Registration of the Human Femur

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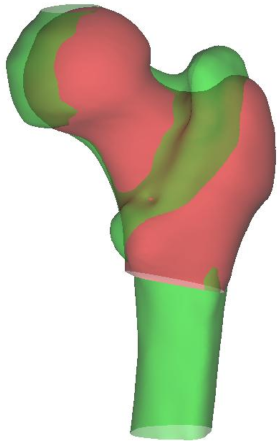
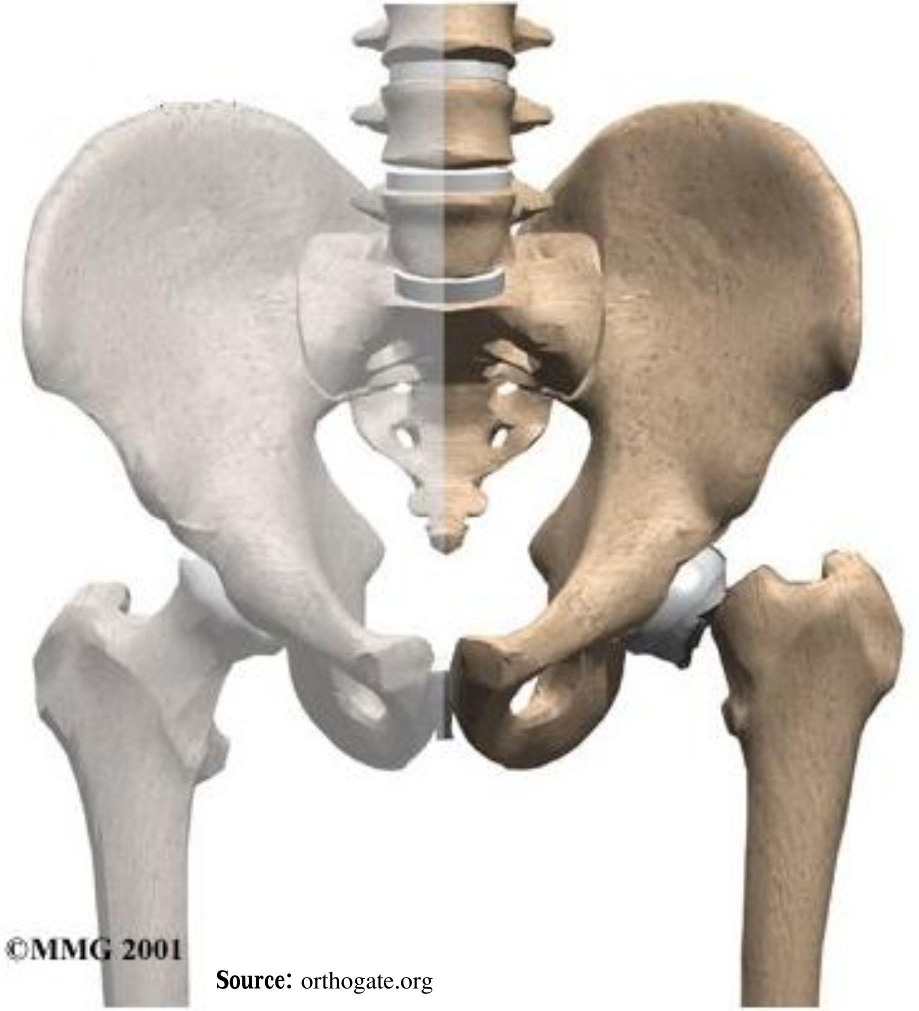


