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# Cone-beam computed tomography of the orbit and optic canal volumes

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A B S T R A C T

*Purpose:* The aim of this study was to measure orbital and optic canal volumes by means of cone-beam computed tomography (CBCT) of human skulls as a prerequisite for estimating alterations of this bony region by this method.
*Materials and methods:* A total of 200 orbits of 100 adult individuals were investigated. These patients had no history of orbital trauma, dysplasia, or other diseases with a putative effect on orbital growth (female/male = 50/50; age: 20–70 years). Each 10 individuals with a male-to-female ratio of 1:1 constituted a 10-year age group. Area measurements and calculations of volumes were performed with OsiriX software.
*Results:* Orbital mean volume values did not differ significantly with respect to site. However, orbital volume slightly increased with age, whereas the optic canal volume declined over time. Mean orbital and optic canal volumes were larger in males than in females. Volumetric measurements of the orbit are in line with published data derived from computed tomograms and magnetic resonance images.
*Conclusion:* Orbital and optical canal volumes in adults show sexual dimorphism and alter depending on age. CBCT is suitable for determining orbital volumes and the provided data can be useful, for example, for defining orbital pathologies, to calculate orbital reconstructions, or for use in anthropological studies.

## 1. Introduction

Topographical knowledge about the orbital volume and the optic canal volume are prerequisites for several medical disciplines and are also relevant in basic sciences in human biology (Alinasab et al., 2011; Berlis et al., 1992a, 1992b; Furuta, 2001; Ji et al., 2010). Anatomical studies present detailed knowledge about the topography of the orbit, the relationships between landmarks in this region, and developmental changes of the cavity (Ji et al., 2010; Lang, 1981; Lang and Lanz, 1979; Masters et al., 2015; Oehmann, 1975). These data provide valuable background information for diagnosing variations within the range of normal development and in certain pathologies, and also provide data for surgical treatment planning and follow-up (Clauser et al., 2004; Gellrich et al., 2002; Zizelmann et al., 2007; Kwon et al., 2009; Bittermann et al., 2014; Kim et al., 2015; Rana et al., 2015; Wagner et al., 2015). Measurements of the orbit in living individuals are performed with several techniques, including computed tomography (CT) (Cooper, 1985; Forbes et al., 1985; Kahn and Shaw, 2008; Sicurezza et al., 2011; Shyu et al., 2015; Lee et al., 2015), cone-beam computed tomography (CBCT) (Zizelmann et al., 2007), magnetic resonance imaging (MRI) (Bentley et al., 2002; Schmutz et al., 2014), and ultrasonography (Friedrich et al., 2003).

CBCT is used in medical specialities concerning the skull due to the excellent visualisation of bone (Feldkamp et al., 1984; Naji et al., 2014; Zizelmann et al., 2007). CBCT of craniofacial bones is used for diagnosing a number of bone pathologies and for planning surgical procedures, for example, individualised implant fabrication (Kim et al., 2012). Spatial resolution of bone is generally higher in CBCT than in CT and the field of view can be individually adjusted, allowing further reduction of the radiation exposure to the patient (Ganz, 2008; Brisco et al., 2014). However, accuracy of imaging using CBCT in clinical application is estimated to be in the range of 0.5 mm at best (Horner et al., 2013).

Alterations of the optic canal may require surgical intervention. Anatomical imaging studies of the optic canal are preferentially performed with CT and rely on measuring distances and calculating

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areas (Berlis et al., 1992a, 1992b; Bite et al., 1985; Chou et al., 1995; Lang, 1981; Tao et al., 2000).

This study investigated whether CBCT-derived data could be used to calculate the orbital volume and optic canal volume. A comparison was made with established methods of orbital volume measurement. Furthermore, the study intended to clarify differences in the volume with respect to gender and age in adults (Osaki et al., 2013a, 2013b). To the best of our knowledge, optic canal morphometric data refer to distances and areas only (Lang, 1981; Tao et al., 2000). Age-adapted volumetric data of the optic canal appear not to be published until now. CBCT-derived volumetric data could assist in several indications, including the following: (i) improving the estimation of age- or gender-related alterations of the orbital volume as a paramount factor in aesthetic orbital surgery; (ii) generating optimised standard prototypes for alloplastic orbital wall reconstruction with reference to age and gender; and (iii) early diagnosis of pathologies affecting the volume or structure of the optic canal.

## 2. Materials and methods

### 2.1. CBCT scans

All scans were performed with the 3D Accuitomo 170 CBCT scanner model MCT-1-EX-1, (Morita, Kyoto, Japan). In all cases, a field of view of 120 × 170 mm was selected (voxel size 0.25 mm). Slice thickness was 1 mm in all images. All volumes are defined in cubic centimetres ($cm^3$).

