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KHON KAEN UNIVERSITY

Bridge Model for Individualized Digital NasoAlveolar Molding using Uniform Cross-Section Elliptic Segment

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Cleft Lip and Palate (CLP)

* Congenital craniofacial defect.
* Approximately 1 in 700 births.
* Caused by various factors, inc. genetic, environmental, or combination of both.
* NasoAlveolar Molding (NAM) is a well-adopted adjunctive therapy before lip surgery.

Conventional and Digital NAMs

Conventional workflow

Take impression

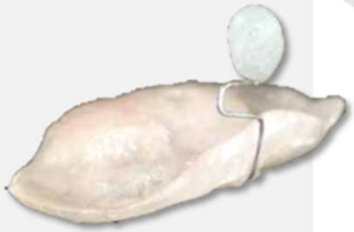
Risks of aspiration

Stone model

Fabricate NAM plate using self-cure acrylic resin

NAM plate

Selective grinding to mold the arch and incorporating nasal stent manually



Digital workflow

Take intraoral scan

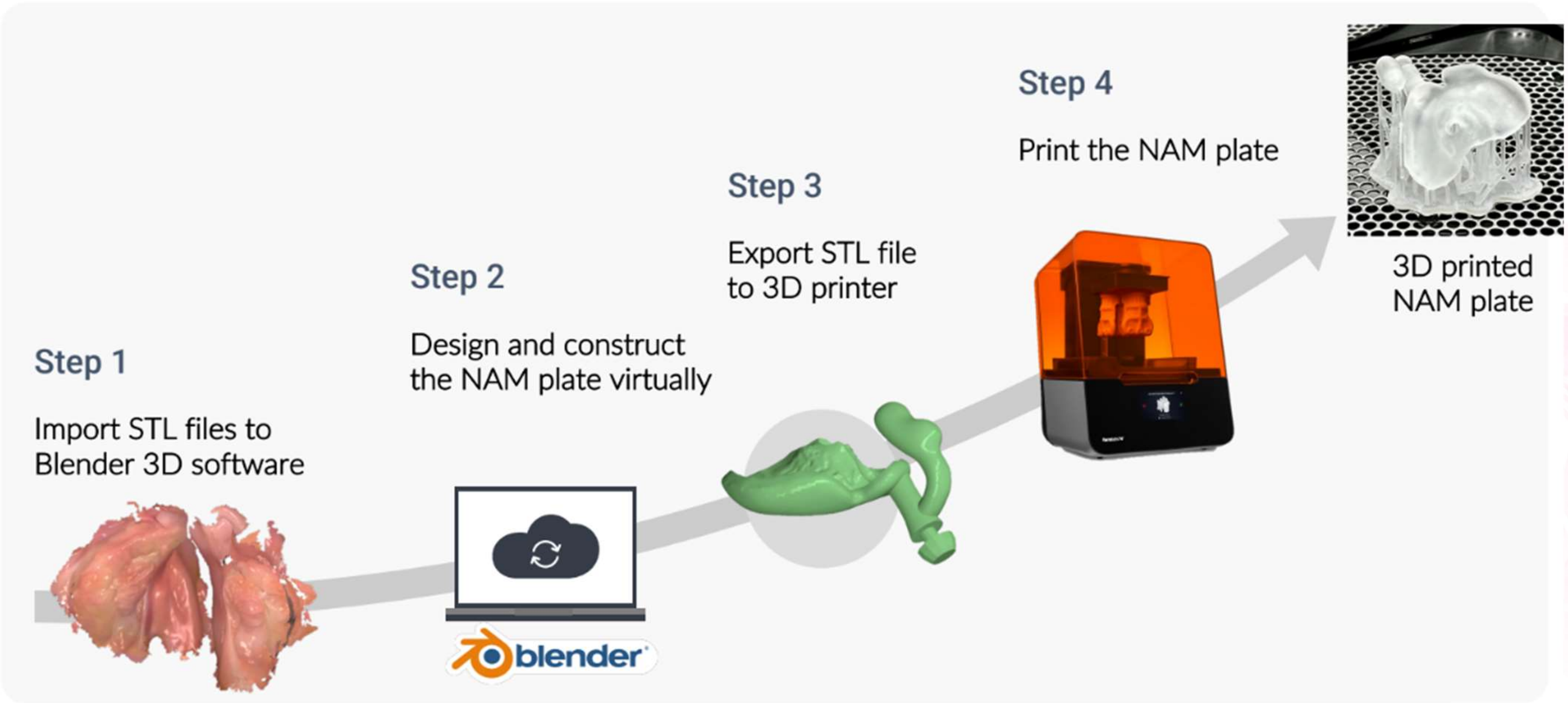
Decrease risks from taking impression

Design via 3D software and 3D-printed

CAD-CAM NAM

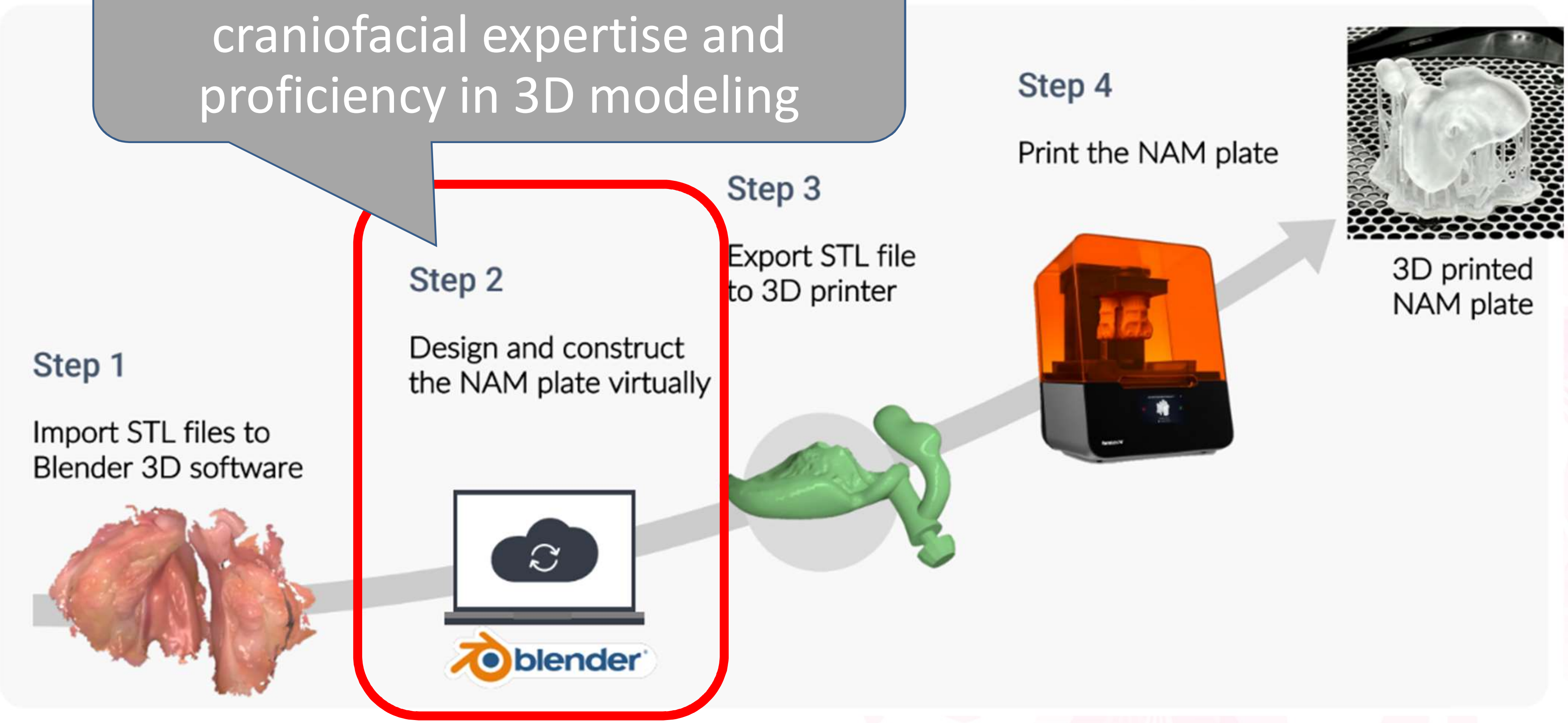
Manually incorporates nasal stent

Individual Digital NAM



