

Optimizing the 3D Plate Shape for Proximal Humerus Fractures

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Context

Contoured spiral plates are a type of implant used to treat proximal and shaft humerus fractures. They aim to:

- Maintain pieces of bone together \bullet
- Achieve a small plate-to-bone distance, which is important for healing \bullet

During surgery the surgeon bends the plate to make it fit to the bone.

This process is:

- Imprecise
- Time consuming \bullet
- Fragilizes the plates



Plate Plate Fit position deformation





Comparison with SOTA

Objective

- Personalized plate shapes
- Improved fit over bent plates
- Set of shapes to be pre-printed

Custom Plate

Optimal plate defined by the surgeon



Given a bone, how to generate it?

Register a humerus template to each bone of our dataset

- Anatomic regions should be preserved (smooth shells [1])
- Build a statistical shape model of the bone using PCA



For a scanned bone, we compare:

- The existing commercial plate bent by the surgeon
- The custom plate extracted from the bone surface
- The **best** plate **from** the **plate set** of size 5

2. 3D printed

- 3D print the plates and bones
- Ask surgeon to choose the best plate and position it
- Compare with our automatic plate selection and placement







plate set

hand bent

- From the registration, we can **get a plate shape for any bone**
- From 96 bones we extract **96 plates**

Generate a Plate Set

3D printing a personalized plate is long

- Set of plates to choose from
- Readily available

Can one plate fit several bones?

We define a **fit criteria** for a plate on a bone.

We **position each plate** on a bone by

$\boldsymbol{B}_4 \quad \boldsymbol{B}_5 \quad \boldsymbol{B}_6 \quad \boldsymbol{B}_7 \quad \boldsymbol{B}_8 \quad \boldsymbol{B}_9 \quad \boldsymbol{B}_{10}$

3. Ex-vivo

Insert 3D printed plates inside the cadaveric arm

Humerus head

CT scan and surgeon feedback for evaluation





Plate



minimizing a cost function to:

- Bring the plate close to the custom plate position
- Meet the fit criteria
- ✓ Most plates accommodate several bones. \checkmark We order them to maximize population accommodation.

Plate-bone distance < 5mm

Plate-bone distance < 2mm

We obtain a **reduced plate set**

Plate set fit rate





Take Away

- Importance of Evaluation lacksquare
 - On 3D Printed Bones
 - On Ex-Vivo Arms
- Theoretical fitting constraints can be relaxed



[1] Eisenberger, M., Lahner, Z., & Cremers, D. (2020). Smooth shells: Multi-scale shape registration with functional maps. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 12265-12274).

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