# Simulation of TMJ condylar defects over gray scale images

**Rationale:** Current radiological diagnosis of temporomandibular joints (TMJ ) condylar pathology using 3-D CBCT are sometimes limited by the acquisition procedures: oblique cuts of the CT and head positioning errors, can incorrect diagnosis of flattening of the head of the condyle, formation of osteophyte, or condylar pitting.

**Goal:** We want to create a database of synthetic TMJ condylar pathology defects to test how sensitive the current standard for 3-D diagnosis of TMJ pathology (Ahmad Classification [1]) is with respect to alterations of the head position/orientation.

**Methods:**

1. Defects will be simulated on 3D virtual models of TMJ condyles obtained from binary segmentations of healthy bone in CBCT data. Defects at predefined locations and various (randomized) depths will be generated. Corresponding 3D virtual models of the condylar fossa will be also generated.

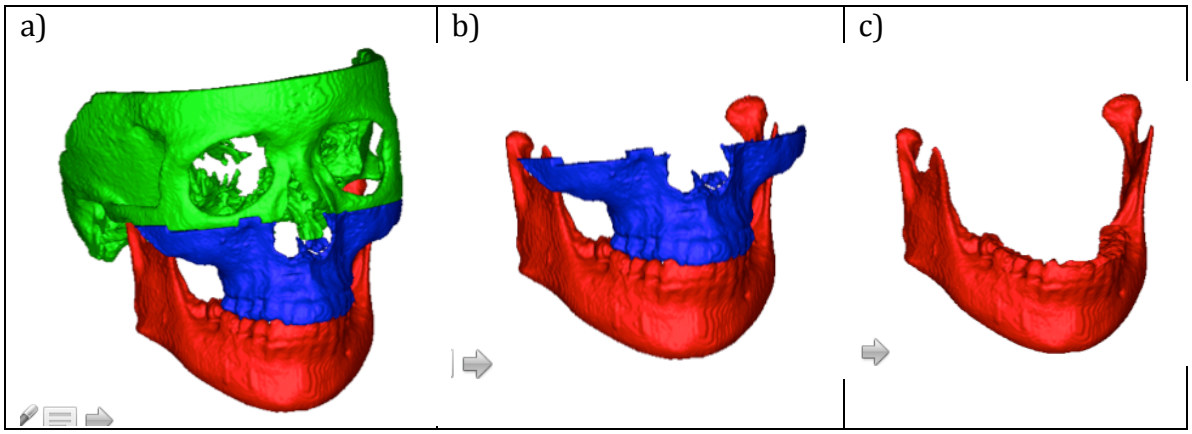


Figure 1. Anatomical reference. a) CranioMaxilloFacial complex, showing cranial base (CB) in green, maxilla in blue and mandible in red, b) maxilla in blue and mandible in red, without the CB the two TMJ condyles are displayed, c) mandible only.

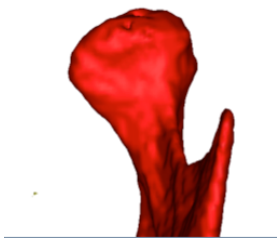

Figure 2. TMJ condyle close-up.

Defects will be simulated on binary segmentations using ITKsnap. The rush tool can be used to generate round defects in 3D (see figure 3).

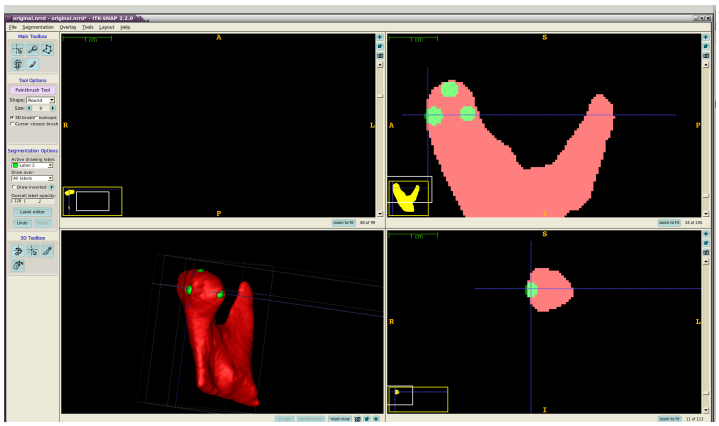

Figure 3. ITKSnap snapshot.

Defects of different sizes can be simulated in different locations of the TMJ condyle, as tangent to the bone surface as possible. Possible locations are: Anterior Pole (AP), Posterior Pole (PP), Lateral Pole (LP), Medial Pole (MP) and Superior Pole (SP).