Motivation: Hip Fracture



Source: orthogate.org

- Hip fracture: **serious** and **common**

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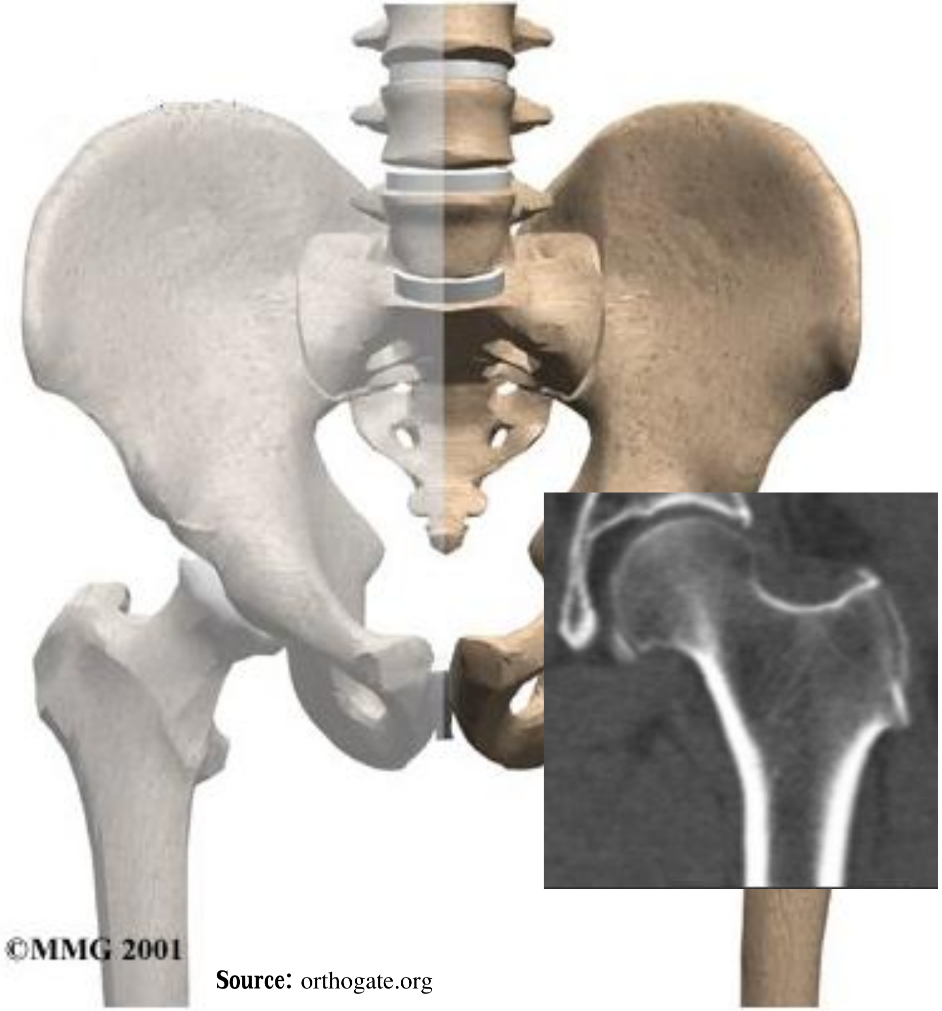
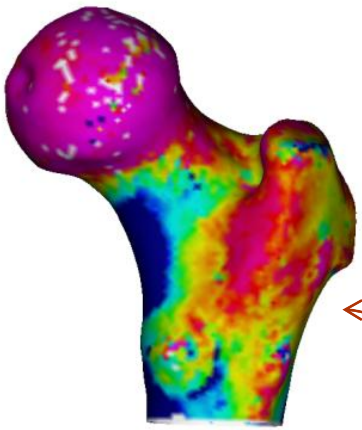


Source: orthogate.org

- Hip fracture: **serious** and **common**
- Thickness of **cortical layer** thought to be a key factor.
- **Cohort analysis:** Compare cortical thickness across large datasets. Aims:

