Experimental and Clinical Evaluation of a Newly Developed Cone Beam Device for Maxillofacial Imaging

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Introduction

Cone Beam (CB) technique for maxillofacial imaging was first introduced in 1997. Since then several devices based on this method have been presented. Today, CB scanners are widely used for a variety of indications in maxillofacial surgery. This study evaluates a newly developed cone beam (CB) device for three dimensional maxillofacial imaging.

Material and Methods

The CB system (GALILEOS®, Sirona, Bensheim, Germany) consists of an x-ray generator and a 2D detector in oppositional alignment rotating around patients head. The device has a compact size similar to a digital panoramic x-ray unit (Fig 1). The experimental evaluation using a prototype of the retail version included radiation dose measurements on an anthropometric Alderson-Rando head phantom, and geometric accuracy tests. In a clinical evaluation (approved by the ethics committee of the Medical Faculty of the University of Cologne), 100 conventional digital ortho-pantomogram images obtained with a digital panoramic x-ray device (Orthophos Multipuls, Sirona, Bensheim, Germany) were compared with CB-based panoramic reconstruction. Additionally, 30 CT scans of the maxillofacial area were compared with images obtained with the CB machine.

Fig. 1: Computer simulation of GALILEOS® in retail version.

Results

The effective radiation dose of a CB study was about four times as large as in a digital panoramic x-ray scan. The geometric accuracy measurements revealed no significant differences between CT and CB scans (Fig. 2 and 3). The clinical investigation showed a similar diagnostic value of the CB panoramic views compared to the conventional panoramic x-ray imaging using the possibilities of the integrated software (Table 1 and Fig. 4). The comparison with CT scans showed that the CB device can be considered as equivalent for detection of bony structures in the maxillofacial area (Table 2 and Fig. 5).

Group	*Parameter*	*Result*	*Significance*
General and specific image quality	Findings detection	DVT = OPT	0.346
	General image quality	DVT < OPT	< 0.001
	Artefacts	DVT < OPT	< 0.001
Anatomical structures	Maxillary sinus floor	DVT > OPT	< 0.001
	Nasal floor	DVT > OPT	< 0.001
	Incisal Foramen	DVT > OPT	< 0.001
	TMJ	DVT > OPT	< 0.001
	Mandibular canal	DVT = OPT	0.622
	Mental foramen	DVT > OPT	0.001
	Gingiva thickness	DVT = OPT	0.351

⇦ Table 1: Diagnostic quality comparison between CB based panoramic views and digital panoramic x-rays. 100 image pairs ranked by 5 observers on a 1 - 5 scale. Results obtained with Wilcoxon rank sum test. < For inferior, > for superior, = for equal ranking.

Group	*Parameter*	*Result*	*Significance*
General and specific image quality	Findings detection	CB = CT	0.705
	General image quality	CB < CT	0.018
Artefacts	Artefacts	CB > CT	0.003
	Influence on findings detection	CB = CT	0.527
Anatomical structures	Frontal sinus	CB < CT	0.038
Fronto-naso-ethmoidal region	Sphenoidal sinus	CB = CT	0.102
	Ethmoidal cells	CB = CT	0.180
	Nasal septum	CB = CT	1.000
	Nasal bone	CB = CT	0.317
	Superior nasal concha	CB = CT	0.246
	Medial nasal concha	CB = CT	0.414
	Inferior nasal concha	CB = CT	1.000
	Piriform aperture	CB > CT	0.046
	Anterior nasal spine	CB = CT	0.157
	Posterior nasal spine	CB = CT	0.157
Orbital region	Superior orbital rim	CB < CT	0.004
	Lateral orbital rim	CB < CT	0.000
	Medial orbital wall	CT = CB	0.083
	Orbital floor	CB = CT	0.098
	Optic canal	CB < CT	0.008
	Infraorbital fissure	CT = CB	0.083
	Supraorbital foramen	CB = CT	0.577
	Infraorbital foramen	CB = CT	0.564
Zygomatico-maxillary region	Maxillary sinus	CB = CT	0.157
	Zygomatic arch	CB < CT	0.000
	Zygomatic buttress	CB = CT	0.564
	Incisal foramen	CB = CT	0.317
Mandibulary region	Condyle	CB = CT	0.059
	Coronoid process	CB = CT	0.317
	Canalis mandibulae	CB = CT	0.558
	Mandibular canal	CB = CT	1.000
	Mental foramen	CB = CT	1.000
Temporo-mandibular joint	Glenoid fossa	CB = CT	0.414
	Tuberculum articulare	CB = CT	0.414
	Spatial relationship fossa/condyle	CB = CT	0.317

⇦ Table 2: Diagnostic quality comparison between CB and CT scans. 30 image pairs ranked by 3 observers. Frontal sinus, superior orbital rim, lateral orbital rim and zygomatic arch often out of volume in standardised positioning of patients head, thus inferior ranking.

