BONEFINDER – A NEW INNOVATIVE SOFTWARE TO OUTLINE CONDYLES IN OPG IMAGES

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INTRODUCTION

MORPHOLOGY OF CONDYLE

- OPG
- CT
- CBCT

WHY OPG?

- Ease of availability
- Initial screening modality
- Low exposure dose
- Ease of prescription
- Ease of accessibility
- Favorable cost-benefit relationship
- Comparison between two sides of condyle

ASSESSMENT OF CONDYLE NEEDED

- Understanding pathological alterations
- Diagnostic evaluation
- Treatment follow up

Literature review

Understanding the morphology of the condyle is essential

SHAPES OF CONDYLE

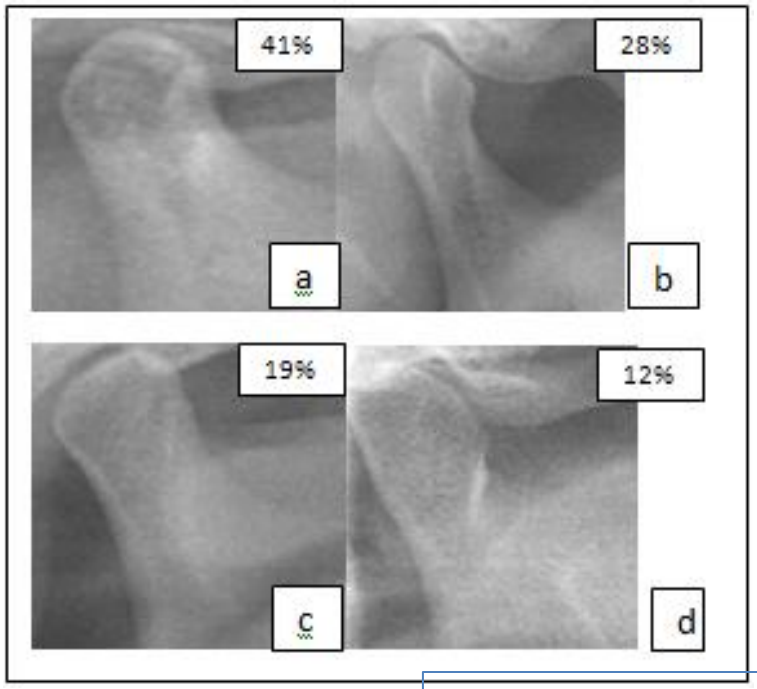
1961, Yale et al

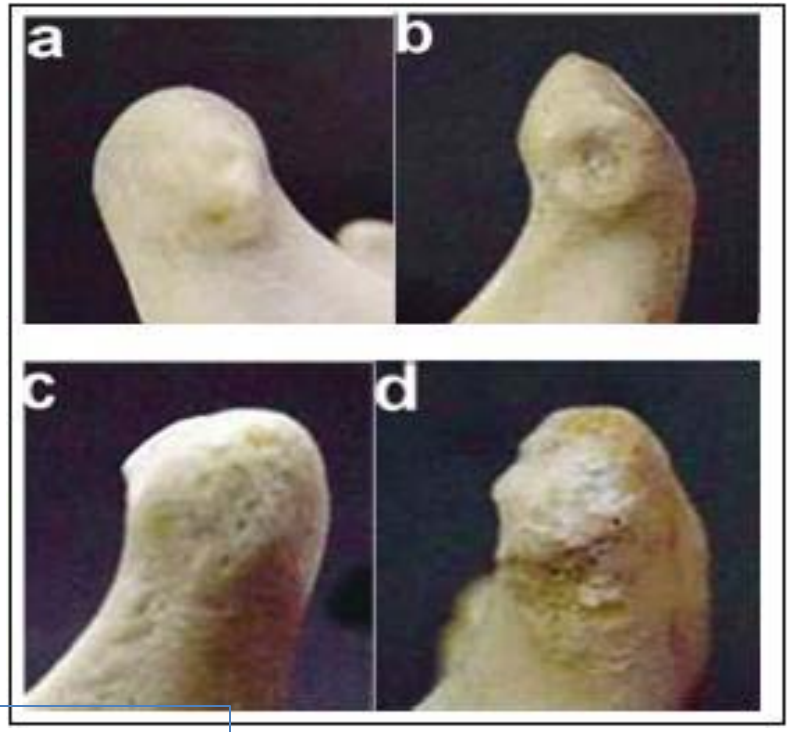
- Type A – Flat
- Type B – Convex
- Type C – Angled
- Type D – Rounded