1. Identify **high risk** individuals
2. Aid development of **preventative medicines**

Motivation: Hip Fracture



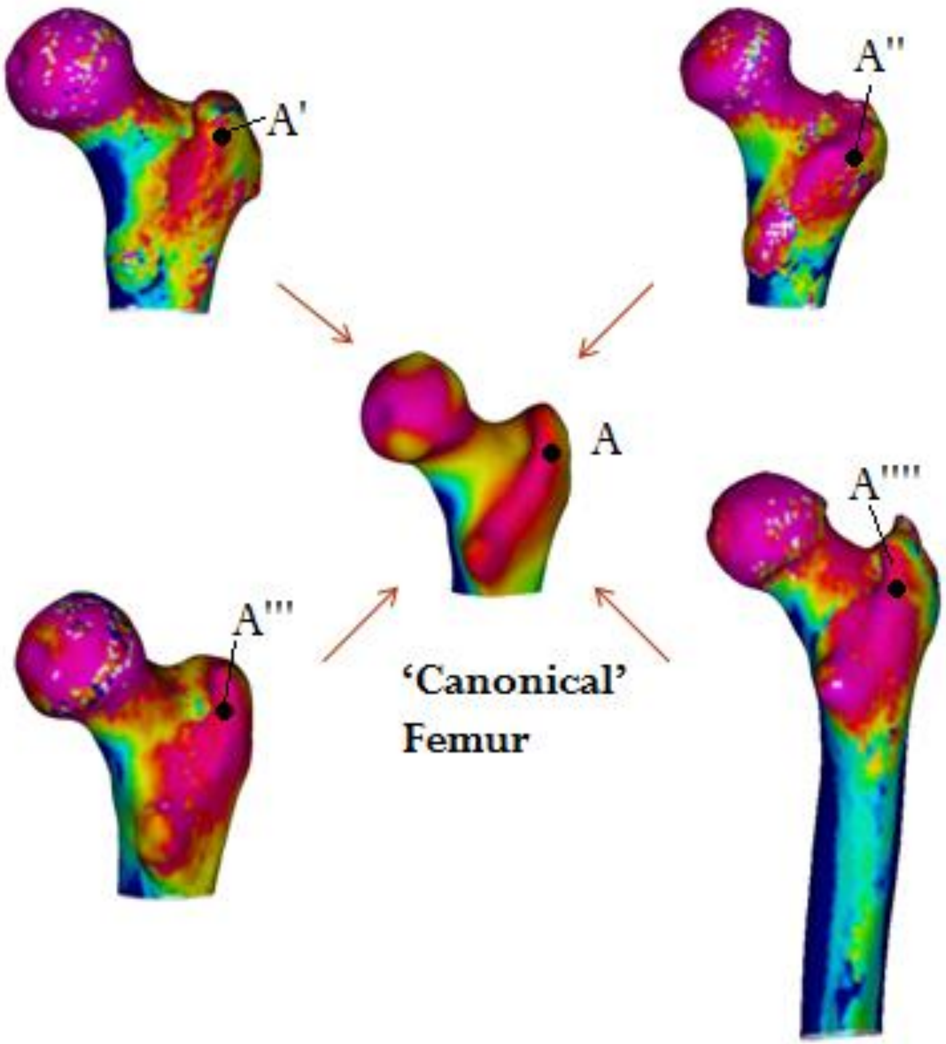
Cortical Thickness Map

CT Volume Image

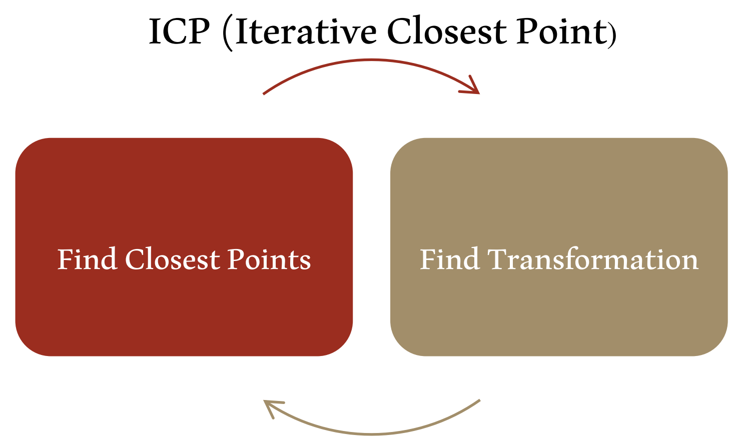
- Hip fracture: **serious** and **common**.
- Thickness of **cortical layer** thought to be a key factor.
- **Cohort analysis:** Compare cortical thickness across large datasets. Aims:
  1. Identify **high risk** individuals
  2. Aid development of **preventative medicines**
- Extract **cortical thickness map** from CT data.