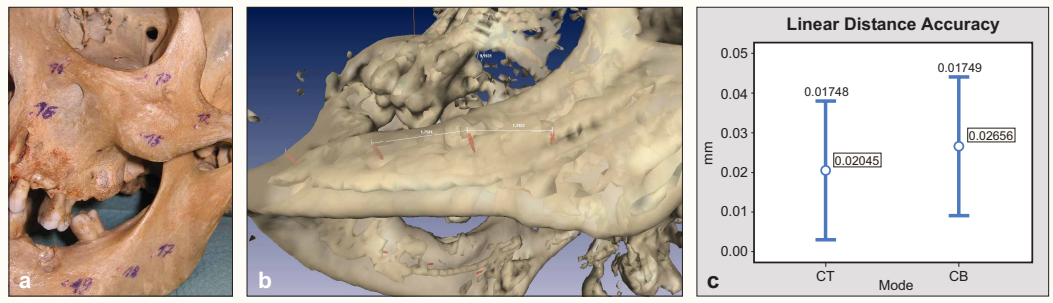

Fig. 2: Linear distance accuracy. a) Drill holes filled with radio-opaque gutta-percha as landmarks in human skull. b) Measurements on 25 distances up to 10 cm between the segmented landmarks using Amira 3.1.1 software (Mercury Computer Systems, Chelmsford, Massachusetts, USA). c) Trueness depicted as mean value, precision as standard deviation; p=0.021 in paired t-test with 100 measurements per mode.

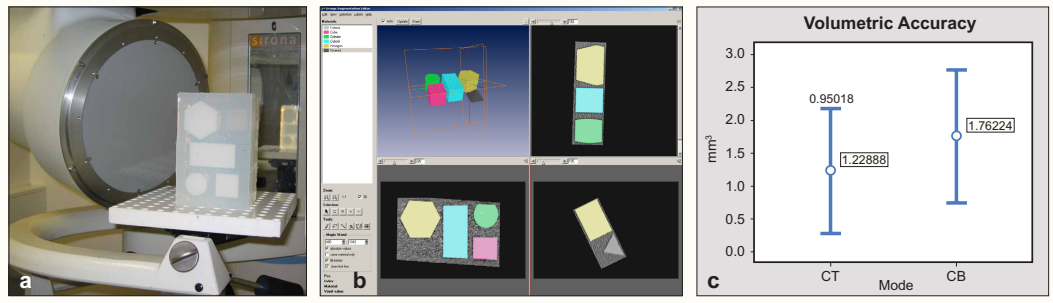

Fig. 3: Volumetric accuracy. a) 5 geometric reference objects embedded in silicone gel scanned in 5 randomly assigned positions. b) Automatic segmentation and volume computation in Amira software. c) Trueness depicted as mean value, precision as standard deviation; p=0.004 paired t-test with in 25 measurements per mode.

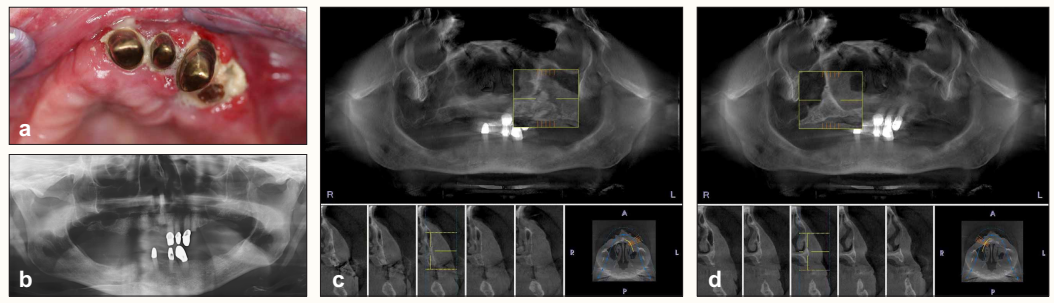

Fig. 4: Suspected lesion in left anterior maxilla in a 71-years old male with history of plasmocytoma. a) Intraoral view b) Panoramic x-ray shows no characteristic bony lesions besides a hyperplastic left maxillary sinus mucosa. c) CB-based panoramic view with so "called inspection window" shows an osteo-destructive and proliferative process at the medial maxillary sinus wall. d) Right side as comparison.

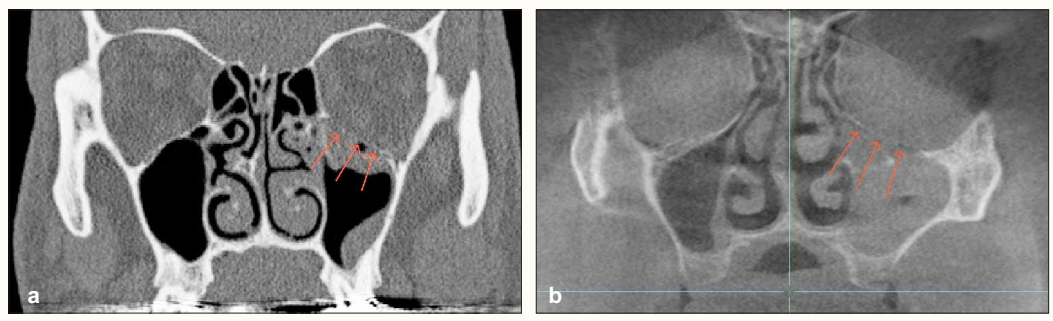

Fig. 5: Visualisation of a 0.25 mm thin PDS patch used for orbital floor reconstruction. Both patients sustained a left orbital floor fracture. a) CT scan. b) CB scan.

Conclusion

The results of this experimental and clinical investigation show that the newly developed CB device can be recommended for general use in maxillofacial radiology. It can be considered as superior to conventional panoramic x-rays and cephalograms regarding spatial accurate detection of anatomical structures. The diagnostic value for detection of bony lesions can be compared to that of a CT examination with the benefit of lower radiation exposure.

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