Literature review

Normal variation of the condylar morphology occurs by various factors

Ribeiro et al, have classified condyle in four types in lateral view – round, angled, flattened and mixed





Round type -common

CONDYLAR MORPHOLOGY

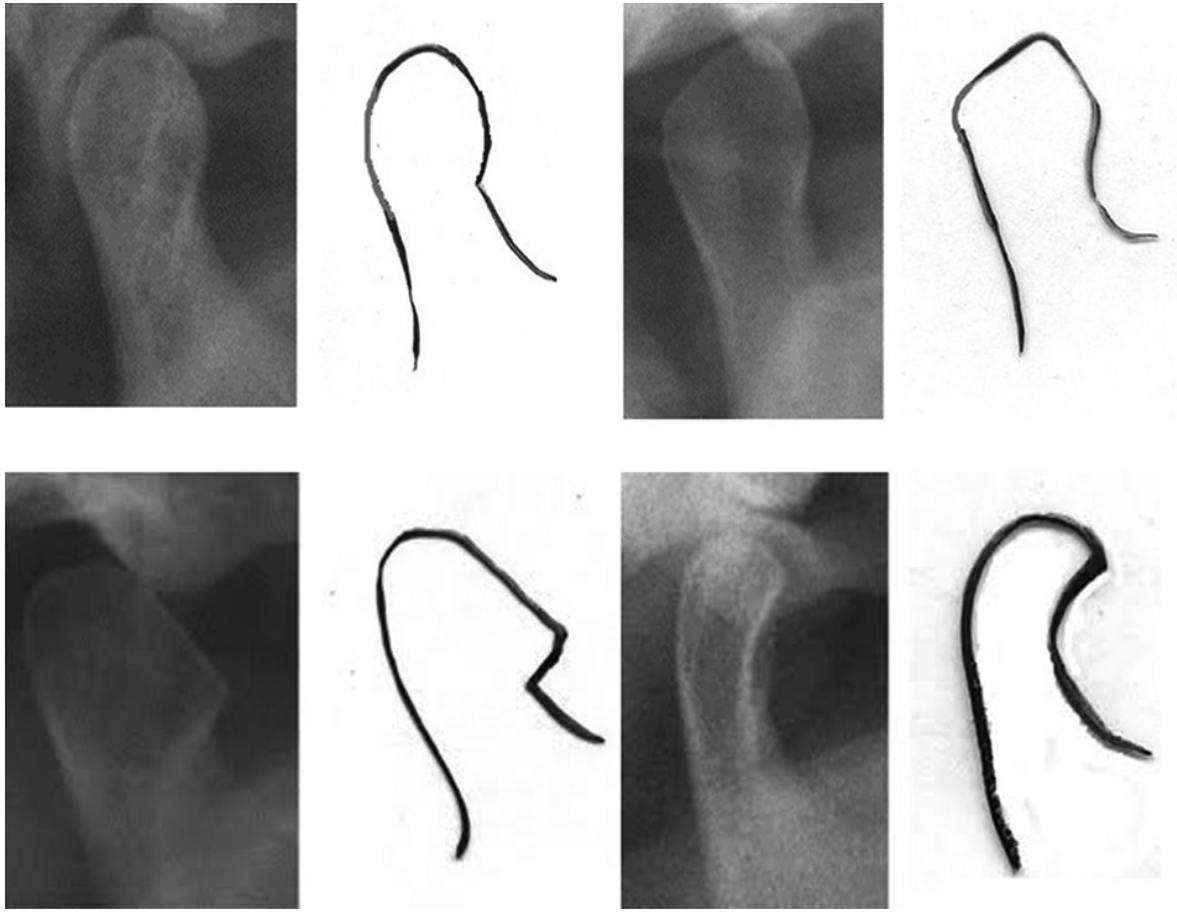
Chaudhry *et al*.

Type I – Oval

Type II – Diamond

Type III – Bird beak

Type IV – Crooked finger shape.