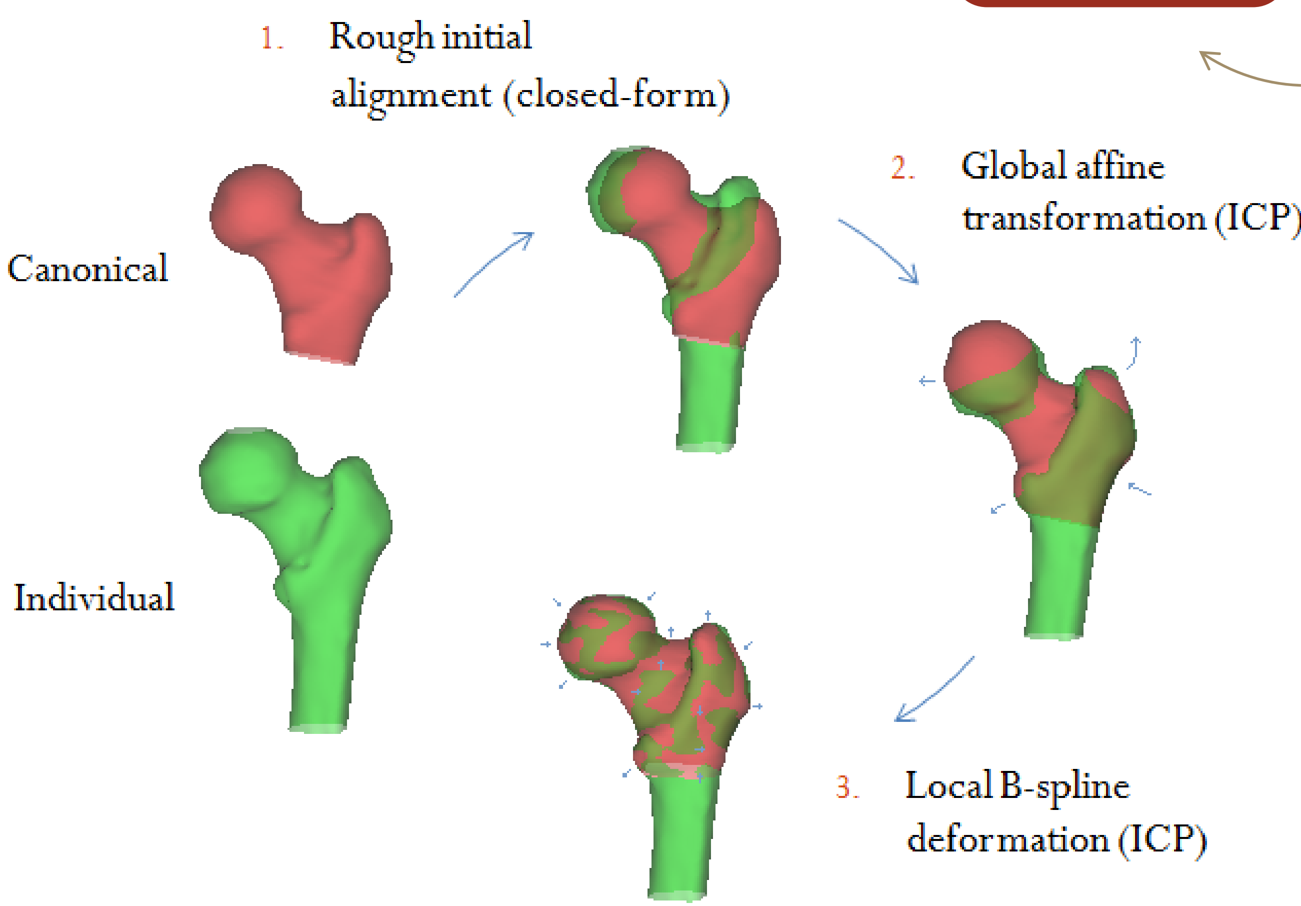
Motivation: Femur Cohort Analysis

- Obtain **cortical thickness map**.
- Femurs come in all shapes and sizes!
- Need to **register** surfaces to **canonical model** for comparison.
- Find **correspondence** between points on surface by applying a **transformation**.



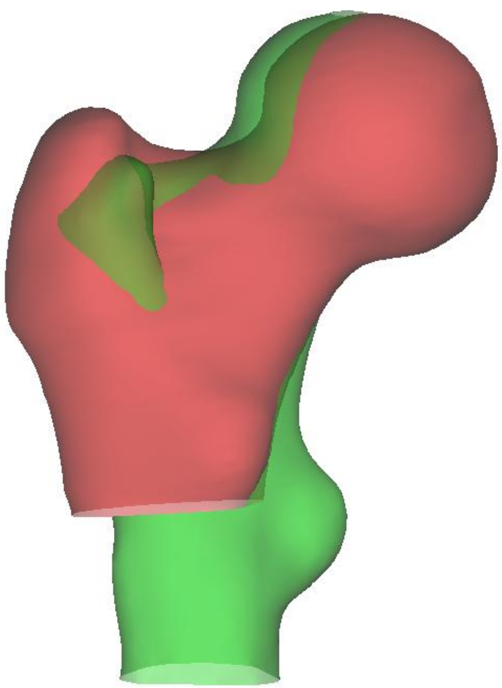
Existing Software



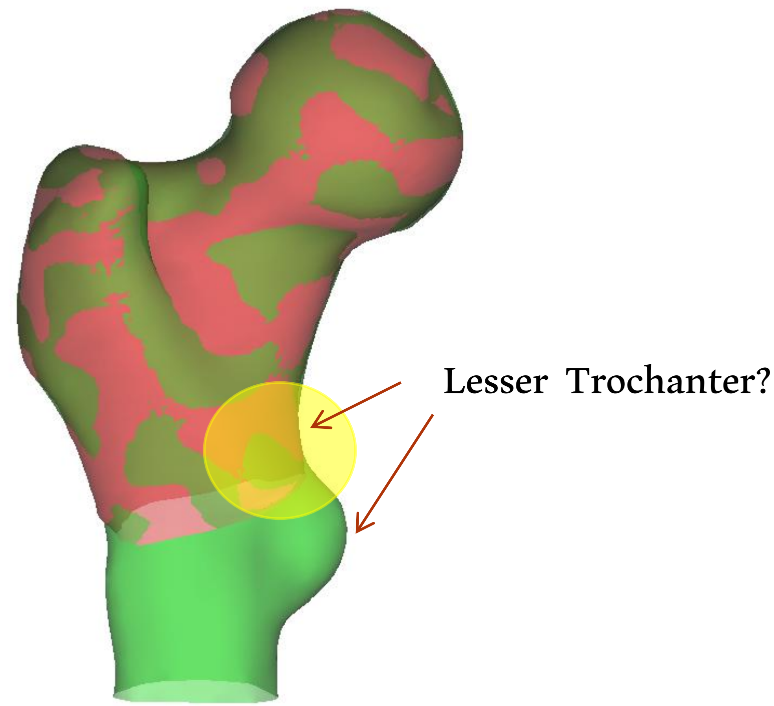


Michaelmas Presentation Summary

- The problem of **registration failures** introduced – registrations where key anatomical points are not aligned.