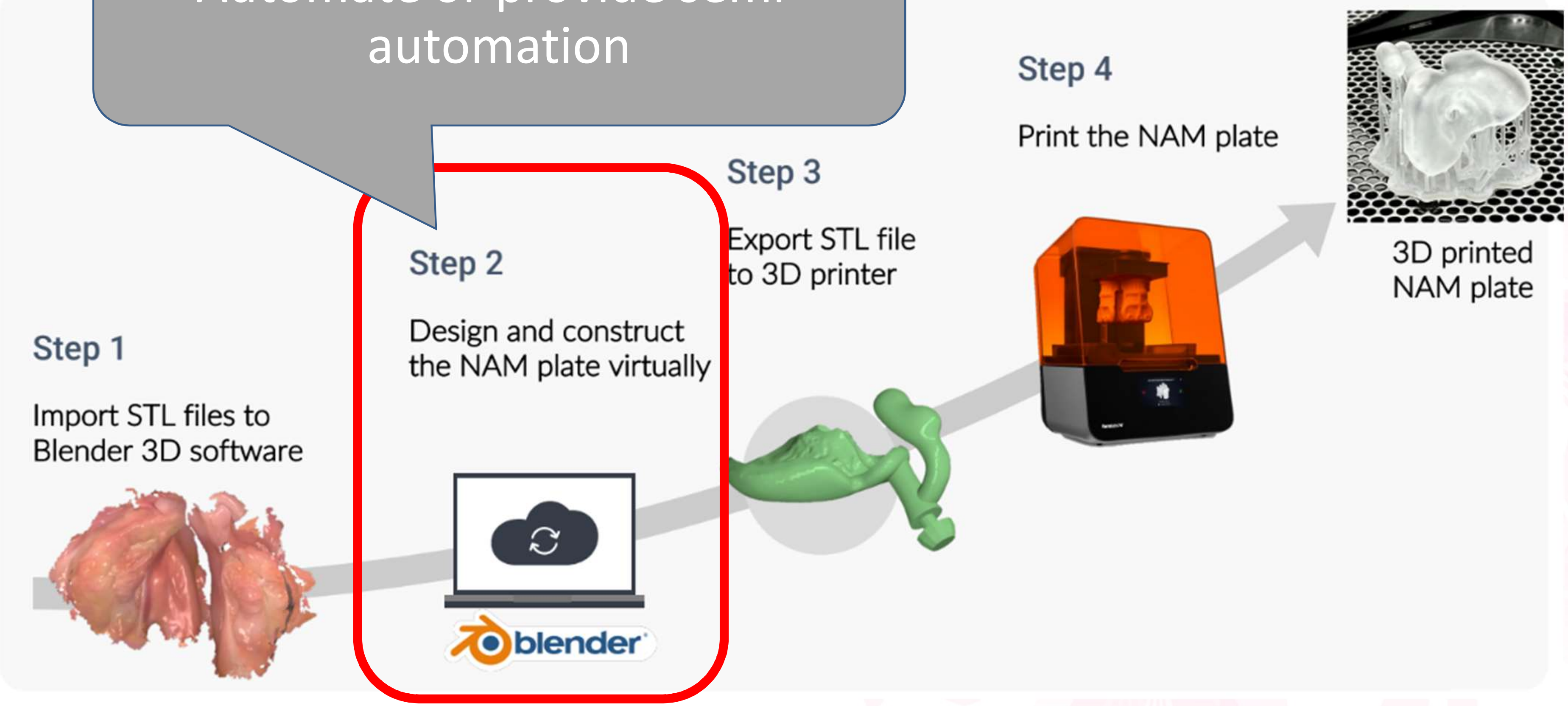
Issues

Need a personnel with both craniofacial expertise and proficiency in 3D modeling



Our Proposed Solution

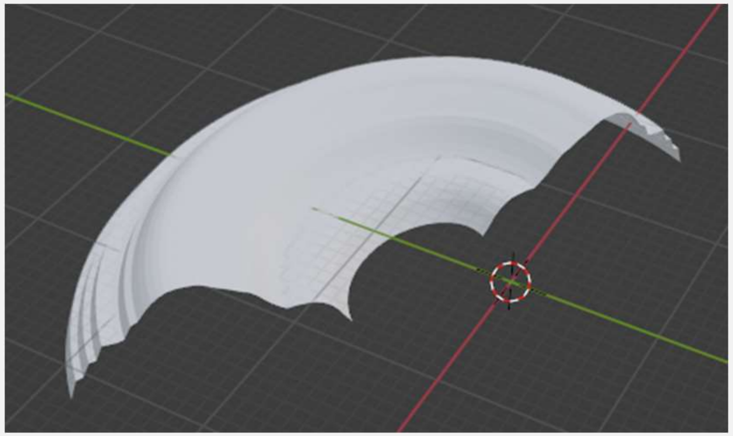
Automate or provide semi-automation



Project Phases

Input
Intra-Oral Scan

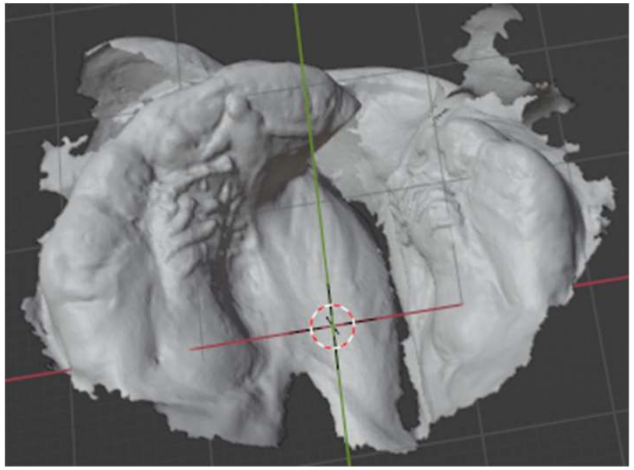
Phase 1
Bridge



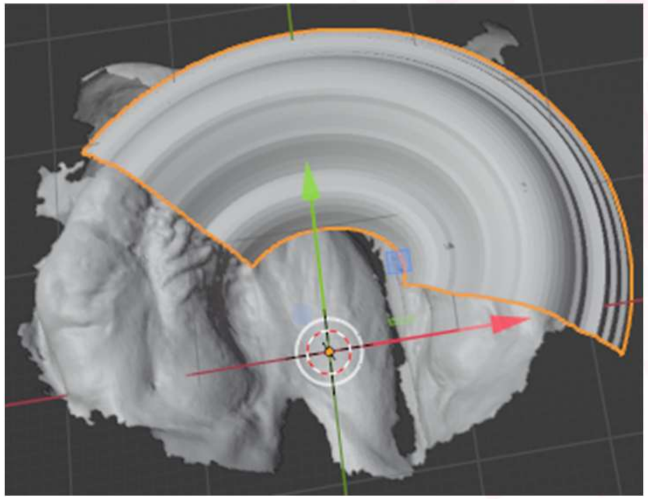
Final Design

The Bridge Model

Intra-Oral Scan



Bridge



Bridge

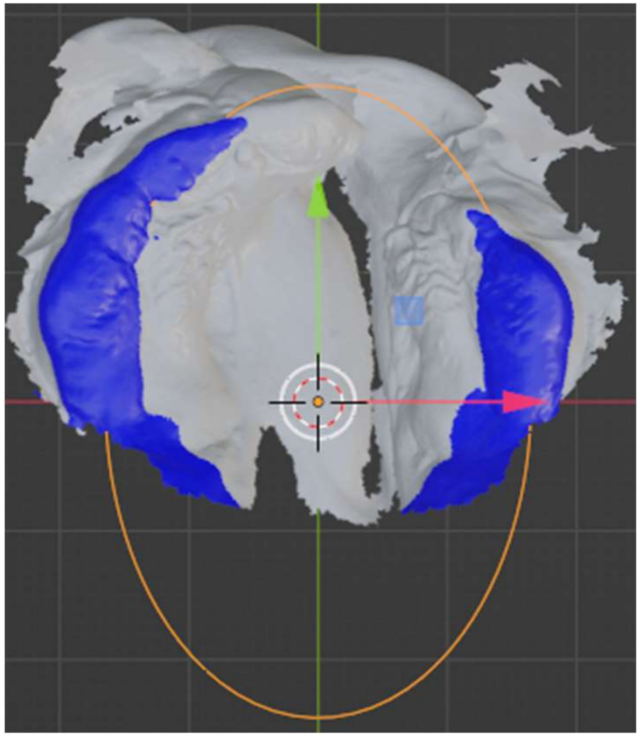
* Its shape agrees with curvature of a patient's alveolar ridge.

