RAPID RECONSTRUCTION OF TEMPOROMANDIBULAR JOINT USING CERAMIC IMPLANTS AND DENTAL ADHESIVES

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ABSTRACT

Most of the TMJ implants (components: condyle and fossa) available have failed; failure may be due to inherent design flaws and use of screws for fixation. In this research, an original offline generic patient-image in the form of MRI/CT scans was converted into 3D data and was used to design patient-specific implant components that conform within the patient's bone anatomy. These final implant components can be manufactured by direct machining from ceramic ingots. Current generation ceramic ingot machining systems accept data only from software of proprietary imaging programs, Rapid Prototyping Technology was used to manufacture temporary implants/devices to be re-imaged by that equipment and permanent implants can be fabricated. The skull-mounted glenoid fossa component and ramus-bone supported condylar shafts of the fabricated structural ceramic parts can be cemented directly to bone using dental adhesives and can serve as a better alternative to screw fixation. FEA has been performed to validate the design for each component. The overall joint reconstruction time can be controlled within 4 hours.

METHODOLOGY

1. New Design

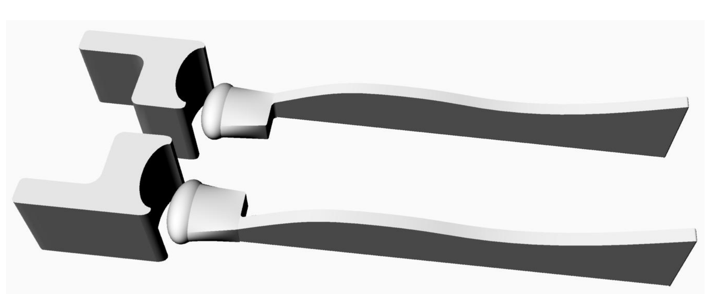


Figure 1: Bilateral Temporomandibular Joint Implant designed using Rhinoceros 4.0 (McNeel & Associates, Seattle, WA, USA) representing the minimum dimensions

2. Conversion of MRI/CT Scans to 3D models

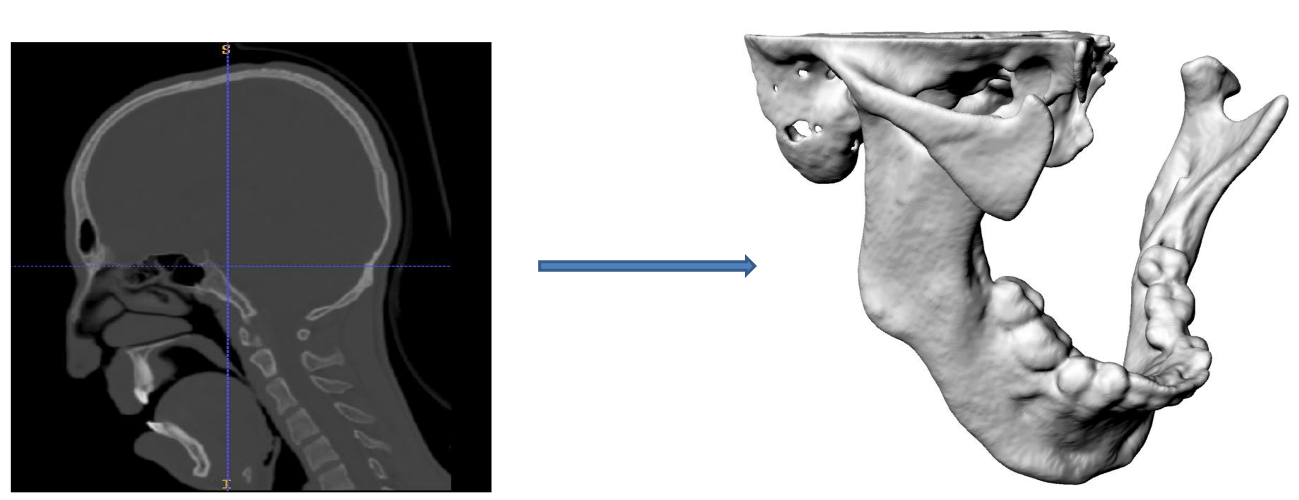


Figure 2: TMJ with mandible from MRI scan of a patients skull converted to 3D model using ITK-SNAP [1] and edited in Rhinoceros 4.0