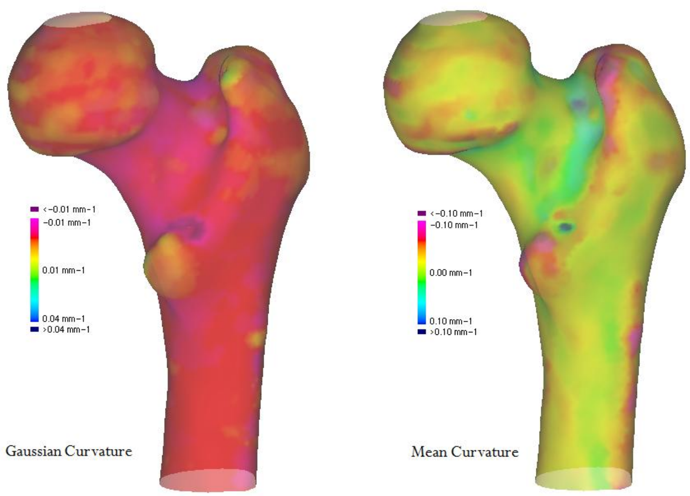
Before Registration



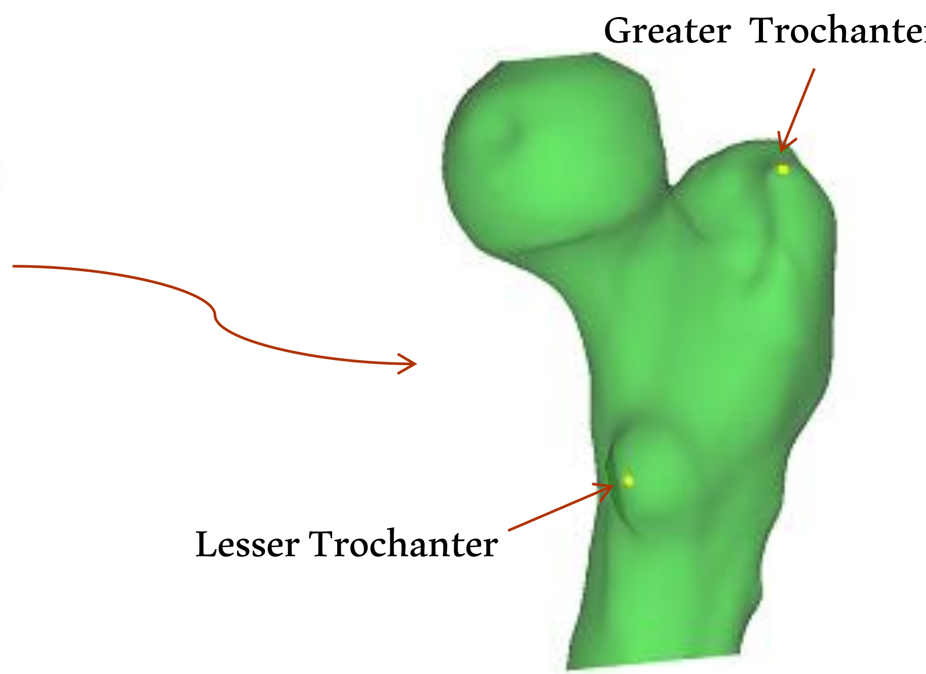
After Registration

Michaelmas Presentation Summary

- ‘Solved’ by using **surface curvatures** to help select **distinguished points,** and forcing these to align.