* It connects the gap.

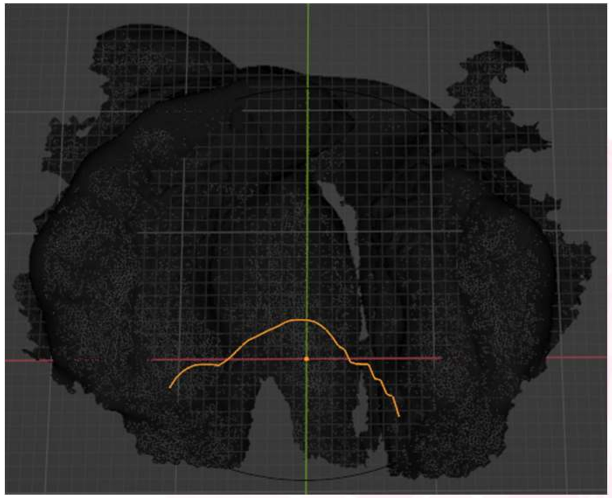
* Its volume loosely fits to the alveolar ridge.

Our Approach

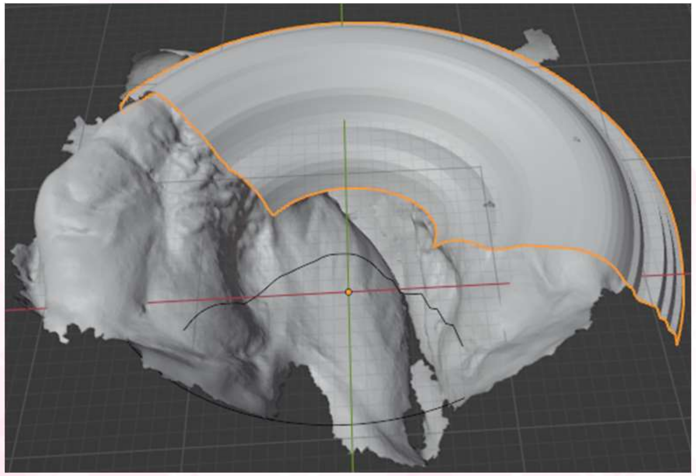
Uniform Cross-Section Elliptic Segment



Shape: ellipse model

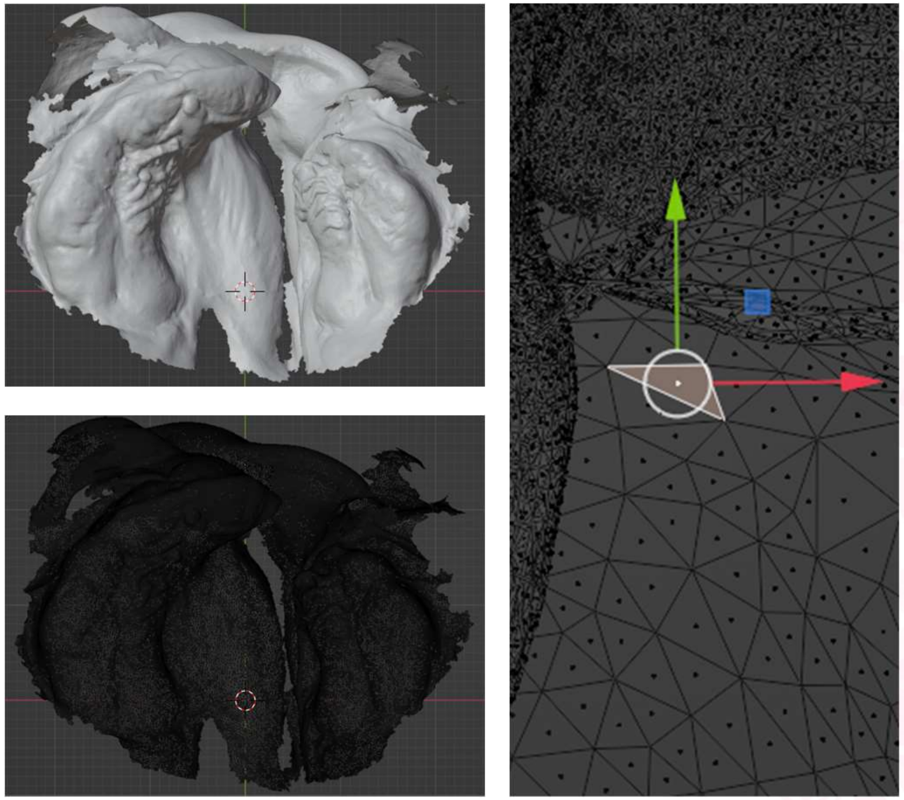


Cross-section



Bridge: shape + cross-section

Working with 3D Geometry Data

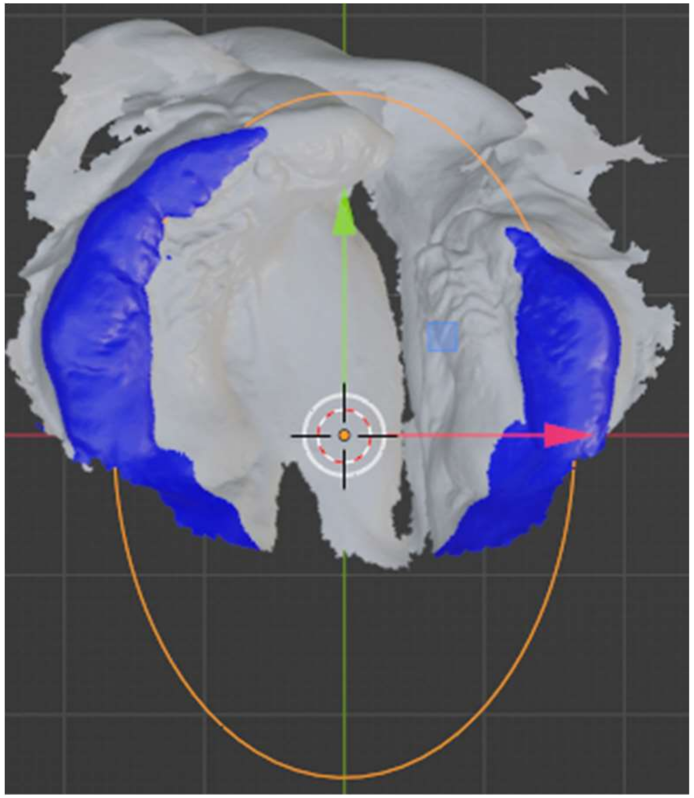


Intraoral scan = 3D Geometry data
* vertices, edges, **faces**

Face
* Vertices and edges
* Face normal vector
* **Face center**

Face center, $c = (x, y, z)$

