Journal of Cranio-Maxillo-Facial Surgery 40 (2012) 731–734

Contents lists available at SciVerse ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Image quality of two different mobile cone beam computed tomographs for maxillofacial surgery

Robin Seeberger [a,*], Markus Buchgeister [c], Andreas C. Seethaler [a], Thomas Shiozawa [b], Juergen Hoffmann [a]

[a] Department of Oral and Maxillofacial Surgery (Head: Juergen Hoffmann MD, DDS, PhD), University Hospital Heidelberg, Germany
[b] Institute of Clinical Anatomy (Head: Bernhard Hirt MD, PhD), University Tübingen, Germany
[c] Institute of Medical Physics, Beuth-Hochschule Berlin, Germany

ARTICLE INFO

Article history:
Paper received 5 September 2011
Accepted 27 January 2012

Keywords:
Mobile CBCT
Intra-operative imaging
Maxillofacial
C-arm

ABSTRACT

Purpose: We evaluated two mobile cone beam computed tomographs (mCBCT) comparing image quality with respect to radiation dosage. Image quality was analyzed by using different scanning modes.
Materials and methods: The skulls of three human cadavers were scanned by use of conventional Computed Tomography (CT) as well as with two mobile cone beam computed tomographs (Siemens Arcadis Orbic 3D and Ziehm Vision Vario 3D). Six different acquisition modes with different radiation dosages were used. The axial views of all scans were evaluated by five medical doctors regarding image quality by identifying predefined anatomical structures of the skull. A five-point ranking scale was used. The inter-rater reliability was statistically depicted by Cohen's Kappa coefficient. A Wilcoxon signed rank test was used to evaluate the rater's results. For evaluating the signal-to-noise ratio (SNR) a Catphan 600 reference body with two different inlays was used.
Results: Comparing the mCBCTs, the image quality of the Siemens Arcadis Orbic 3D in high-dosage mode received the best score (median: 2.27). The inter-rater reliability was fair (Kappa $= -0.030$ to 0.328). The Wilcoxon test showed significant ($p < 0.05$) different median rating values in 18 out of 21 imaging modes. The SNR was higher (better) in the high-dosage modes.
Conclusion: Intra-operative 3D imaging by using mCBCT for maxillofacial surgery in low-dose mode acquisition is adequate in terms of signal-to-noise ratio and image quality. The image quality does not correlate in a linear manner with a higher radiation dosage. Surgeons using this technique should gather their own experience with the different acquisition modes.

1. Introduction

Modern C-arm mobile cone beam computed tomographs (mCBCT) allow for intra-operative multiplanar reconstructions of the acquired image data. Especially in the case of bony reconstructions or fracture reduction, intra-operative imaging is an important issue since the implementation of cone beam computer tomographs in the field of maxillofacial surgery (Klatt et al., 2011). The devices are mobile and can be used without the need for complex technical and personal infrastructure, the investment being much lower compared to conventional computer tomographs (CT) (Heiland et al., 2003, 2004 and 2005). The use of mCBCT in intra-operative navigation has already been described recently (Terzic and Scolozzi, 2011). Nevertheless, one of the main drawbacks of mCBCTs is, in relation to the small field of view the dosage of radiation necessary to obtain images of reliable quality.

According to the radiologic ALARA principle (As Low As Reasonably Achievable) regarding the exposure of patients to X-rays, methods to reduce the effective radiation dosage without compromising the image quality have to be determined when working with mCBCTs.

The purpose of this study was to evaluate the limits of dosage reduction in mCBCTs without compromising the recognisability of important anatomic structures of the skull.

2. Materials and methods

This human cadaver study was approved by the ethics committee of the University of Tübingen (Germany) by ethics application number 417/2007B01. Three human cadaver skulls were selected regarding bone quality and metallic dental restorations to prevent imaging artefacts. Computer tomography (CT)

* Corresponding author. Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, INF 400, 69120 Heidelberg, Germany. Tel.: +49 6221 56 39716; fax: +49 6221 56 4222.
E-mail address: robin.seeberger@med.uni-heidelberg.de (R. Seeberger).

1010-5182/$ – see front matter © 2012 European Association for Cranio-Maxillo-Facial Surgery.
doi:10.1016/j.jcms.2012.01.008

scans of the skulls were performed using a 16 row multidetector CT with 120 kV and 50 mA in axial slice orientation with a 16 × 0.75 mm collimation. The slice thickness was 1 mm and the increment 0.5 mm (Siemens Somatom Sensation). The CT imaging was used as reference for the further evaluation. The same skulls were then scanned again using two different mCBCTs (Siemens Arcadis Orbic 3D and Ziehm Vision Vario 3D). Each of the cadaver skulls was scanned using specified imaging modes with different radiation-doses provided by the devices (Siemens Arcadis Orbic 3D: high- and low-dose mode; Ziehm Vision Vario 3D: with and without Large-Patient-Key (LPK) in high- and low-dose mode).

The Large-Patient-Key (LPK) is a feature presented by Ziehm to increase X-ray intensity by modifying the voltage applied to the tube in order to improve image quality in adipose patients.