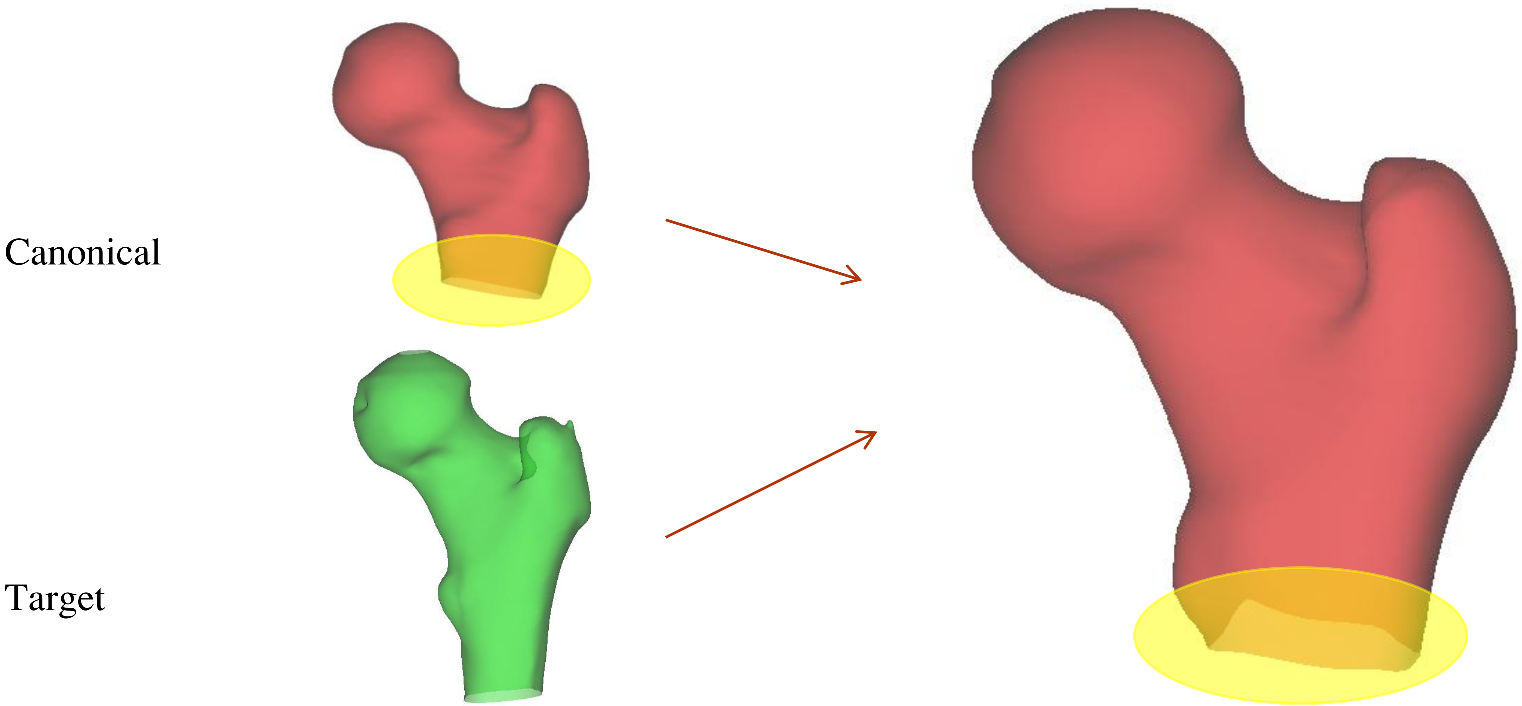
Surface Curvature Estimates



- Gives a **0.8% failure rate** (reduced from 5.9%), but results in catastrophic failures.

New Problem: Warping

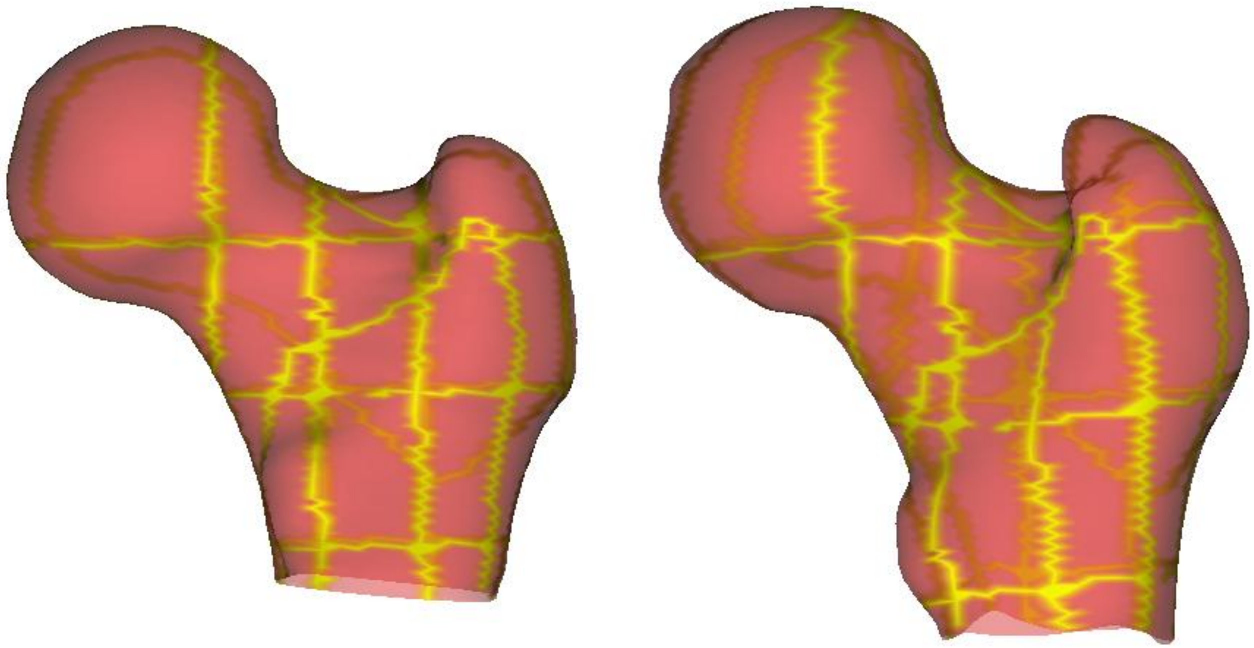
- Resulting transformation should not contain **unnecessary warping**, as it is **physically implausible**.



