Towards Image Quality Analysis of Small and Full Field of View Dental Cone Beam CT Systems

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Abstract— **Cone-beam CT (CBCT) systems have been used for dentomaxillofacial surgery applications. Different dental CBCT devices are being developed and released, with a wide variability of exposure parameters and fields of view. Although they have sufficient diagnostic quality, a quantitative analysis of image quality and radiation dose is required to enable their optimal use. The aim of this study was to develop and implement a feasible methodology for image quality analysis for different dental CBCT devices. The methodology was based on conventional CT quality control procedures and adapted to overcome the limitations of dental CBCT. A prototype phantom was specially designed to allow the acquisition of image quality parameters relevant to dental imaging. Equipments were divided into categories, related to their field of view: Small Field of View (SFOV) and Full Field of View (FFOV). The following image quality parameters were evaluated: uniformity, noise, contrast-to-noise ratio, CT number accuracy, artifacts, spatial resolution and geometric distortion. Applicability of the methodology was assessed using one SFOV and four FFOV CBCT devices. Results from preliminary analyses of the prototype phantom showed its potential for routine quality assurance on dental CBCT. Large differences in image quality performance were seen between the devices.**

Keywords— **Image Quality, Cone Beam CT, Dental Imaging, Phantom**

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I. INTRODUCTION

Over the past years, cone beam computed tomography (CBCT) imaging has been used in diagnostic radiology of the head and neck by dentists, orthopedists and otolaryngologists[1]. This dental imaging modality is generally thought to offer a lower radiation dose and a higher spatial resolution than conventional multislice CT (MSCT), allowing a large degree of versatility in the reformatting of the dataset in orthogonal, oblique, or curved planes or as volumes[2]. Some of the drawbacks of the dental CBCT devices are their inability of discriminating soft tissue because of its low contrast resolution, and the inaccuracy to give information about soft tissue quality[3].

CBCT devices currently on the market have a variety of exposure parameters and field of view (FOV) sizes, which affect the image quality and the exposure dose. Although the same basic CT image acquisition principle is used by all of devices, different hardware and software, mainly related to the reconstruction algorithm, are used.

Standard quality control procedures for conventional CT are not fully applicable for CBCT devices. Commercial QC phantoms used for conventional CT, are not applicable for dental CBCT due to the difference in performance for certain image quality aspects. Furthermore, there is a lack of quantitative methods for image quality analysis suitable for dental CBCT, and it is difficult to establish ranges for these parameters, considering the lack of a general threshold or range for acceptable parameter values.

A variety of phantoms and test objects have been used in the evaluation of CBCT[4,5]. However, it is difficult to relate technical image quality parameters to the clinical situation and to obtain threshold values for clinical use. There has been no wide-scale evaluation of the imaging performance of CBCT and the tools used for analysis are suboptimal, leading to results that are difficult to relate to the diagnostic performance.

The aim of this study is to develop and implement a feasible methodology for image quality analysis for different dental CBCT devices, allowing the measurement of parameters which are relevant to dental imaging requirements.

II. METHODS

A. Development of CBCT Phantom

To investigate the application of different image quality parameters for CBCT devices, a prototype phantom, called CBCT phantom, was specially designed to allow the acquisition of image quality parameters.

For this prototype, a head-size cylindrical polymethyl methacrylate (PMMA) phantom (160 mm diameter, 160 mm height) was designed with three sectors (Figure 1).

The phantom was designed based on previous work[5],

D.A. Jaffray (ed.), *World Congress on Medical Physics and Biomedical Engineering, June 7-12, 2015, Toronto, Canada*,
IFMBE Proceedings 51, DOI: 10.1007/978-3-319-19387-8_16

devices, without reference levels for both technical and visual image-quality parameters.