3. Design of Patient-specific condylar component

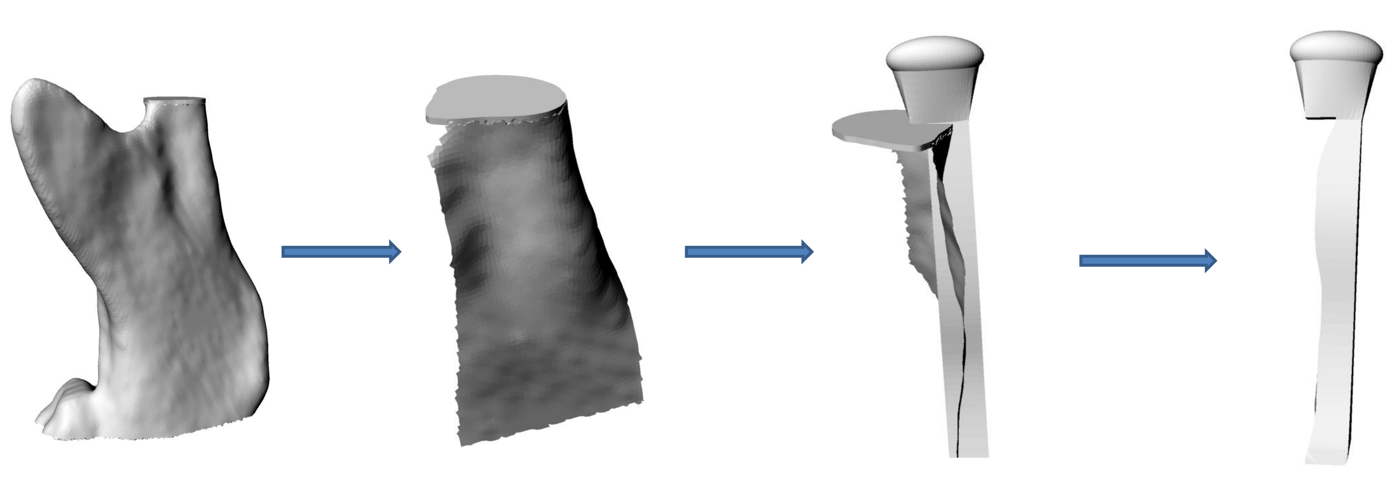


Figure 3: A – 3D model of Mandibular Ramus after condylectomy (The site for implantation of Condylar component) B – Surface Topology extracted from the 3D model of Patients TMJ anatomy C- Obtaining surface topology of ramus on the device D – Final condylar component with mandibular-ramus surface topology

The Condylar component can be modeled to patient specific anatomy by the above method. Fossa component will be unchanged.