- How can we **measure** this?
- How can we **reduce** it?

Measuring Warping

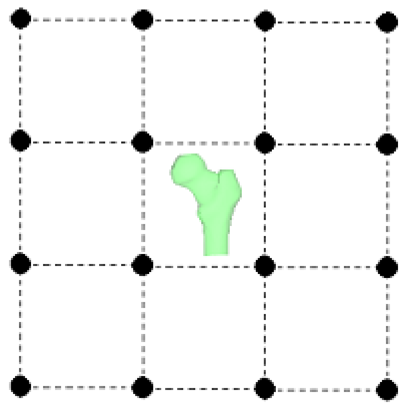
- To what extent do coplanar points remain coplanar?



- Find contours on the un-deformed surface – measure how far from coplanar they are after registration.
- Rather simplistic, but gives a quantitative way to start analysing the problem.

Reducing Warping - Localised Transformations

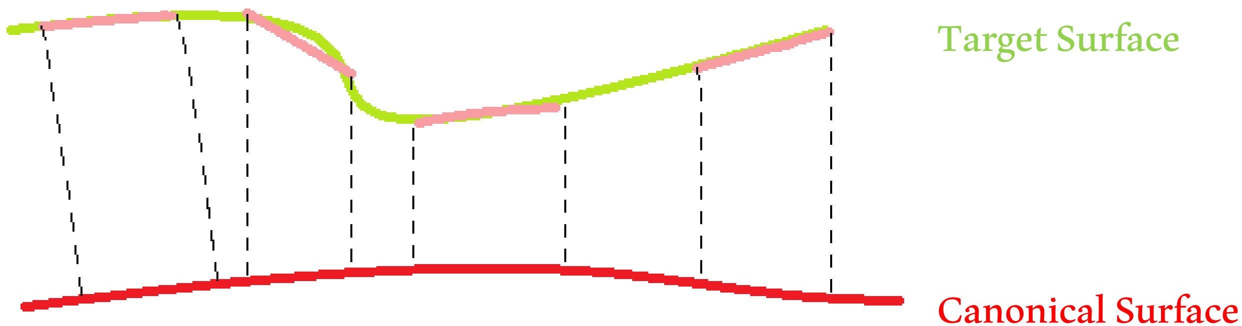
- Volumetric B-spline on 4x4x4 grid – **all** control points affect **all** points on surface.
- E.g. matching the head and neck has unwanted effects on the shaft.



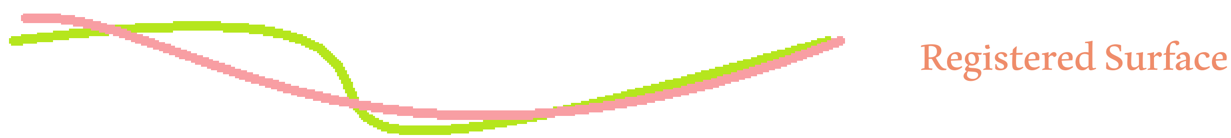
- Use finer grid? Huge optimisation problem (expensive, local minima).
- Constrain the B-spline transformation?
- Use a different, **non-parametric** approach?

The ‘Locally Affine’ Transformation

- Work with small patches at a time:
    - Find **rigid-body transformations** for each patch

