# DESIGN AND CONSTRUCTION OF A PATIENT- SPECIFIC TMJ

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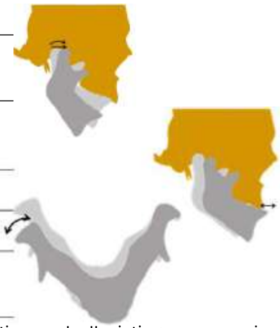
## 1. INTRODUCTION

- The temporomandibular joint (TMJ) is the articulation between temporal bone and mandible head
- TMJs are located at both sides of the jaw. TMJ acts as both a hinge and a sliding joint. This is the most active joint of the body, moving up to 2000 times each day during talking, chewing, swallowing and snoring
- The motions of TMJ are: i) Elevation and Depression , ii) Protrusion and Retrusion, iii) Mandibular lateral deviation

*Table 1: Kinematics of TMJ*

| Motion | Osteokinematic | Range of motion [mm] | Angle [°] |
|---|---|---|---|
| Depression | Sagittal plane | 0 - 40 | 30-40 |
| Elevation | | | |
| Protrusion | Sagittal plane | 0 - 9 | 3-6 |
| Retrusion | | 0 - 3 | 1-2 |
| Lateral deviation (right/left) | Transverse plane | 0 - 8 | 8-15 |

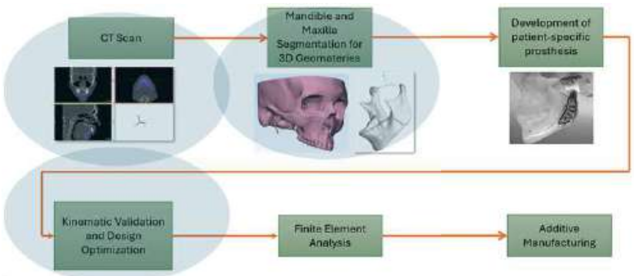


- TMJ prostheses are essential for restoring jaw function and alleviating severe pain caused by **arthritis, trauma, congenital disorders, tumors, degenerative joint disease, and failed prior surgeries**. They significantly improve quality of life for patients with debilitating TMJ conditions.

## 2. WORKFLOW

Designing a TMJ involves:

- Ensuring a good fitting,
- allowing a natural range of motion
- Providing high reliability




## 3. OBJECTIVES

**2nd Year Objectives:**

- To set up a methodology to obtain an accurate **3D model** of the native patient's TMJ using advanced segmentation software
- To create a detailed and accurate **multibody model** to study the TMJ behaviour during physiologic motions
- To set up a methodology **optimize** the geometry of the joint

## 4. MANDIBLE SEGMENTATION ANALYSIS

A study compared **five software** which can be used for TMJ **segmentation**:

- two open-source (**3D Slicer, BlueSky**); one commercial (**Mimics, D2P**), and one AI-based (**Relu**) software

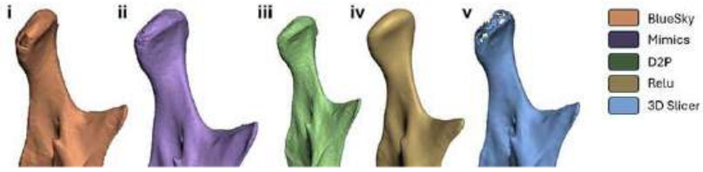
**Metrics** to evaluate segmentation software performance were:

- the usability,
- the segmentation quality,
- the geometric accuracy,
- mesh properties,
- Dice Similarity Coefficient (DSC) among results.

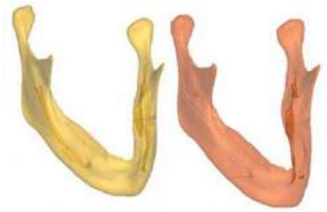
**Main findings**:

- Relu software, leveraging AI, excelled in handling intricate geometry and usability but required over twice the segmentation time compared to Mimics.
- Average deviations in pairwise comparisons ranged from 0.25 mm to 0.50 mm, with highest similarities observed for D2P vs Relu and Mimics vs Slicer (RMS ~0.25 mm), while D2P vs BlueSky and BlueSky vs Relu showed RMS values significantly above 0.5 mm, reaching up to 1 mm

## 4. MANDIBLE SEGMENTATION ANALYSIS (Continue)

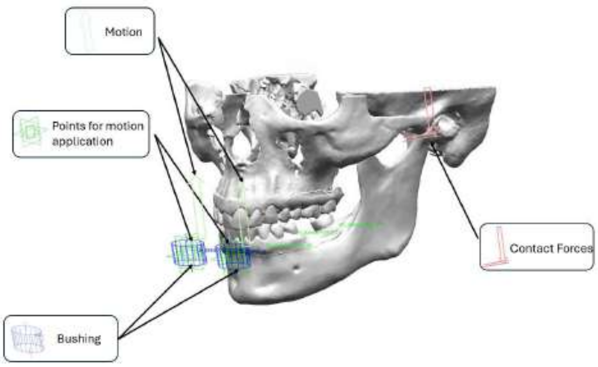



- only Relu software was able to accurately replicate the geometry of the full mandibular canal connecting the mental foramen to the mandibular foramen
- The performance of all software was generally very good. Nonetheless, differences in geometric accuracy, usability, costs and times required can be significant.



## 5. KINEMATIC VALIDATION

- **ITAKA Mandibular Movement Scan** system was used to capture mandibular movements
- A **multibody model** was developed in **ADAMS MSC:**
  - Geometries were obtained from CT scan
  - The maxilla was fixed
  - The contact between the mandible and the maxilla was simulated
  - physiologic movements have been imported into the model and applied as 'Motion' boundary condition, applied on bushing elements
  - The contact force peaks have been considered as an output
- The **fossa geometry** has been refined with the aim of limiting contact forces




## 6. FUTURE STEPS

- **Further refinement of the multibody model to simulate muscle actions:** Enhance the TMJ model by integrating dynamic muscle simulations to assess prosthesis performance in terms of ergonomics, specifically evaluating the muscle effort required to perform physiological movements
- **Finite element analysis:** Conducting simulations to analyse stress distribution and mechanical behaviour of the prosthesis under various loading conditions, ensuring durability and functionality
- **Final design of the prosthesis**: Utilize insights from modeling and analysis to iteratively optimize the prosthesis design, prioritizing biomechanical performance

**References**

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