Workflow for improving 2-D and 3-D skull visualization - a novel iterative voxel/mesh based approach

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Adequate skull visualization is essential for many diagnostic or therapeutic applications in craniomaxillofacial surgery. Two- and three-dimensional (2D/3D) image data generated from Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT) scanners have become a mainstay in the pre-, intra- and postoperative assessment, as well as for planning of craniomaxillofacial surgery procedures. The quality of the 2D image data stack and 3D computer model obtained from these x-ray based tomographic imaging modalities is fairly good. However, there are still system immanent limitations and there is a need to improve 2D/3D image data of the skull. The problem zones are the orbit and dental occlusion. Even though well-known problems and well documented, they are not sufficiently addressed in today's software solutions. Currently, the surgeon and the researcher have to accept, what has been generated by the imaging workstation and/or visualized by the planning software. Additional manual adjustments are very time consuming or not feasible.

Technically, there are several shortcomings associated with CT and CBCT. Image quality may be significantly compromised by beam hardening, photon starvation, undersampling, patient motion, filtering effects or limited image resolution. For craniomaxillofacial surgery, mainly metal artifacts created by metallic dental restorations, partial volume averaging and stair steps due to limited image resolution and insufficient 3D meshing techniques significantly compromise adequate 2D and 3D data assessment in the surgeon's daily practice. They hamper proper visualization of the teeth. Metal artifacts create image streaks even affecting adjacent structures such as the mandible, maxilla, soft tissue or cervical spine. Both, partial volume averaging and insufficient meshing, compromise 3D skull visualization, mainly the bony orbit at its thinnest bone parts. Other regions such as the infraorbital and mastoid region or temporalis fossa may be affected in a similar but to less marked extent.

We would like to bring in new thoughts into 2D and 3D skull visualization and to computer modeling. We propose developing a workflow for enhanced post-processing of routine clinical CT and CBCT data to improve 2D and 3D image data quality and visualization of the skull. It will include computer tools for significant metal artifact reduction, for improved 3D mesh generation and for the repair of thin bony parts such as the orbit. A novel approach will be implemented to optimize the visualization of the dental occlusion in CT and CBCT data. It will hopefully allow for automated integration of high precision laser data taken from the dental occlusion. In a second phase, the workflow will be tested in a series of clinical data.

We hope this to set a new standard in skull visualization to enhance craniomaxillofacial diagnostic, preoperative planning and treatment. The computer tools developed might be used for clinical application, for research and development or education.