Elliptic Segment



Ridge identification (shown in blue)

* Face u is identified as ridge if its $z > 0$

Shape approximation

* Polar coordinate

Face center $(x_n, y_n, z_n) \to (r_n, \theta_n, z_n)$.

* Elliptic model (fixed center)

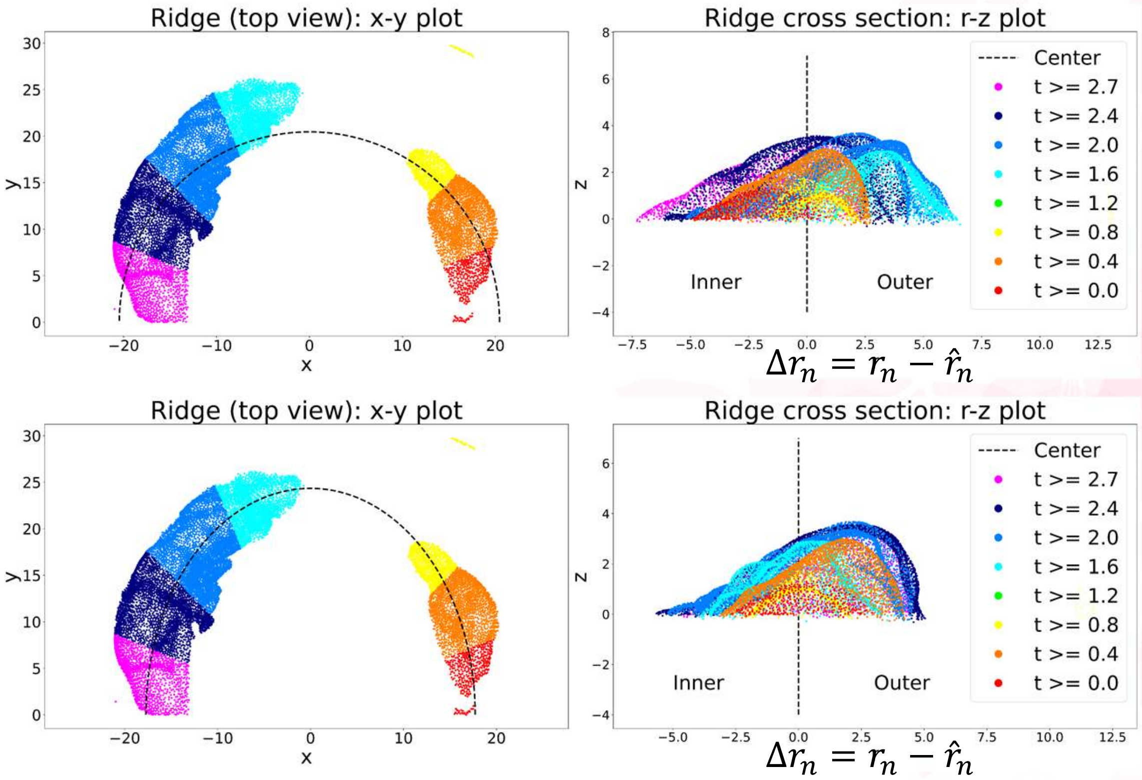
$$\hat{r} = \frac{c}{\sqrt{\frac{\cos^2\theta}{a^2}+\frac{\sin^2\theta}{b^2}}}.$$

* Fit the model: $\min_{a,b,c} \sum_n (\hat{r}(\theta_n, a, b, c) - r_n)^2$

Cross Section: Learn from a Natural Ridge

How do we model the cross section?

* Learn from the natural cross section.



