THE IMPORTANCE OF 3D GEOMETRIC MODELS OF THE MAXILLOFACIAL REGION IN THE PLANNING OF SURGICAL TREATMENT BASED ON COMPUTED TOMOGRAPHY

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Abstract. *The solution to the problem of preoperative planning of surgical treatment of the maxillofacial region is the use of a single MSCT scanning protocol suitable for both diagnosis and subsequent design modeling. The universal the maxillofacial region scanning protocol eliminates repeated examinations, thereby reducing radiation exposure, material costs and preparation time for surgical treatment.*
Keywords: *multispiral computed tomography, 3D geometric models, the maxillofacial region, surgical practice, children.*

Relevance. Restoration of the maxillofacial area (MFA) in patients with defects and deformities of various origins is an important social, anatomical-physiological and functional aspect of treatment (Kulakov A.A., 2009; Gvetadze R.Sh., 2011; Butsan S.B., 2013).

The need for accurate diagnosis and reconstructive treatment at a higher level is due to the annually increasing severity, quantitative and qualitative growth of maxillofacial pathology of various origins (Kulakov A.A., Chkadua T.Z., 2013).

Injuries, cancer, infectious and inflammatory diseases, congenital deformities and conditions after treatment of pathology are the leading factors in the formation of defects and deformations of the maxillofacial area (Kulakov A.A., Nerobeev A.I., 2010).

Data suitable for design modeling in computer-aided design (CAD) systems are geometric models of reconstructed areas, maximally reliable to the real anatomical picture, without distortions and artifacts, obtained from axial sections of MSCT using segmentation methods and recorded in the DICOM format (Nasyrov R.V., 2011; Norenkov I.P., 2009). Taking into account the specifics of the lesion and the concept of reconstructive treatment (RTR) of the maxillofacial area only, the radiologist can provide reliable data suitable for design modeling and diagnosis.

Existing modes for processing and analyzing diagnostic MSCT images are based on recognizing clear threshold values of the Hounsfield scale; the most common and studied method is the automatic segmentation of bone and radiopaque substances (Zonneveld F.W., 2004; Reshetov I.V., 2017). The resulting geometric models are transferred to the engineering stage for further design and load calculations in CAD systems (Perfilyev S.A., 2009).

Purpose of the study. Improving 3D geometric models of the maxillofacial region based on MSCT data using the DICOM application for planning surgical treatment.

Material and research methods. 24 patients were examined in a multidisciplinary clinic of the Tashkent Medical Academy aged from 12 to 18 years. All patients underwent MSCT scanning of the maxillofacial area on a GE HiSpeed USA spiral tomograph using modern protocols, and the “RadiAnt DICOM Viewer” package version 4.2.1.17555 (64bit) was used to create 3D geometric models. This software package performed automatic and semi-automatic segmentation of MSCT images. The geometry of the resulting polygonal 3D surfaces of the skull was studied and compared when changing: slice thickness of 1 mm and 0.5 mm, changing the gantry angle and zero position, applying filters, and using reconstruction modes.

The study included patients with unilateral lesions of the maxillofacial region, where the contralateral part was considered conditionally normal based on the anatomical and topographic relationship of organs and tissues; patients with bilateral lesions of the maxillofacial area were also excluded from the studies.

Segmentation of diagnostic MSCT images made it possible to reliably identify and highlight any anatomical areas and preparations of interest for solving diagnostic problems and design modeling. Identification of the necessary structures is carried out on axial sections within the anatomical boundaries with correction according to the density values of the Hounsfield scale. There are automatic, semi-automatic and manual segmentations. The principle of recognizing anatomical structures in normal and pathological conditions is the main difference between the segmentation of these conditions. Normally, during segmentation, structures of known topography are identified and the principle of "identification - segmentation" is carried out, and in pathology, objects are first identified and then recognized according to the principle of "segmentation - identification".

The main requirement for solving medical problems of design modeling is the selection of an anatomically clean surface that best matches the actual surface of the patient. The surface identified according to MSCT data is converted into a mathematical one - a virtual prototype (CAD), which makes it possible to carry out the necessary calculations (CAM) and plan all stages of treatment and rehabilitation based on the final goal of maxillofacial treatment (CAE).

Research results. The parameters of protocols that are appropriate and inappropriate for design modeling are studied.