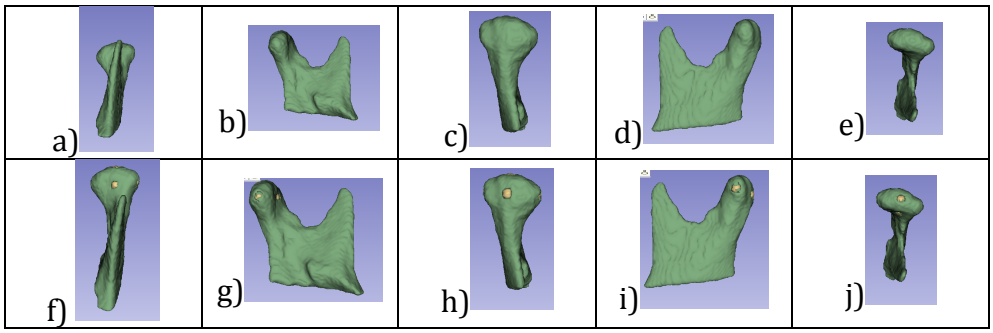


Figure 4. Locations and defects (displayed 8mm defect). a & f) Anterior Pole, b & g) Medial Pole, the MP is oriented towards the midline of the face, c & h) Posterior Pole, d & i) Lateral Pole, the LP is oriented towards the skin, e & j) Superior Pole.

In the beginning **only one patient will be used for defect simulation**. Defects of 0.5mm, 1mm, 3mm and 6mm will be simulated in the SP of the condyle, unilaterally. This will result in 4 TMJ healthy-simulated pathology complexes.

2. Point-based models of the original (healthy) condylar head and the fossa with point-wise correspondence across subjects will be generated via SPHARM-PDM [2] [3]. SPHARM-PDM has been used for quantification of bony defects in the TMJ before [4] [5]. Point-based models of the simulated pathology will be also computed. Each condylar head and fossa (the same model for all combinations):

$M_0$ = original condyle+fossa complex

$M_1 \ldots M_N$ = simulated condyle+fossa complex

Complexes will be generated via mesh merging in Slicer (All modules > Surface Models > Model Merge).

SPHARM-PDM is available as a Slicer extension, as loadable Slicer CLI module and as commandline module [6].

3. Point-based elastic registration methods i.e. TPS (thin plate splines)[7], Plastimatch (RBF = radial basis functions) [8] will be used to compute deformation kernel from each $M_1$... $M_N$ to $M_0$.. Deformation kernels will be sampled into a deformation field at the original grayscale image reference gridding.

4. Deformation fields will be applied to the original grayscale image to generate a simulated pathology image. NIRAL has several tools to apply deformation fields to GrayScale images.

**Evaluation:**

Using a team of radiologists we will perform several experiments:

1. In a dataset of simulated images, the team will have to detect the location and extend of the defect (radiological score of defect).

    a. what is the threshold size of the boney defect before it is reliably and accurately detected on a multiplanar view.

    b. are different specialist better at 3-D TMJ pathology diagnosis (inter-rater, residents vs attendings)

2. In a dataset of simulated pathology, we will alter the head orientation to see if oblique sections on multiplanar view affect the diagnosis of condylar pathology.

**Timeline:**

| | Feb | Mar | Abr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|
| Reading papers | x | | | | | | | |
| Simulating DB | x | x | | | | | | |
| Running SPHARM | | x | | | | | | |
| Deformation field computation | | | x | x | | | | |
| Deformation field application to GS | | | x | x | | | | |
| Evaluation | | | | | x | x | | |
| Manuscript preparation | | | | | | | x | x |

Figure 5. Proposed timeline. Juliette will be part of the steps highlighted in light grey, and the project will continue beyond her departure to France with the dark grey steps.

**Future work:**

Investigate multiple pathologies and test which are more reliably detected by radiologists (flattening, erosion, osteophyte)

**Meetings and reports:**

Juliette & Tung: Each other Thursday (bi-weekly) at a time they both will agree with.

Juliette & Francois: Continuing with Tuesday after lunch meetings. Martin will join the meeting on demand when questions arise. If a meeting including Martin will be necessary, Juliette will send Martin an email checking for availability in advance.

Juliette & Bea: Initially no meetings will be scheduled between Feb-midMay. If really necessary Skype meetings will happen.

Weekly report: Juliette will write a weekly email due every Friday, with a description of the progress achieved during the week. The email will be addressed to Bea (beatriz_paniagua@med.unc.edu), with copies to Francois (fbudin@unc.edu), Martin (styner@cs.unc.edu) and Tung (nguyentu@dentistry.unc.edu).

**References:**

**(located at /NIRAL/projects5/CMF/TMJSimulation/Docs)**

1. Ahmad M, Hollender L, Anderson Q, et al. Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 2009;107:844-60.

2. Brechbuhler et al. Parametrization of closed surfaces for 3-D shape description. Computer Vision and Image Understanding (1995) vol. 61 (2) pp. 154-170

3. Styner et al. Framework for the statistical shape analysis of brain structures using spharm-pdm. Open Science Workshop at MICCAI (2006)

4. Paniagua et al. Clinical application of SPHARM-PDM to quantify temporomandibular joint osteoarthritis. Computerized medical imaging and graphics : the official journal of the Computerized Medical Imaging Society (2010) pp.

5. Cevidanes et al. Quantification of condylar resorption in temporomandibular joint osteoarthritis. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics (2010) vol. 110 (1) pp. 110-7

6. http://www.nitrc.org/projects/spharm-pdm

7. http://www.vtk.org/doc/nightly/html/classvtkThinPlateSplineTransform.html

8. http://plastimatch.org/getting_started.html