CBCT phantom is divided into 3 sectors (Fig. 1). The first sector is designed to evaluate the CT number, contrast resolution, artifacts and spatial resolution. It consists of a PMMA cylinder (160 mm diameter, 20 mm height), with 7 cylindrical holes (35 mm diameter, 20 mm height) positioned at the center and vertices of a regular hexagon, where interchangeable cylindrical inserts containing different materials and structures are placed. The second sector is a uniform PMMA cylinder (160 mm diameter, 20 mm height), designed to evaluate the uniformity and noise. The third sector is composed by 6 PMMA cylinders (160 mm diameter, 20 mm height) with an array of regularly arranged small holes (4 mm diameter, 20 mm depth), designed to evaluate geometric distortion.

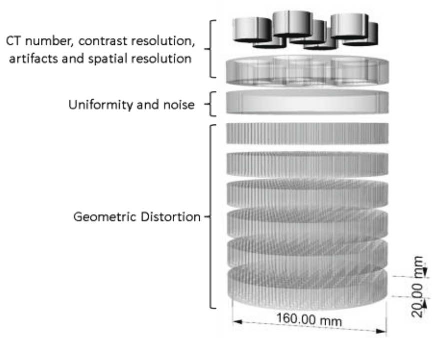

Fig. 1 CBCT phantom sectors and related image quality parameters.

Figure 2 shows CBCT phantom positioning at the FFOV-2 (9500 3D Kodak). A platform to assure the correct phantom alignment in CBCT devices was designed.

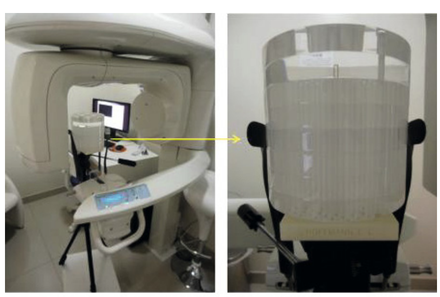

Fig. 2 CBCT phantom positioned at FFOV-2 (9500 3D Kodak).

B. Image Acquisition on MSCT and CBCT devices

Table 1 shows the exposure conditions used in this study. MSCT was used as reference for the image quality parameters, except for spatial resolution. Equipments were divided into categories for the analysis, related to their field of view: Small Field of View (SFOV) and Full Field of View (FFOV). SSFOV are those equipments in which the field of view is limited to a volume smaller than the jaws (mandible and maxilla). Typically this refers to small fields of view suitable for imaging one, or a few teeth.

Table 1 Exposure parameters and physical characteristics of MSCT and CBCT devices

Equipment	Model Manufacturer	kVp	mA	t(s)	FOV WxLxH (cm^3)	Pixel Size (mm)
MSCT	Discovery 600 CT Lightspeed GE	120	99	5	70x70x*	0.35
FFOV-1	i-CAT Im.Sci.Int.	120	5	8	17x17x23	0.2
FFOV-2	9500 3D Kodak	90	10	10.8	18.4x18.4x20.6	0.3
FFOV-3	Orthophos XG 3D Sirona	85	7	5	8x8x8	0.16
SFOV-1	9000C 3D Kodak	70	8	10,8	5.0x5.0x3.7	0,076

C. Image Quality Analysis for CBCT Devices

The methodology developed for image quality analysis for CBCT devices is based on conventional CT QC procedures. The main properties and constrains of CBCT modality was considered in the phantom design. The physical parameters for image analysis and the proposed methodology are described below:

a) Uniformity:

CBCT devices image larger objects with a reduced FOV, resulting in increased scatter, and producing a negative impact on CT imaging performance by introducing non-uniformities in the reconstructed image, like cupping effect and streaks[5].

The methodology proposed in this work to evaluate the uniformity avoids the reference ROI in the center of the FOV, and proposes the use of peripheral ROIs (anterior, lateral right and lateral left, related to the dental arcade) as references. This approach avoids the high influence of cupping in the uniformity measurement.

b) CT number Accuracy:

Our methodology proposes to build a fitting curve of CT numbers with different low and high density materials for each CBCT device, in order to correlate the measured values for conventional CT and those measured in CBCT.

c) Image Noise:

Most devices use kVp below 100, and a low mAs, resulting in higher image noise.

For image noise, the proposed methodology is similar to the QC procedure in conventional CT, calculating the