for treatment planning. Surgery was to be provided by the same individual responsible for the CBCT prescription.

Exposure protocols were selected on clinical grounds with reference to existing radiographs, site maturity, patient age and size. Exposure parameters considered were:

1. Degree of gantry rotation: 360° (full rotation of the patient's head by the X-ray tube) vs 180° (half rotation of the patient's head by the X-ray tube);
2. Scan speed settings: high speed (5.3 s (180°) or 10.4 s (360°)) vs standard speed (8.9 s (180°) or 17.5 s (360°));
3. mA settings: these ranged from low mA (2 mA female adult; 3 mA male adult) to high mA (5 mA female; 6 mA male).

The manufacturer's recommended exposure factors of 360° rotation, 5 mA (female adult) or 6 mA (male adult), 17.5 s were originally taken as baseline from

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Received 2 December 2010; revised 15 April 2011; accepted 19 April 2011

Table 1 The various protocols used and the number of examinations conducted using each protocol

<i>Protocol</i>	<i>Rotation (°)</i>	<i>Current (mA)</i>	<i>Duration (s)</i>	<i>Manufacturer's estimated standard dose %</i>	<i>Number of cases</i>
360°, standard mA, standard speed	360	5–6	17.5	100	14
180°, standard mA, standard speed	180	5–6	8.9	50	6
180°, standard mA, high speed	180	5–6	5.3	50	9
360°, low mA, standard speed	360	2–3	17.5	50	7
360°, standard mA, high speed	360	5–6	10.4	50	11
360°, low mA, high speed	360	2–3	10.4	25	4
180°, low mA, standard speed	180	2–3	8.9	25	6
180°, low mA, high speed	180	2–3	5.3	12.5	11

which exposure factors were adjusted downwards. The three variables allowed eight groups for dose reduction by various combinations of the exposure parameters (Table 1). The records of 68 consecutively scanned patients were reviewed and identified as falling into one of these 8 groups. Table 1 describes the various protocols used and the number of examinations conducted using each protocol.

As an example of application of optimisation by clinical criteria in this pilot study, smaller, younger patients, particularly those for whom conventional two dimensional (2D) radiographs were already available and appeared to show distinct anatomical structures, were selected for lower dose protocols.

The screenshot of the axial, parasagittal and 3D reconstruction images through the area of interest and a cross-section through the middle of the implant position were chosen from a total of 68 small FOV data (Figure 1) and made anonymous. The relevant images from each data set were selected and were

displayed under reduced lighting conditions on a monitor. Six observers who were blind to the imaging protocols reviewed the cases to (1) assess the adequacy of depiction of bone volume and shape in the intended implant sites (bone width) and (2) to identify the height of available bone for implant insertion with reference to the proximity of relevant anatomical structures. In addition to the dental surgeon, five experienced individuals (also dental surgeons) reviewed the data. The observers rated the image quality for adequacy in providing the required information in two categories: bone height from the alveolar crest to the relevant anatomical structure and bone width. The relevant anatomical structures included the floor of the nose and floor of the antrum in the maxilla and inferior dental canal, mental foramen and inferior cortex in the mandible. They scored the features in each case using a 5-point scale to describe adequacy for pre-implant surgical assessment, ranging from 1 (not at all confident) to 5 (very confident) for both bone height and bone width,

Figure 1 Example screen shots from a 4 cm field of view data through a potential implant site where bone height from alveolar crest and bone width are being assessed. (a) Reduced exposure settings in all three parameters: high Speed, low mA (3 mA) and 180° gantry rotation—the resulting exposure is approximately 1/8th of the standard exposure; (b) manufacturer's recommended exposure factors: standard speed, standard mA (6mA) and 360° gantry rotation

Table 2 Reviewers' results for each protocol (percentage)

as used by Sur *et al.*² Observers received instruction from the primary investigator (AD) on how to complete the questionnaire and the scoring of a trial case was demonstrated before commencement of the study.

Results

Table 2 illustrates the reviewers scoring of the data. The confidence scores from all observers were averaged for each exposure protocol. Lower dose protocols only marginally affected the preferences of the reviewers of the resulting images. However, there was no significant difference in the confidence scores given by the observers in judging bone height (ANOVA test, eight groups, $p = 0.097$) and in judging bone width (ANOVA test, eight groups, $p = 0.084$). In nearly all cases, results of the scoring exercise showed that the observers believed that adequate information was available to fully address the surgeon's need to evaluate the site. The lowest confidence score was found for images taken on a full 360° rotation at standard speed but with reduced milliamps.