4. Patient-Specific Condyles modeled for different mandibular-ramus developed from MRI and CT scans

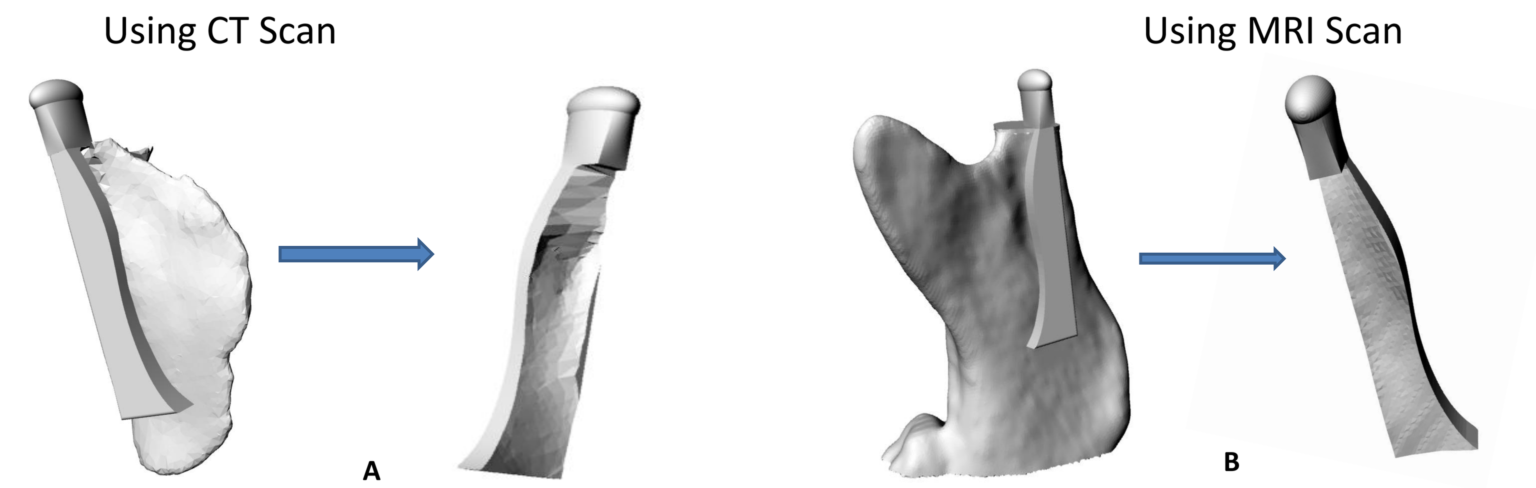


Figure 4: A – Condyle modeled for right mandibular ramus developed from CT Scan of a human B – Condyle modeled for left mandibular ramus developed from MRI Scan of a human

5. 2D Von Mises Stress Plot of Implant components attached to bone cohesively

1. Fossa Component attached to Zygomatic arch by dental adhesives

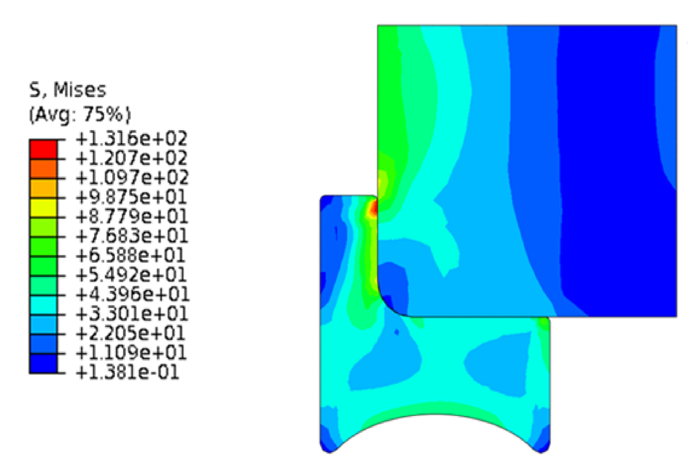


Figure 5(A): Von Mises Plot of Fossa component fabricated with material IPS e.max CAD (Lithium Disilicate ceramic) using ABAQUS CAE 6.9

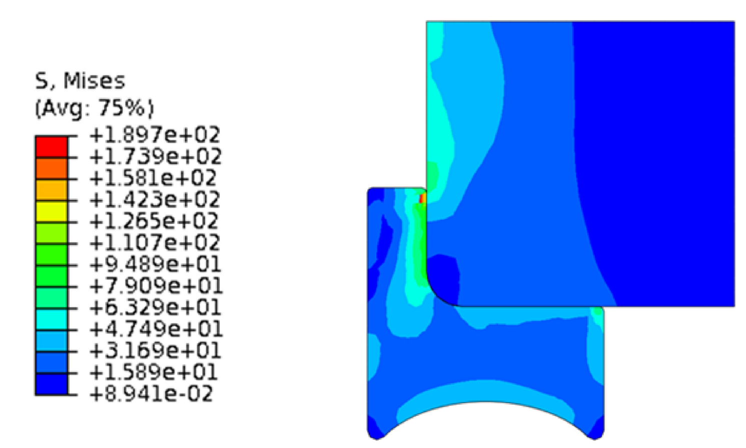


Figure 5(B): Von Mises Plot of of Fossa component fabricated with material IPS e.max ZirCAD (zirconium Oxide ceramic) using ABAQUS CAE 6.9

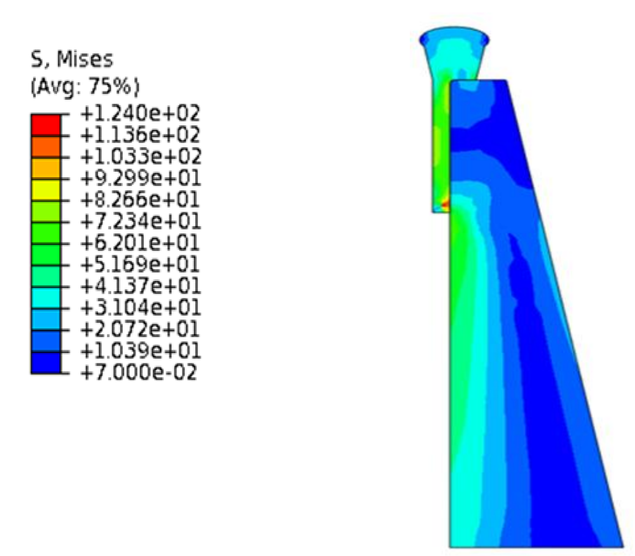


Figure 6(A): Von Mises Plot of condylar component fabricated with material IPS e.max CAD (Lithium Disilicate ceramic) using ABAQUS CAE 6.9