The Siemens Arcadis Orbic 3D reconstructs image sequences with a 256 × 256 matrix as a fixed setting, whereas Ziehm Vision Vario 3D allows the operator to choose between reconstructions on the base of a 256 × 256 matrix or a 512 × 512 matrix. The 512 × 512 matrix provides a higher resolution of the selected skull structures and was used in this study. All images from both mCBCTs were post-processed equally (layer thickness = 0.5 mm; layer distance = 0.5 mm for the mandible and 1.0 mm for the midface) and then exported on CD-ROMs. Noticeable differences between the Siemens and Ziehm image sequences with respect to their formats (different matrix; different frame) were found on evaluation of the exported files. The Siemens images were masked with a circular frame similar to the Ziehm images and all pixels were doubled to extrapolate them to a comparable 512 × 512 matrix by using Matlab 6.5.1 (MathWorks, Natick, Massachusetts, USA), without influence on image quality.

2.1. Evaluation of image quality

The image quality of the slice sets was evaluated by five medical doctors. Raters had to score the quality of selected anatomical structures on the blinded image sequences independently. They evaluated the following structures according to the defined five-point ranking scale as shown in Table 1: mandibular nerve canal, mental foramen, ethmoidal sinus, infraorbital foramen, nasal septum, maxillary sinus, optic canal, medial orbital margin. ImageJ 1.39 (National Institutes of Health, USA) was used as the radiological viewing platform. The order of the image sequences was randomized for each rater individually. Every rater started the evaluation process using the conventional CT images.

2.2. Evaluation of the signal-to-noise ratio (SNR)

The SNR was evaluated by use of a CT phantom ("Catphan 600") to describe the image quality physically [10, 13]. The phantom contains several discoid modules (Fig. 1), of which the module "CTP 404" was used. It contains different cylindrical inlays of homogenous attenuation. For this study the inlays "Teflon" (Hounsfield-Unit = +990, similar to cortical bone) and "Polymethylepenten" (Hounsfield-Unit = −200, similar to spongy bone) were selected as regions of interest (ROI) in ImageJ 1.39. The mean signal intensity and the standard deviation of this mean intensity was displayed by the viewer and the SNR was calculated by the following formula:

$$\mathrm{SNR} = \frac{\mathrm{Mean(I)}}{\mathrm{STD(I)}}$$

SNR = signal-to-noise ratio; I = signal intensity in the region of interest; STD (I) = standard deviation of I.

2.3. Statistics

Statistic analysis was performed by using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) and Microsoft Excel 2007 (Microsoft Germany

Table 1
Five-graded rating scale for demarcation of anatomical structures on radiological images.

Grades	Interpretation
1	Excellent demarcation
2	Good demarcation
3	Moderate demarcation
4	Clinically sufficient demarcation
5	Clinically insufficient demarcation

Table 2
Interpretation of Cohen's Kappa due to Landis and Koch.

Kappa-value	Interpretation
$\kappa < 0$	No agreement
$\kappa = 0–0.2$	Slight agreement
$\kappa = 0.21–0.40$	Fair agreement
$\kappa = 0.41–0.60$	Moderate agreement
$\kappa = 0.61–0.80$	Substantial agreement
$\kappa = 0.81–1.0$	(Almost) perfect agreement

Table 3
Quantification scale for differences in median values.

Difference in median of grouped values	Interpretation
0	Difference negligible
0.25	Difference low
0.5	Difference moderate
0.75	Difference markedly
1.0	Difference large

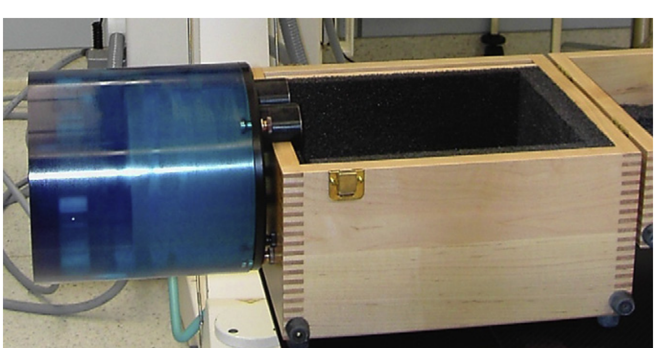

Fig. 1. CT phantom Catphan 600" mounted on its container.

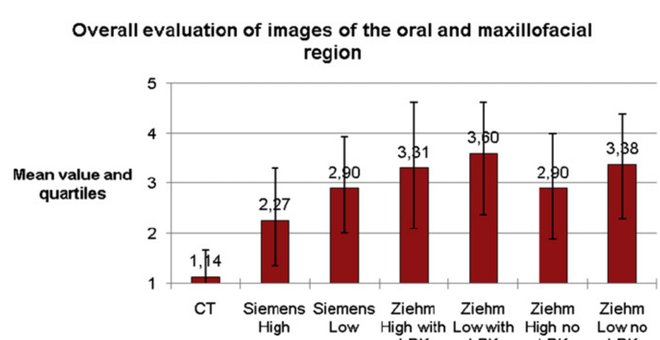

Fig. 2. Overall evaluation of different imaging modes of the oral and maxillofacial region.