All patients were uneventfully treated by the surgeon who prescribed the CBCT examination; no examination needed to be repeated in order to plan surgery.

Discussion

There are several studies in the literature that investigate the accuracy^{3,4} and dose^{2,5} associated with CT or CBCT examinations, or compare one technology or apparatus with another with respect to dose⁶ or image quality,⁷ without reference to the clinical utility of the resulting data. This appears to be the first study to examine the potential to reduce dose in the CBCT examination of the implant patient in a clinical setting.

There is a directly proportional relationship between dose and tube current, exposure duration and degree of rotation of the gantry. Reducing any of these parameters alone or in combination has the potential to reduce patient exposure. Significant dose reductions may be achieved by careful reflection upon the surgical concerns, individual characteristics and imaging requirements and parameters of each case. This principle of

dose optimisation is advocated in guidelines on use of CBCT by the European Academy of Dentomaxillofacial Radiology, SEDENTEXCT and has recently been published by the Health Protection Agency.^{8–10}

The results show a similarity in the level of confidence felt in the diagnostic yield of the images regardless of the exposure factors used. It is interesting that the highest level of confidence was not necessarily found with the images of highest exposure (the manufacturers default exposures). This illustrates a useful outcome of this small study—it appears unnecessary to expose the patient to the highest exposure levels in order to gain a working diagnosis in which the operator has confidence. It is noted that not all the patients scanned with the standard parameters were classified as “5” by all examiners. This is likely to be due to the fact that the examiners were not presented with the whole CT dataset but only with a static three-planar view of each case. In practice, the clinician would analyse the whole dataset, scrolling back and forth through the slices in various reconstructed planes to give a clinical judgment and reach a treatment plan. This study also shows that in clinical practice, despite the 2D and 3D information available, not all cases are straightforward and the imaging cannot always bring the confidence in bone assessment that the surgeon is seeking. Furthermore, patients were only selected for lower dose protocols if important landmarks were visible and bone quantity was perceived to be reasonable on 2D radiographs. This in itself illustrates the potential importance of using 2D information available from conventional radiographs to optimize the exposure for subsequent CBCT examinations.

Surgeons using 3D planning techniques for dental implants are accustomed to viewing CT data with planning software, which generally presents image data as 2D reconstructed images, alongside 3D rendered models of the jaw. In particular cases, use of this software may lead to the design and production of stereolithographic drill guides for computer-guided implant surgery,¹¹ integrating CBCT data with the prosthesis manufacturing process.¹² It is possible that the “standard” exposure parameters defined by manufacturers of CBCT apparatus are optimized for exporting data to such software. Creating a 3D virtual model from CT or CBCT data requires the software to assemble a virtual structure by a process of segmentation, whereby a user determined “threshold” or grey value is attributed to selected structures. In order to construct a meaningful virtual model, low-noise data is a prerequisite. When such data is available, a

dimensionally accurate model may be created from CBCT data.¹³

This requirement for low-noise data is at odds with the desire to minimize dose—resulting in noisier data. Whilst the human eye appears to be able to intelligently distinguish the cortical boundary of the jaw in a 2D reconstructed image, this process cannot be so easily achieved in 3D modelling software. Therefore there is a conflict when using CBCT data for the creation of 3D models, as for surgical drill guides. These 3D reconstructions require more detailed images and larger datasets, which require higher exposures of radiation.

All those involved in the imaging process, but in particular the surgeon who must apply what is visualized in the virtual environment to the real world, must keep in mind the actual needs of each individual when prescribing and conducting the radiographic examination. It may be that in many situations there is no particular benefit to creating a 3D rendered model as accurate measurements made from a series of reformatted cross sectional images through the individual implant site may be considered to be a perfectly adequate alternative.¹⁴

If a decision is made not to use 3D modelling, there is huge potential to reduce dose; in the particular case of radiographic examination using the Accuitomo F170 apparatus, which has a multitude of user defined settings, dose may be reduced by as much as an order of magnitude in some cases.

Conclusion

This retrospective practice-based pilot study showed that by judging individual cases on their particular merits, there is potential to reduce patient dose very significantly in CBCT examinations for implant site evaluation. Whilst the diagnostic value of the examination may be maintained when planning for conventional surgery, the use of a low-dose protocol may reduce the quality of a 3D virtual model rendered from such data as might be needed for planning computer-guided surgery.

Acknowledgments

The authors would like to thank Emily Kent-Smith for preparing the images and also the dental surgeons who reviewed the images: Fiona MacKillop, Shanon Patel, Andrew Cantwell, Zaki Kanaan and Michael Zybutz.

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