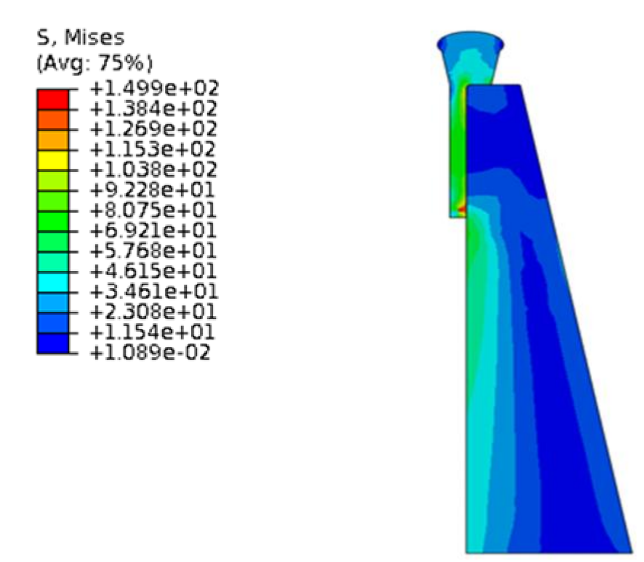


Figure 6(B): Von Mises Plot of ofcondylar component fabricated with material IPS e.max ZirCAD (zirconium Oxide ceramic) using ABAQUS CAE 6.9

The peak stress of the components obtained is within the flexural strength of the material (360 Mpa for IPS e.max CAD and 960 Mpa for IPS e.max ZirCAD)

6. Prototype manufactured using FDM method of Rapid Prototyping Technology

Figure 7: Prototype of Implant components manufactured using Rapid Prototyping Technology

The above device prototypes are manufactured with the minimum dimensions that must be satisfied so that the device can withstand the biomechanical stresses at the time of application. The patient-specific condylar-component will have mandibular-ramus surface topography along the inner side of the shaft

6. Nakabayashi's Hybrid Layer concept for adhesion of implants to bone

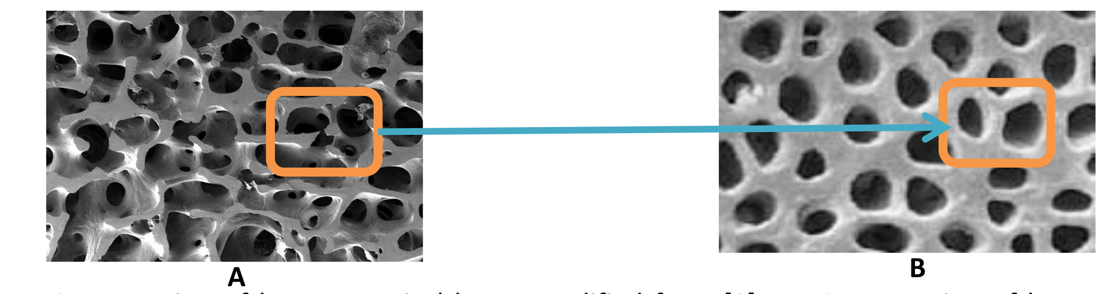


Figure 8: A – Cross-section of human cortical bone, modified from [2] B – Cross-section of human dentin (mineralized section of tooth) modified from [3]