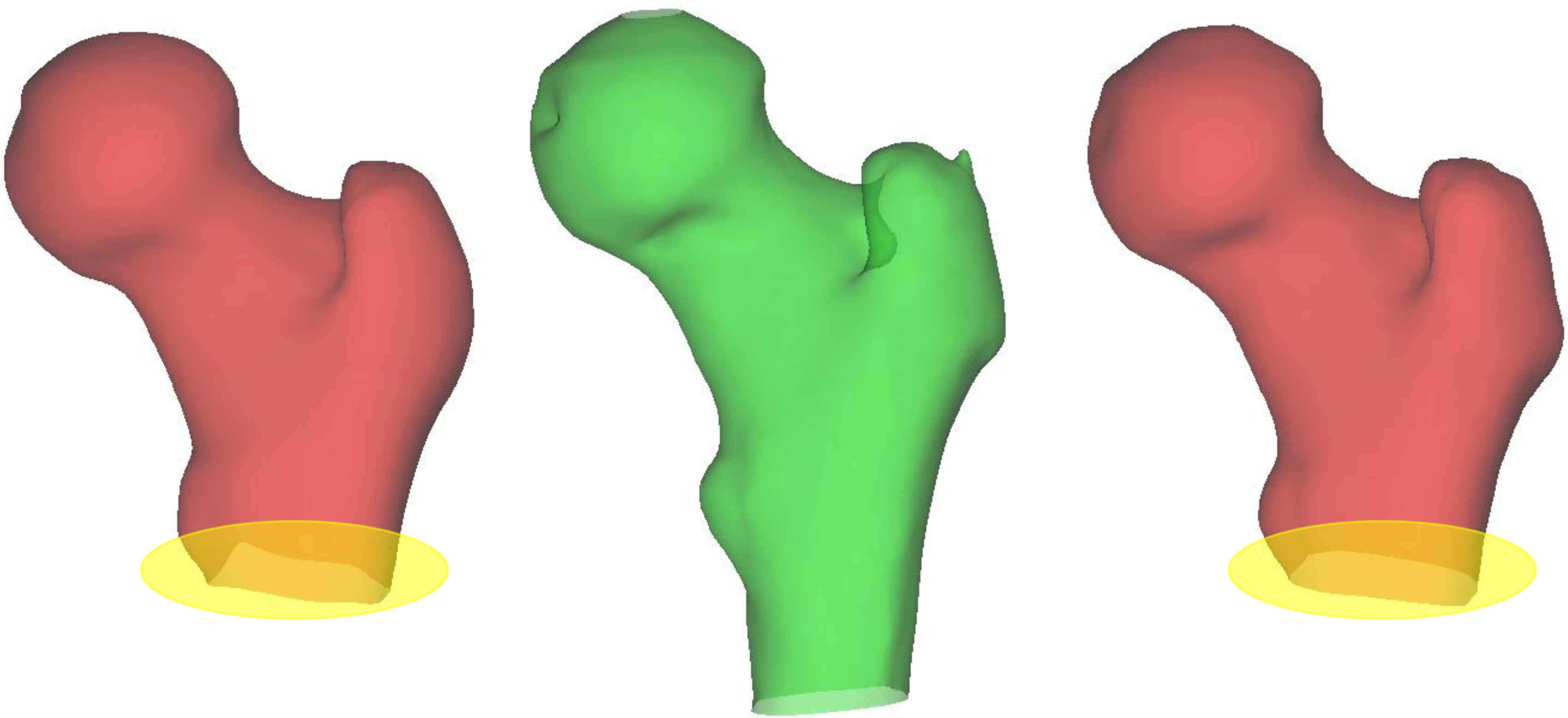


    - **Smooth** these to give affine transformation at each point



- Localisation explicitly controlled by patch size.
- Many, small optimisations.

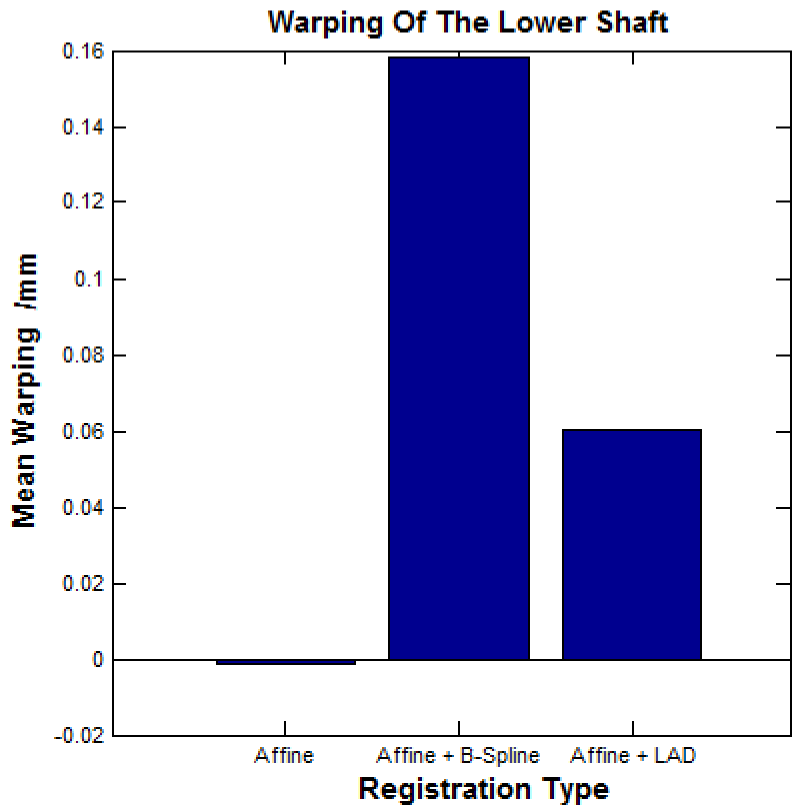
Results



B-Spline Registration | Target Surface | Locally Affine Registration

Results

- Tests run on a dataset of over 600 femurs.
- Measure warping using change in distance of points from coplanarity



- Some improvement over B-spline, especially on the lower shaft.

Conclusions

- **Distinguished points** useful for preventing registration failures.
- The **locally affine** method useful for reducing warping.
- Some other methods evaluated – not so successful.
- Difficult and subtle problem – further work needed.