All these studies done manually

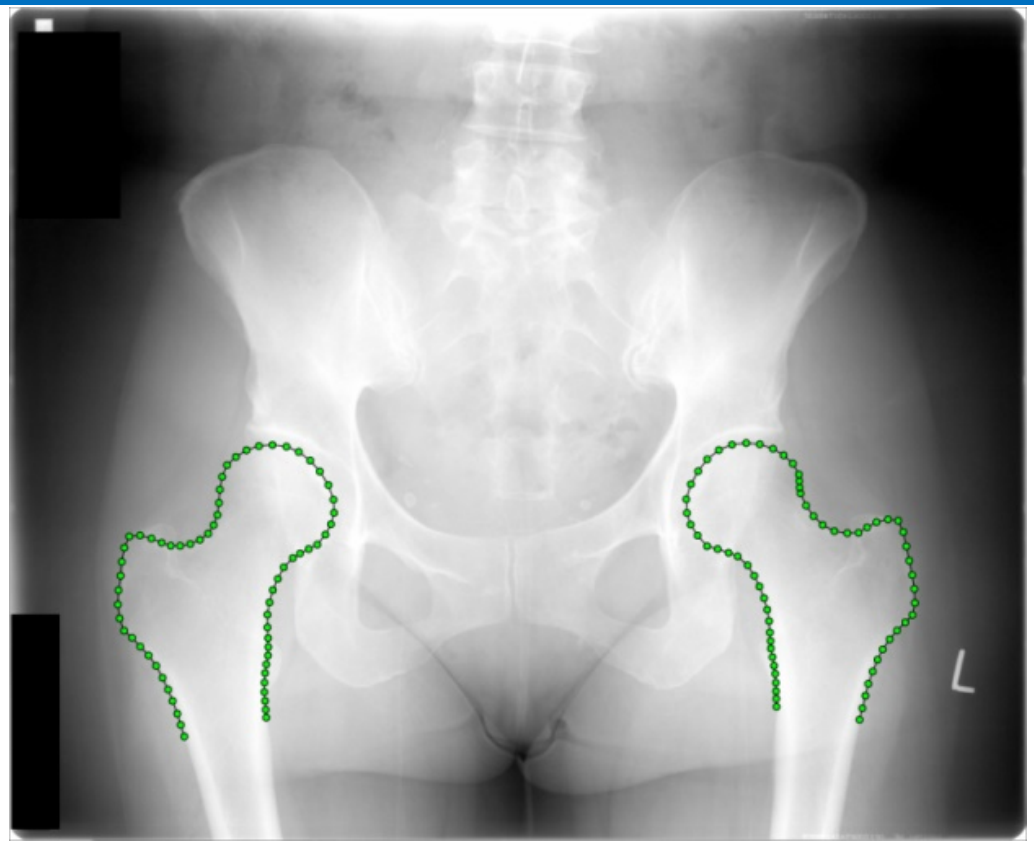
Objectives of the study

USING BONEFINDER SOFTWARE

1. To evaluate the variation in shape of condyle in Indian population
2. To determine the shape dominant in the population
3. To assess whether there is a peculiarity in either gender
4. To compare the symmetry between right and left side of joint in same patient