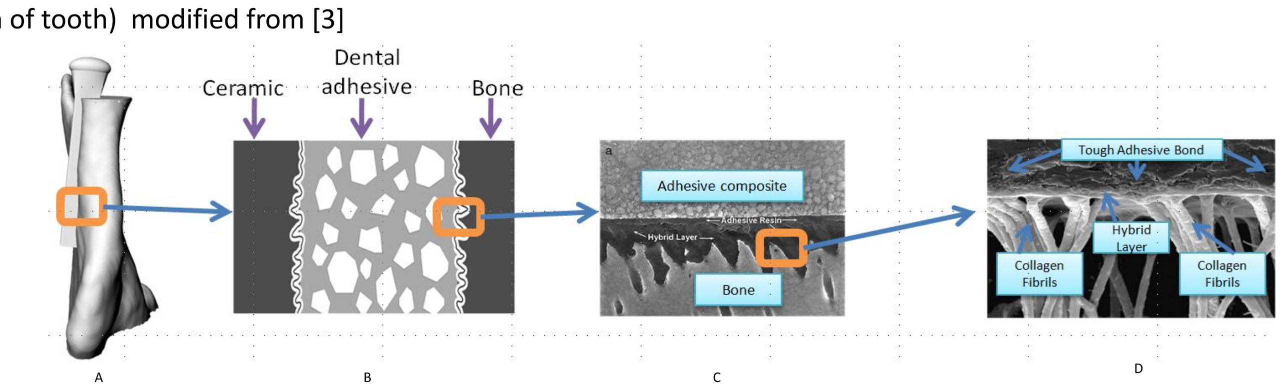
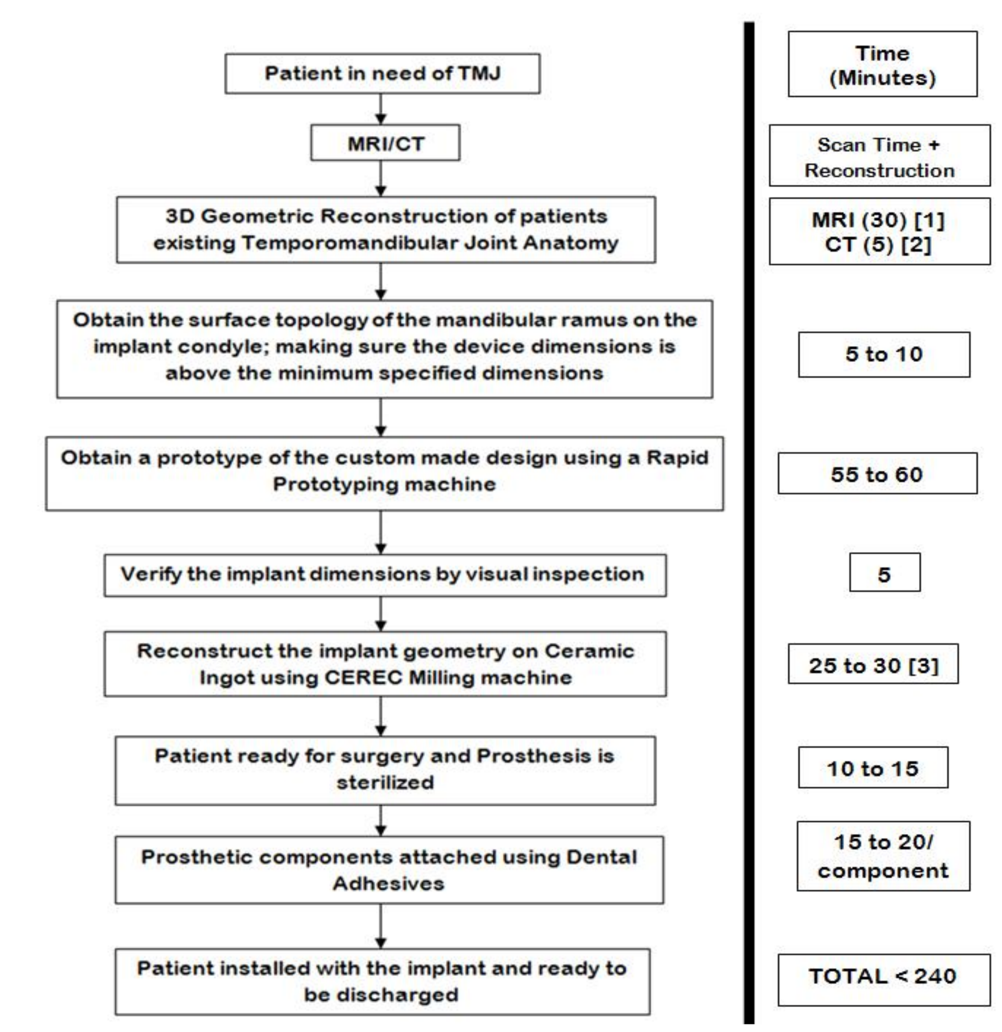


Figure 9: A- Implant fixed on bone by dental adhesive B- Bone-implant interface , modified from [4] C- Formation of hybrid layer (partial resin and partial bone minerals) , modified from [5] D- Entanglement of resin monomers with collagen fibrils of bone forming hybrid layer , modified from [6]

The hybrid layer (HL) is formed after acid etching of surface and application of dental adhesives. This HL provides strength and rigidity to the bond.

RESULTS



This shows patient specific implant can be made and installed within 4 hours

FUTURE WORK

- Mechanical Testing of implant for strength, wear and friction
- Application and testing of bonding ceramic to bone using dental adhesives

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