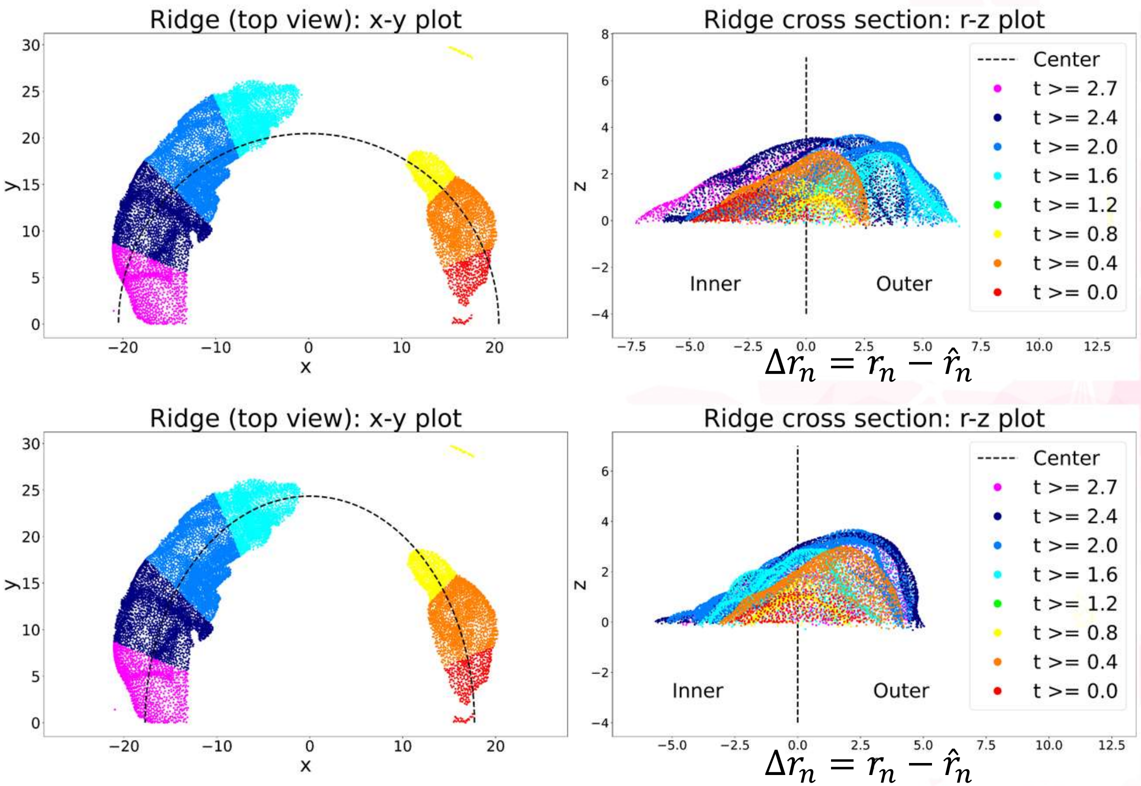
Circle shape

Ellipse shape

Cross Section: Natural Ridge

Circle

Ellipse

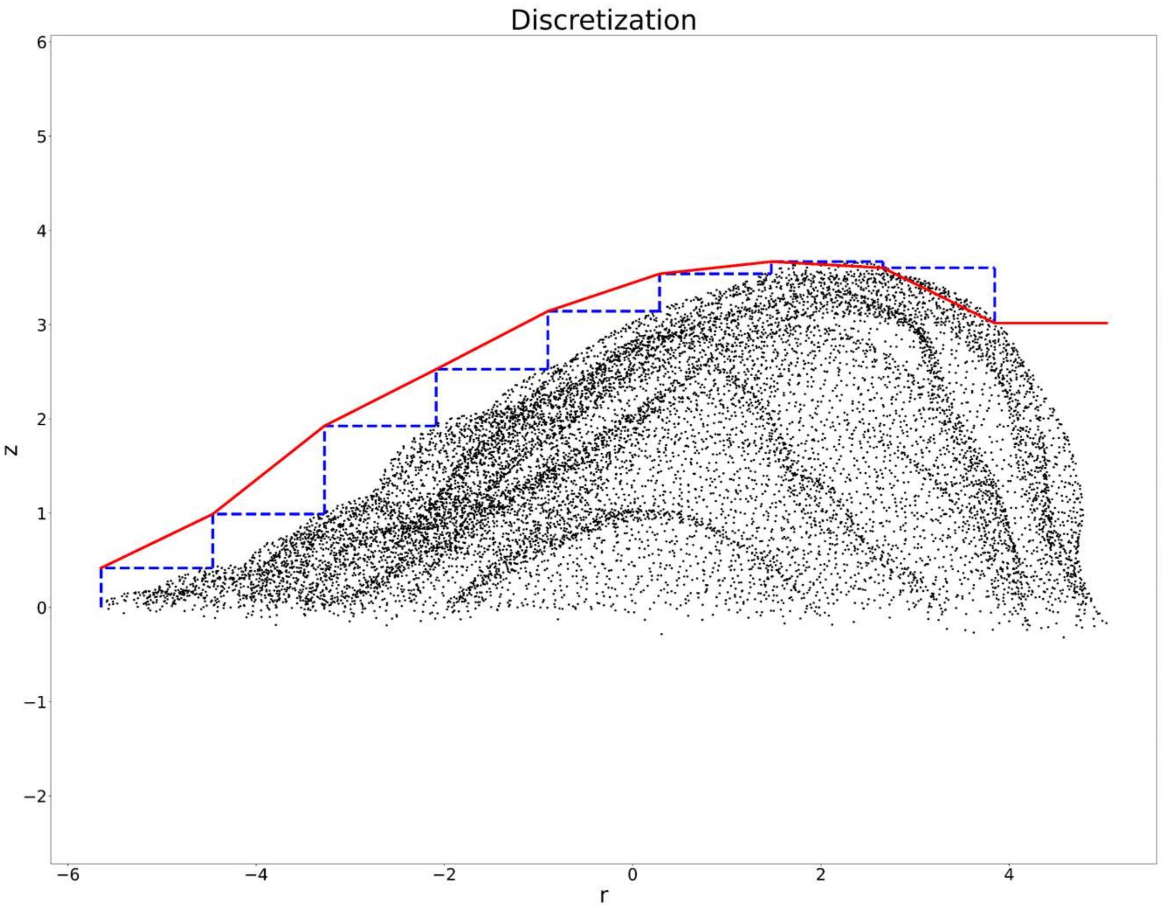


What we have learned:

* Ellipse captures the natural shape much better than circle.

