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Oral and Maxillofacial Surgery Research Lab

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Zastosowanie trójwymiarowych wydruków celulozowych dla potrzeb chirurgii oczodołów

Rozprawa doktorska

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Introduction

Orbital wall fractures are quite common consequence of maxillofacial trauma. Common complications of such fractures are diplopia, enophtalmos, disturbances of sensation. In order to reduce them some patients require operative treatment involving relocating herniated orbital tissues into maxillary sinus and reconstructing orbital wall with either bone substitutes (most common titanium mesh, polyethylene) or with patients bone. Aim of such reconstruction is recreation of orbital walls continuity. In order to improve success rate of treatment patient specific reconstructions pre bent on three-dimensional models were proposed.

Previous research proved that orbits are nearly symmetrical. On the basis of computed tomography images it is possible to create a virtual model of damaged orbit and to reconstruct its original shape by superimposing mirrored healthy orbit. In the next step prepared model of the orbit is printed from paper on MCor Technologies three dimensional printer. The model used intraoperatively allows reducing the time of surgery, better adjustment of the implant, reduce the risk of complications and improve the results of diplopia treatment.

Working hypothesis of this dissertation is statement, that it is possible to clinically use paper-based MCor Technologies three dimensional models in the orbital surgery.

Aim of the thesis is to control if the above hypothesis is true. In order to verify it, the following research questions were asked:

- Is the accuracy of printed skull model is sufficient?
- Can the MCor Technologies three dimensional model be safely used intraoperatively?

Material and methods

In order to assess the accuracy of printed models CBCT of human skull and mandible was performed. On this basis three dimensional models were created and later printed on MCor Technologies Matrix 300 paper-based three dimensional printer. Model of the skull was printed thrice, each time the plane of printing was changed. Analysis of distances between selected anatomical points on the mandible and the skull and analogical points on printed models was performed with Microscribe G2X 3D measuring arm (Revware Inc., Raleigh, NC, USA). Furthermore in order to more accurately verify the accuracy of reproduced surfaces of the orbits a three dimensional optical scanning of skull and it printed models was performed

and the comparison of scanned skull, virtual model generated from CBCT data and scanned printed model was done.

In order to verify the possibility of safe intraoperational use of models created with Matrix 300 printer the influence of sterilization on shape stability and cytotoxicity tests were performed.

Infulence of sterilization on models shape stability was determined with 30 cuboids of dimensions 10x20x30mm. Each cuboid was measured along each dimension three times using calliper with accuracy of 0.05mm. Next, cuboids were divided into three groups and each group was sterilized either with ethylen oxide, hydrogen peroxide gas plasma or gamma irradiation. Each cuboid was measured using calliper three times again.

In order to verify the possibility of using the created models in contact with blood the cytotoxicity tests were performed. It was tested on 60 3D printed cylinders of 3mm of height and of 14mm of diameter. They were divided into 2 groups: covered with 2-octyl-cyanoacrylate (Dermabond by Ethicon) and without such coating. In the next step those groups were divided further depending on sterilization method (ethylen oxide, hydrogen peroxide gas plasma, gamma irradiation) so in the result there were 6 groups by 10 samples. Discs of analysed substance were placed in an aseptic 6-well tissue culture plate and were flooded with 3ml of complete Fibroblast Basal Medium. After 24 hours medium containing substances unbound from analysed discs was added to cell cultures. Negative control were cells treated with 50% ethanol. Method was taken from norm PN-EN-ISO 10993-12. Discs of analysed substance were placed in an aseptic 6-well tissue culture plate and were seeded with cells in number 8x104 cells/ml/well in 3ml growth medium. After 24h incubation cultures were washed twice with DPBS and 3ml of fluorescent dyes calcein/ethidium in DPBS were added according to LIVE/DEAD Viability/Cytotoxicity Kit (Molecular Probes No. L3224, , Life Technologies, Waltham, USA) protocol. After 30 minutes of incubation samples were washed with DPBS. Observation was done under GX71 (Olympus, Tokyo, Japan) fluorescence microscope.

Results were analysed statistically. Statistical significance was determined as $p< 0.05$

Results

Mean relative difference (%) between mandible and its model measured with measuring arm for 2015 measurements was 1.87±3.14%, where mean absolute difference was

0.36±0.29mm. Mean relative difference between skull and its printed models measured with measuring arm for 231 measurements was 2.28±2.83% for the model cut sagittally, 2.12±2.87% for the model cut coronally and 2.35±3.26% for the model cut axially. Mean absolute difference was 0.76±0.58mm; 0.76±0.63mm; 0.82±0.64mm respectively. ANOVA statistical analysis of mean realative and absolute differences did not show statystically important difference between the models. Mean number of generated measurement points for superimpositions of scanned skull and models was 804.43±19.39 for all orbital walls. Measured mean deviation between skull and the virtual model was 0.15±0.11mm, between virtual model and model cut axially 0.13±0.09mm, cornally 0.11±0.07mm, sagitally 0.22±0.16mm. Differences measured between the skull and printed models were 0.20±0.14mm, 0.18±0.14mm, 0.35±0.28mm respectively.

There was no statistically significant difference in models dimensions before and after sterilization regardless of sterilization method. In XTT analysis samples showed higher cytotoxicity against normal, human, adult dermal fibroblast culture when compared to positive control (+). ANOVA statistical analysis confirmed that 2-octyl cyanoacrylate coating of paper model improved biological behaviour of the material. It decreased cytotoxicity of the model independently of sterilization method. In calcein/ethidium dyeing test due to the high fluorescence of the background caused by cylinders of analysed substance it was impossible to perform exact analysis of number of marked cells. Samples not covered with 2-octyl cyanoacrylate strongly absorbed growth medium what caused increase in volume and stratification of samples.

Discussion

Differences between specimen of a human mandible and its three dimensional printed model may be the result of errors, which could have occurred on each of stages of preparing the model: from the cone beam computed tomography, through the automatic segmentation, preparing model fort printing, the printing process itself, freeing the model from the excess paper, ending with used measurement methods. Nevertheless gathered results are similar to other studies concerning rapid prototyping of models.

In order to be safely used as a surgical template printed model should have as low cytotoxic effect as possible. Prints from Mcor Technology Matrix 300 paper based printer had shown significant cytotoxic effect. Coating the models with Dermabond cyanoacrylate tissue adhesive significantly reduced cytotoxicity, although did not eliminate them. What is more,

samples covered with Dermabond did not absorbed growth medium in calcein/ethidium dyeing test and showed no stratification effect at all in comparison to intact samples. Further studies regarding safe covering of printed models are required.

Conclusion

Acquired results allow to conclude that Mcor Technology Matrix 300 paper models can be used in orbital surgery.