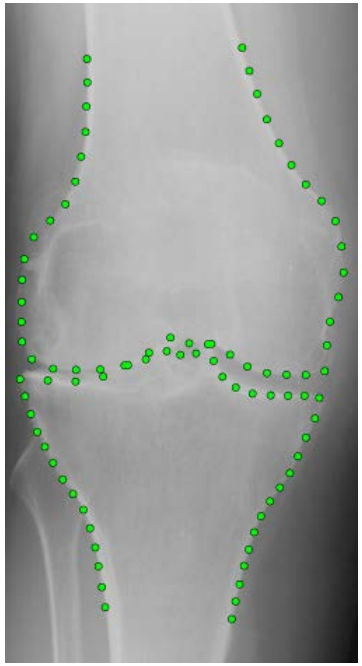
BONEFINDER SOFTWARE

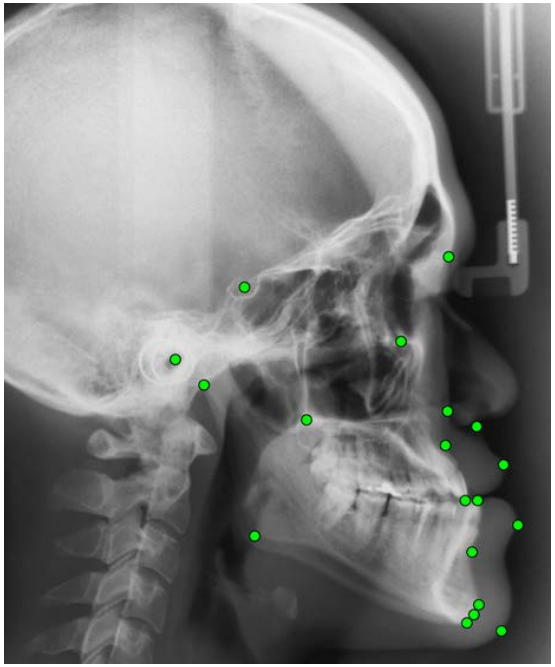
- Fully automatic software tool to find and segment skeletal structures in 2D radiographs.
- BoneFinder was developed at the University of Manchester, UK, and is already in use for assessing the shape of the joints of the hip and knee by arthritis research groups across Europe and in the US.

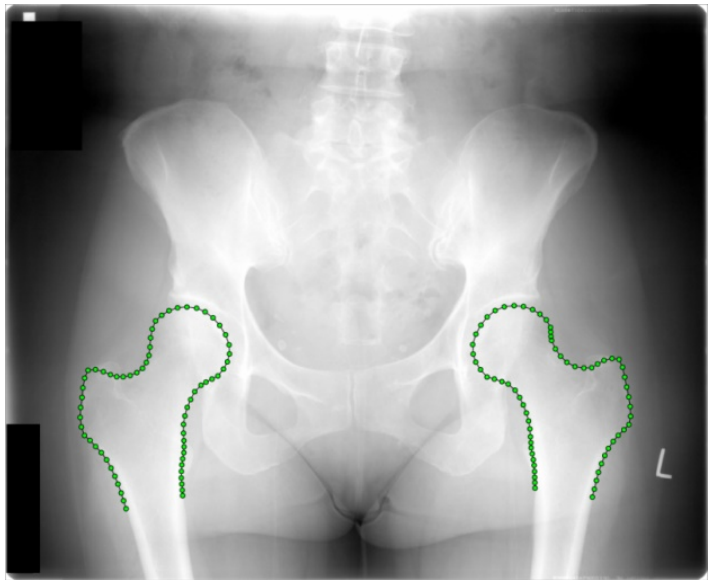


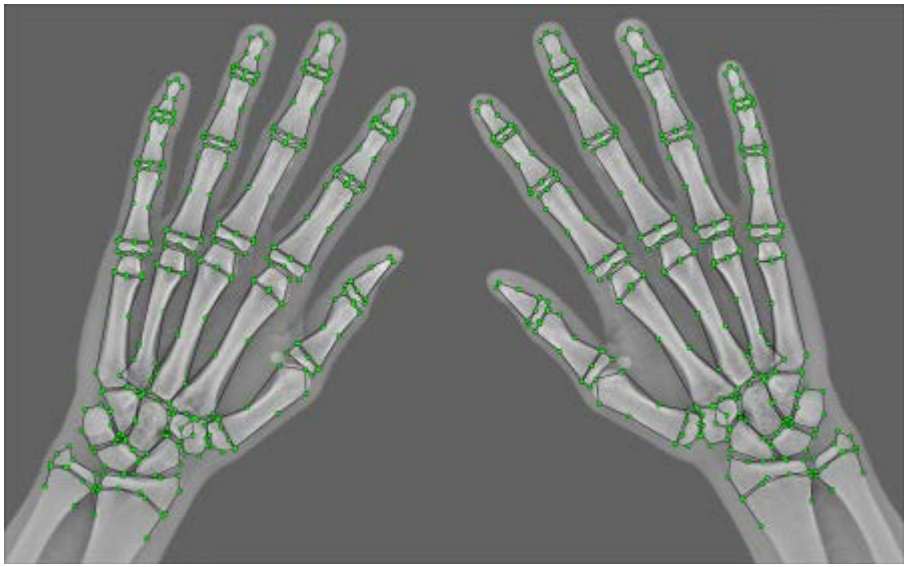
- Originally designed - segmentation of the femoral head in hip joint (osteoarthritis)