As a result of the analysis, it was determined that the protocols for MSCT examination of the head, accepted for preoperative planning, have similar parameters: slice thickness size (no more than 0.625), table feed pitch (should not exceed the slice thickness), gantry inclination angle (should be zero), as well as the presence of reconstruction in bone and soft tissue modes. Also, a wide range of voltage kV and current mAs indicates the absence of clear requirements for them, which means that these parameters can be reduced to reduce the level of radiation exposure.

Based on customizable parameters of MSCT scanning, which improve the quality of detail of the polygonal model, a "recommendation protocol" for MSCT scanning of the head has been developed, suitable for both diagnostics and design modeling.

The reasons for the formation of false defects are identified and their pattern is determined. A technique for closing false defects has been determined. Possibilities in automatic, semi-automatic and manual segmentation modes have been studied.

In addition to the experimentally determined values of the adjustable parameters, the study area was increased to the boundaries of the anatomical region of the head, and the minimum values of the voltage and current of the X-ray tube were taken.

As a result of segmentation of diagnostic MSCT images in patients, the following tissues of the maxillofacial area were reliably identified and isolated as independent anatomical objects, and also translated into geometric models suitable for design modeling: skull bones, muscles, fat, skin. The possibilities of automatic, semi-automatic and manual segmentation for all types of tissues of the maxillofacial area, both normal and pathological, have been determined. When automatically segmenting bones in the Hounsfield scale range from +100 to +1500 HU, the following results were obtained. On the volumetric model of the skull, in 100% of cases multiple defects of bone structures were found according to the type of destruction, which in no way corresponded to the real anatomical situation. This discrepancy was proven by comparing the defect area on the surface of the volumetric model with axial sections on which the integrity of the bone tissue was clearly visible.

Such surface image artifacts, which do not correspond to the true state of the maxillofacial region, have received the working name “false defect”.

False defects during automatic segmentation were found in the following bones: the walls of the maxillary sinuses, the orbital floor, the anterior wall of the frontal sinus, the greater wings of the sphenoid bone, the cells of the ethmoid labyrinth, the walls and cells of the mastoid process, the walls of the nasal turbinates, the lacrimal bone, the hard palate, and the alveolar ridge.

According to MSCT data obtained in the “recommendation protocol”, automatic segmentation revealed false defects in the same bones, but with less frequency. Changing the conditions of the CT scanning protocol reduces the number of artifacts in the form of LD of thin bone structures. This is significant in age groups with completed osteogenesis, regardless of gender, where a decrease in defects in bone structures indicates their typical location.

The data on a decrease in the number of LDs of thin bone structures using the example of the orbital walls and maxillary sinuses are clear; where their anatomical position to the tomographic slice creates the conditions for the occurrence of the “partial volume effect,” which implies an almost parallel position with the slice for the walls of the orbits and perpendicular for the walls of the sinuses. The results of the work allow us stick to the following bone segmentation algorithm: the skull bones are segmented automatically. Volumetric reconstruction determines defects and their topography; differentiation of “false defects” in semi-automatic mode using the “threshold” tool; in manual mode, the true boundaries of the bone tissue are determined at the level of the false defect.

The data is stored in DICOM and transferred to the further design modeling stage.

Conclusions. Thus, adhering to high requirements for reconstructive treatment, the methodology for preoperative planning of surgical treatment of the maxillofacial area is successfully applied and is constantly being refined. Preoperative planning allows you to calculate all stages of surgical treatment, which in turn considers the final result of treatment as the starting point from which all calculations are made. The first place in planning algorithms is occupied by multislice computed tomography, based on the data of which calculations are performed. The value of MSCT images increases when translating diagnostic DCOM data into calculated mathematical surfaces, which can be endowed with any physical properties and load calculations can be carried out in CAD systems. The reliability of mathematical surfaces and, accordingly, the results of design modeling directly depend on the quality of the primary DICOM data obtained from MSCT scanning. Considering the importance of primary DICOM data, design modeling places special demands on their quality and not every MSCT study result is suitable for constructing a reliable mathematical surface. The solution to the problem of repeated scans is the use of a unified protocol for MSCT scanning of the maxillofacial area, suitable for both diagnostics and subsequent design modeling. The universal protocol for scanning the maxillofacial area eliminates repeated examinations, thereby reducing radiation exposure, material costs and preparation time for surgical treatment.

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