Bewertung der klinischen Eigenschaften von anatomischen Modellen aus drei unterschiedlichen Rapid Prototyping Techniken

Assessment of the clinical usability of anatomical models produced by three different rapid prototyping techniques

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Purpose

To assess qualitative and quantitative differences between anatomical models generated from three different rapid prototyping (RP) techniques. To explore the implications of the results and seek optimizations for clinical use.

Material and Methods

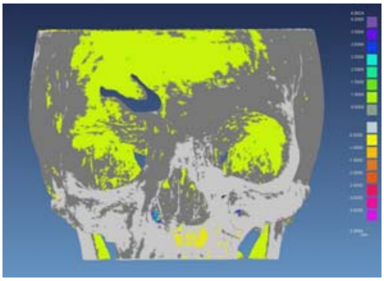
Five preoperative high resolution CT scans (Sensation 16, Siemens Medical Systems, Erlangen, Germany) were obtained from patients for the planning of complex maxillofacial surgery. The bony structures were segmented using the Mimics software (Mimics, Materialise, Leuven, Belgium). The surfaces were exported using the STL (stereolithography) data format which serves as an industry standard for RP manufacturing. For each patient RP-models were built from the same dataset using stereolithography, laser sintering and 3D printing. The techniques used, differ fundamentally. The stereolithography process solidifies liquid epoxy resin with a laser beam. Unlike the other techniques, STL requires support structures to stabilize the model during the build process, which have to be removed afterwards. Laser sintering fuses polyamide together using a laser beam, without completely melting the polyamide powder; thus processing from layer to layer. 3D-printing solidifies layers of plaster powder with an ink-like glue. These models are infiltrated with epoxy resin for stability afterwards. All models were visually inspected and used for surgery planning. Additionally, CT scans of the models were performed. The derived surfaces were compared with the initial patient data.

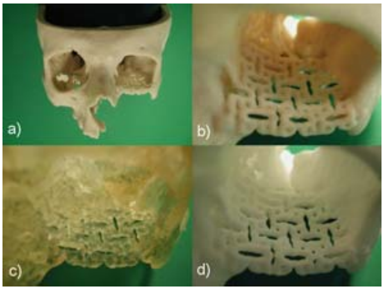
Results

The accuracy of all models was sufficient for the intended planning process. The deviations from the patient data were mostly less than 1 mm (Fig. 1; light/dark-grey: deviations below 0.5mm, green/yellow: deviations below 1mm). The STL models provided the most realistic handling when surgical tools were used to simulate the intervention. A certain loss of fine structures resulted from the removal of the support structures. When a special expoxy resin is used, these models can even be sterilized. The laser sintered models showed more detail but were difficult to process due to their robustness, which instead proved to be particulary useful for communication and teaching. The plaster models provided least accuracy and sometimes a loss of fine structures and a limited mechanical stability. But their manufacture is cheapest and least time consuming and the overall quality still sufficient. Fig. 2 shows a 3D print model (a), with a detail view of an implanted mesh (b) and the respective structures in a stereolithograpy model (c) and a laser sintered model (d). An optimization of the 3D print process was achieved by the use of a temperature resistant epoxy resin and very careful and deliberate infiltration. These models could be sawed and cut cautiously. After open surfaces were sealed again with epoxy resin they could even be sterilized.

Discussion

The ongoing development of new RP techniques is driven by a strong demand from industrial applications. An evaluation for medical use is justified to select specific techniques for realistic or fast surgery planning, teaching, communication and documentation. Some processes can even be optimized for clinical use, giving surgeons faster and less expensive access to RP-models for surgical planning.




a)
b)
c)
d)