- Later - knee joint, hand bones and cephalometric landmarks

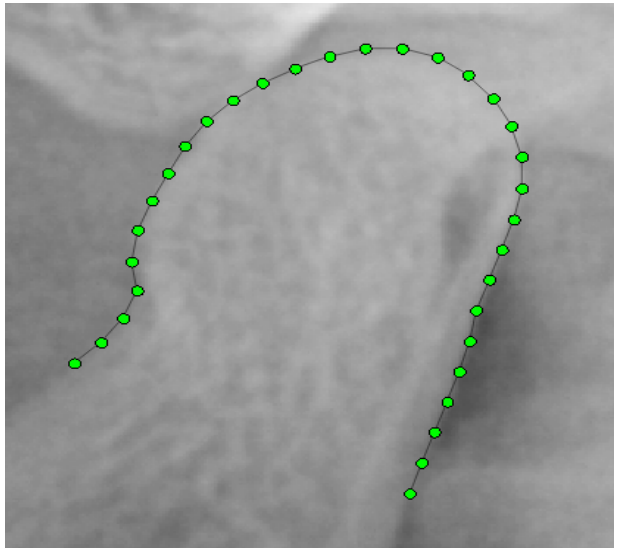








Assessing shape of the condyle using BoneFinder software



- Spend less time for manually enhancing x-rays, and more time "drawing conclusions and developing treatments."
- Save thousands of hours on manual work performed by radiographers.

BONEFINDER SOFTWARE

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Machine learning approach

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Trained on lots of images

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Identify rough position of bone in image

↓

Outline its contour

↓

To find and segment similar bones in new image

↓

Robust & accurate point placements across skeletal application areas

↓

Shape analysis

Hough Forest like approach
Random Forest Regression-Voting

↓

Building statistical shape models / Automatically deriving geometric measurements

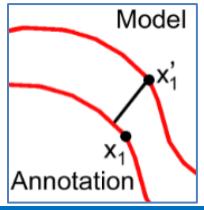
METHODOLOGY

- Sample- 100 digital OPG (200 condyles)
- 33- M, 67- F
- 18-45 years
- No history of TMJ pain

Fully Automatic Search Results obtained via BoneFinder (www.bone-finder.com)

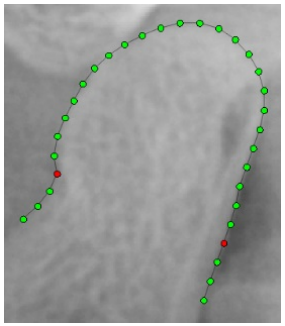
- BoneFinder is a machine-learning system that learns from manually annotated data.
- It fully automatically outlines the structure of interest in new unseen images.

Mean point-to-curve distance (averaged over all 32 points per image):



Mean point-to-curve distance of 2-fold cross-validation results
Median: 1.1 pixels
90%ile: 3.6 pixels
95%ile: 5.7pixels

For reference, average distance between points 3 and 28 (red points): 128 pixels



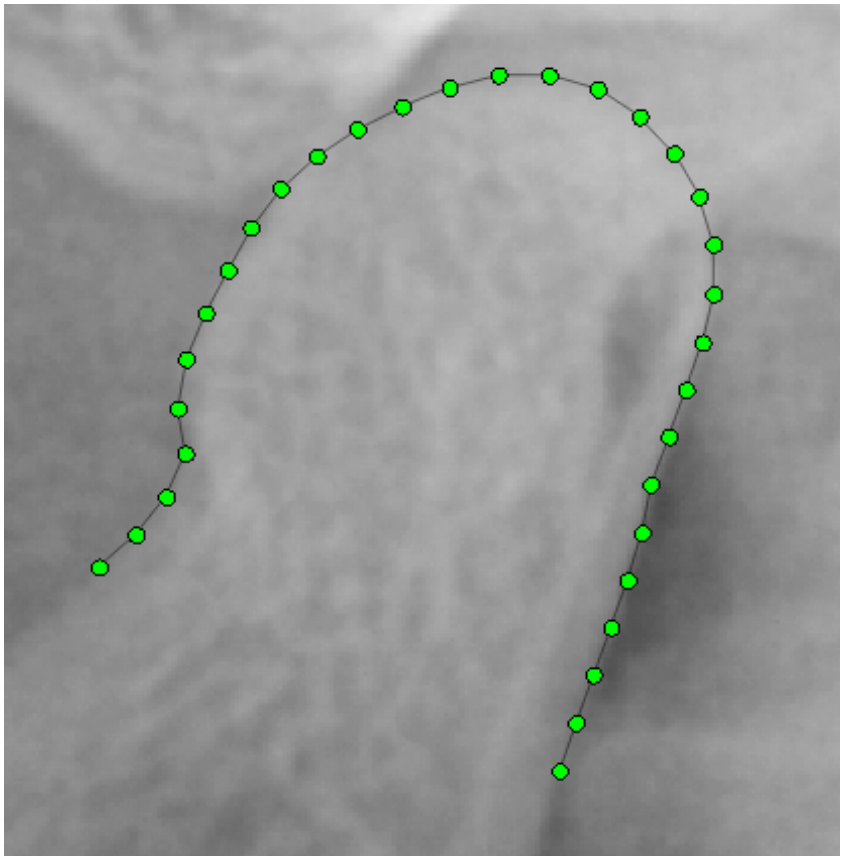
Conclusion:
BoneFinder is highly accurate in automatically outlining the condyles in OPG images.