* Having datapoints in $(z_n, \Delta r_n)$ reveals a natural outline of the ridge.

Natural Ridge to Cross-Section Outline



* Ridge datapoints $(z_n, \Delta r_n)$ form point-cloud data.

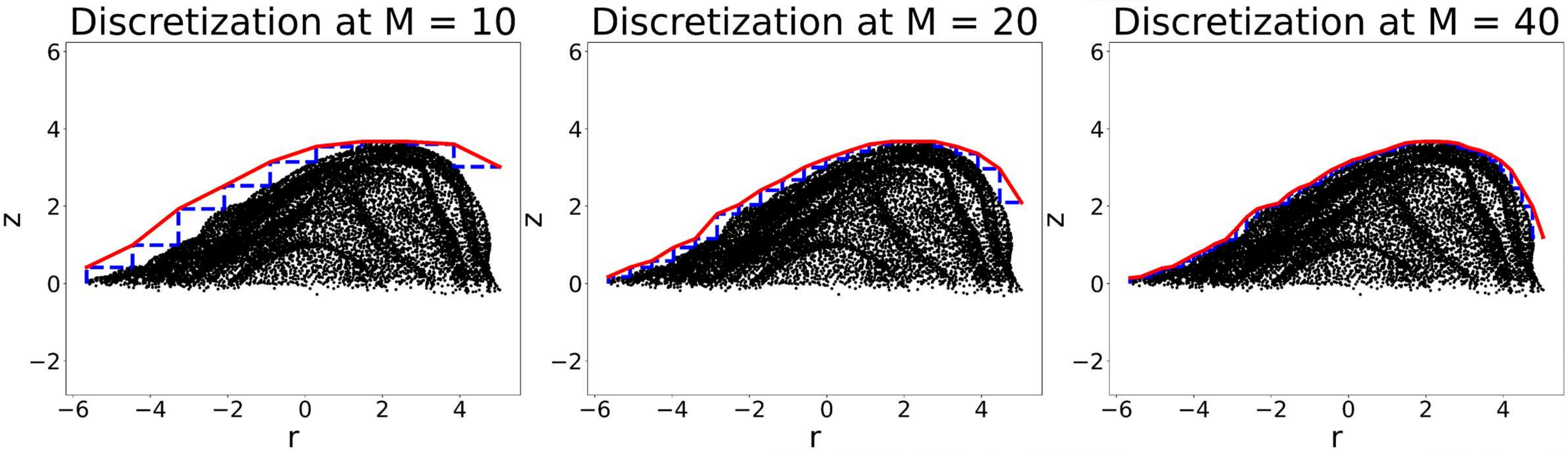
* The outline of the cross-section is obtained by discretization (blue dashed).

  * M bins
  * bin height, $h_i = \max(\{z : z \in bin_i\})$

Note: with correction for global height.

* Smoothen out by linear interpolation (red).