### 2.2. Patients

CBCTs of the midfacial region of 100 patients were investigated (male: n = 50; female: n = 50, age: 20–69 years, mean: 44.96 years). The study group was further split into five subgroups according to age intervals of 10 years. Ten females and 10 males of each decade of age constituted a subgroup.

All CBCT investigations included both complete orbits and optic canals. Patients in this study had been subjected to routine radiological investigations for exclusion of craniofacial fracture in the Department of Oral and Cranio-Maxillofacial Surgery, Eppendorf University Hospital. Patients were excluded from the study who had a history of former midfacial fracture or known pathological condition concerning the orbit and optic canal. All X-ray documents were anonymous so that only age and gender were known to the investigator. Prior to the start of the study, the investigation was approved by the local institutional board to fulfil the scientific prerequisite for the preparation of a dissertation in dentistry (M.B.). All patients gave informed consent regarding the scientific evaluation of radiographic data prior to their treatment in the hospital. Images were assessed by two of the authors with experience in X-ray image analysis for more than 5 years and 25 years, respectively. Assessment of the orbital border was done manually in every slice. A total of 35–48 slices were evaluated in every orbital region (mean value: 41.17, median: 41). Patients were seated in the CBCT device and the fixed head position was secured with a head mount. Although a tilting of the head in the sagittal plane could have occurred in individual cases giving rise to slightly oblique sectional image instead of a strictly axial sectional image, this malposition is very unlikely in the present setting. During the whole CBCT procedure, the parallel orientation of the head position to the ground was maintained as indicated by the laser light lining of the Frankfort horizontal on the patient's face. The same consistency of the conditions for receiving the X-ray image was obtained by the horizontal alignment of the interpupillary line to the reference during exposure.

### 2.3. Measurement method of volumes

Each cone-beam computed tomogram was digitally transferred to an Apple computer running open-source software OsiriX. The ‘bone window’ setting of OsiriX was applied to define hard tissues on the cone-beam computed tomograms. This calibration allowed a constant contrast between soft and hard tissues throughout all measurements. The measurement protocol was as in previously published orbital volumetrics (Bentley et al., 2002). All measurements were performed solely in the axial plane. The preference for this plane allowed the most exact definition of osseous landmarks and thus a reproducible differentiation between soft and hard tissues compared to measurements in the sagittal or transverse plane (Kretschmann and Weinrich, 2003). In particular, the measurement of the optic canal is preferentially determined in the axial plane (Daniels et al., 1985). Single measurements of the area were registered, and the sum of all area measurements was used to calculate the volume of a single orbit with reference to the preset layer thickness (sum of area method). Volumetrics were prepared by digitally circling the target volume along the osseous lining of the orbital cavity in each image. Anterior and posterior openings of the orbit were defined by CBCT signals that were hypointense to the adjacent bone. The borders of the orbit were defined by radiological landmarks (Fig. 1). The shortest line between these landmarks crossing the cavity defined the orbital contour in these sections of the orbital circumference where soft tissue interrupted the bone contour. Evaluation of the CBCT-derived images and all measurement procedures were performed in a darkened room.

### 2.4. Orbital measurement

Prior to volumetrics, the orbital structures were defined in the axial plane. The lateral border of the orbit is composed by the orbital facies of the zygomatic bone and the ala major of the sphenoid bone. The lacrimal bone, ethmoid bone (lamina papyracea), orbital facies of the frontal bone, and the ala minor of the sphenoid constitutes the medial wall.

The soft tissue borders of the orbit required arbitrary definition of landmarks to allow reproducible measurements. Discontinuities of the osseous lining due to the superior orbital fissure were bridged by a connecting line between the ala major and ala minor of the sphenoid. The posterior transition of the orbit to the optic canal was defined by a connecting line at the opening of the canal to the orbit (Fig. 1).

The anterior orbital margin was defined by a line between the most anterior bony point of the lateral osseous boundary to the

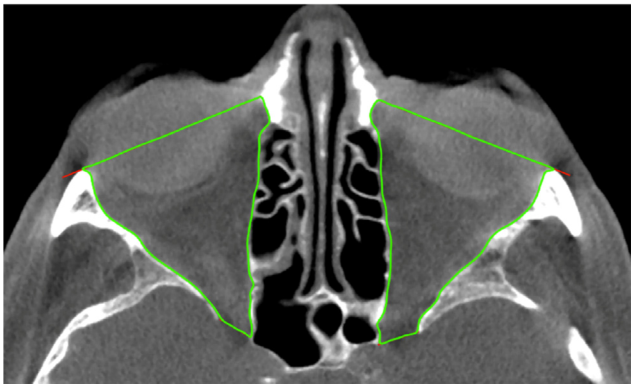

**Fig. 1.** Illustration of orbital area measurement in axial plane, cone-beam computed tomogram.