Rapid Prototyping of Patient-Specific Titanium Plates for Canine Cranioplasty
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Introduction

• The emergence of rapid prototyping technology has allowed for the development of patient-specific implants and cutting guides to assist in both the pre and intraoperative phases.
• Patient-specific rapid prototyped implants have been described for many applications in human patients including the correction of dental and maxillofacial deformities. The use of this technology reduces surgery time1-3, speeds healing3, and improves clinical outcome3,4.
• In veterinary medicine, reports of rapid prototyping is limited to case studies or experimental studies, including the creation of a customized surgical plate for canine tibial plateau leveling osteotomy5; correction of a persistent hard palate defect6, the production of titanium mesh cages and plates (imbued with repair stimulating substances) to repair canine radial defects3, and most recently a feline titanium mandibular prosthesis6.

The purpose of this study was to determine the feasibility and workflow for creating and printing a patient-specific titanium skull plate for cranioplasty in dogs following craniectomy.

Materials and Methods

Computed tomography (CT) scans from patients admitted for craniectomy surgery were retrospectively evaluated and case selected for this pilot study

Image Capture

• Scans were included if they were available in a bone algorithm with high spatial resolution and 0.625-1.25mm slice thickness

Image Processing

• Digital Imaging and Communications in Medicine (DICOM) format was used and the images were imported into OsiriX.
• Images were evaluated in transverse, sagittal and coronal reconstructions and a medial, lateral, rostral, and caudal margin of the tumor was identified
• Tumor margins were determined based on agreement between an ACVR (AZ) and ACVS (MO) diplomate and a CVS file was generated.
• Once a virtual tumor margin was identified images were exported using a cloud based storage system.
• The DICOM images were 3D reconstructed using the segmented software Materialise Mimics 19
• STL files were generated using Materialise3-Matic 11
• Ansys SpaceClaim was used to import and smooth the CVS file generated in OsiriX
• Geomagics Freeform was used to generate the virtual surgical margin cut with an additional 5mm margin of normal bone beyond the tumor margin

Plate Printing

• STL surgical plate designs from Adept were imported into Renishaw Adept software
• The plate was printed at The Additive Design in Surgical Solutions (ADEISS) Centre in London Ontario on a AM 400 Metal 3D printer in titanium

Image 3: Printing output of skull with tumour (L) after virtual surgery and defect creation (C) and custom titanium plate (R)

Results

• Image processing time: 
  • Margin assessment ~30 minutes
  • Defect creation and processing ~1.5h
  • Plate design time: ~2h
  • Plate printing time: 6-7 hours
  • Post processing: 2 h

Discussion

Based on the findings of this study, with access to this technology and an individual/group with advanced expertise in CAD/segmentation software, patient-specific 3D printed titanium implants can be manufactured for patient use within a 4-week turnaround from diagnosis to surgery for canine patients undergoing cranioplasty.


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Figure 1: CT scan of a dog with an osteoma that was included for virtual surgical planning and plate design

Figure 2: Sample output of plan for a cranial plate prior to printing

Figure 3: Printing output of skull with tumour (L) after virtual surgery and defect creation (C) and custom titanium plate (R)