Cross-Section: Discretization

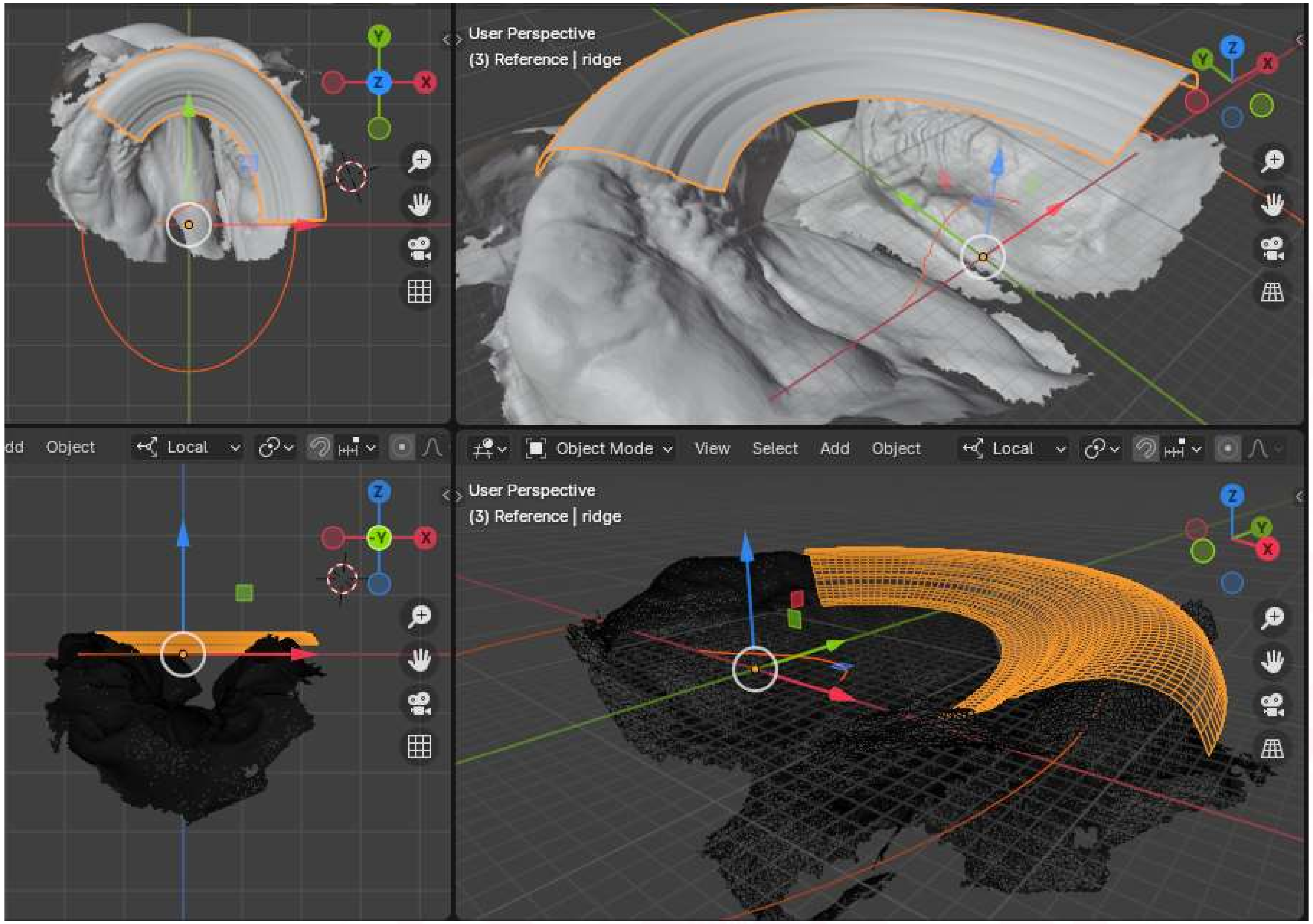


The higher resolution (more bins) we use, the closer the approximation to the natural outline.

Creating The Bridge Model

A bridge with
* elliptic shape
* uniform cross-section

can be created using a common CAD operation, e.g., bevel in Blender.

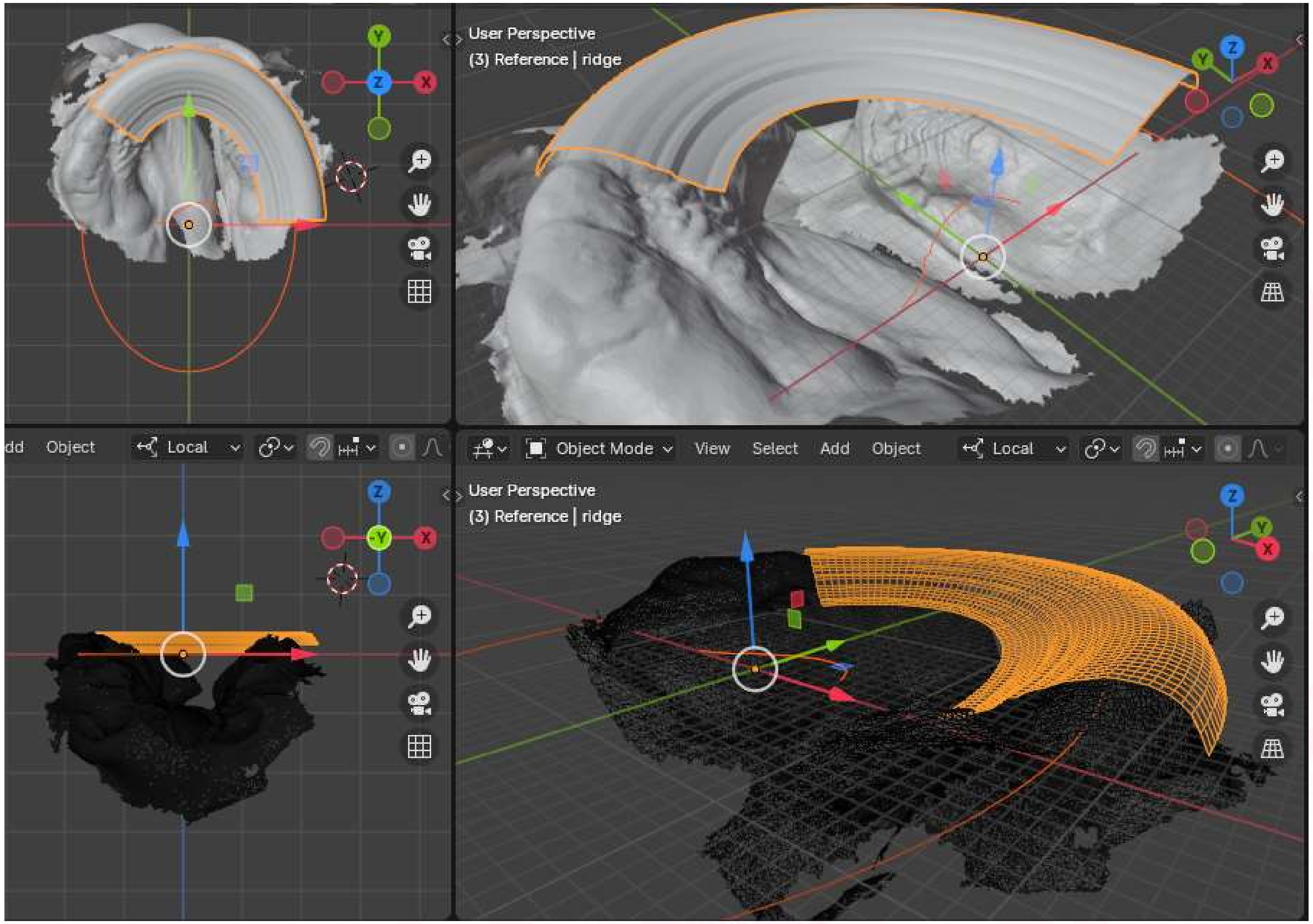


Assessment

Subjective assessment by experts

* Average quantitative score: 6.75

* Major concerns:
  1. The coverage of the bridge is not sufficient.
  2. Adjustability of the segment.



Conclusion

* A pilot study on generating a 3D geometry of the bridge model---precursor to the iDNAM design.

* Achieving 3D geometry generation using low computation techniques: coordination transformation, ellipse modeling, discretization, linear interpolation, and common CAD operations.

* Assessment shows viability of the key mechanisms in the approach, yet reveals rooms for improvement.

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Reference points

Anthropometric landmarks