Comments:

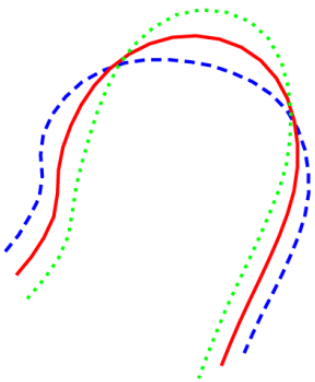
- The BoneFinder system that was trained for the quantitative evaluation above was only trained on 50 subjects (2 sides each).
- Experiments from other skeletal structures suggest that the automatic search performance will significantly improve if 300+ subjects were used to train the system.
- Future work will include the above performance analyses using a larger training dataset.

Statistical Shape Modelling of the Condyles in OPG Images

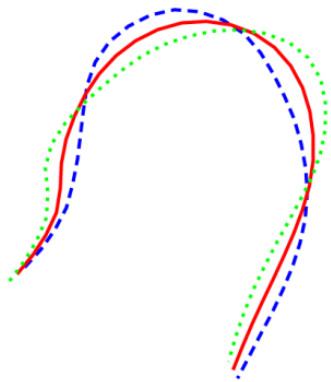
Annotation:
Each condyle was manually annotated with 32 points



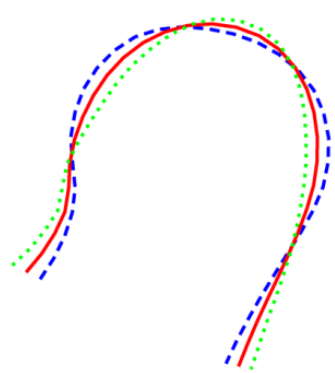
Full shape model (n=100, two sides each):
5 modes explain 95% of shape variation.
8 modes explain 98% of shape variation.



Mode 1

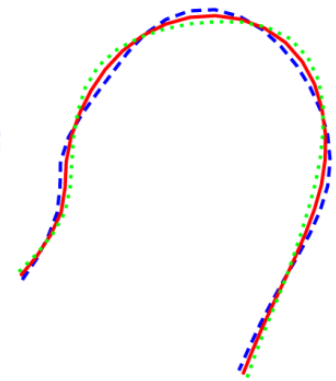


Mode 2

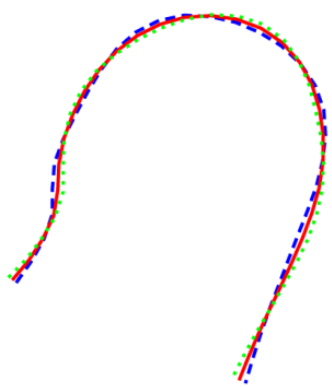


Mode 3

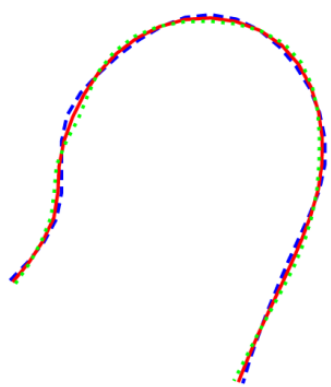
Mode 4



Mode 5



Mode 6



Mode 7

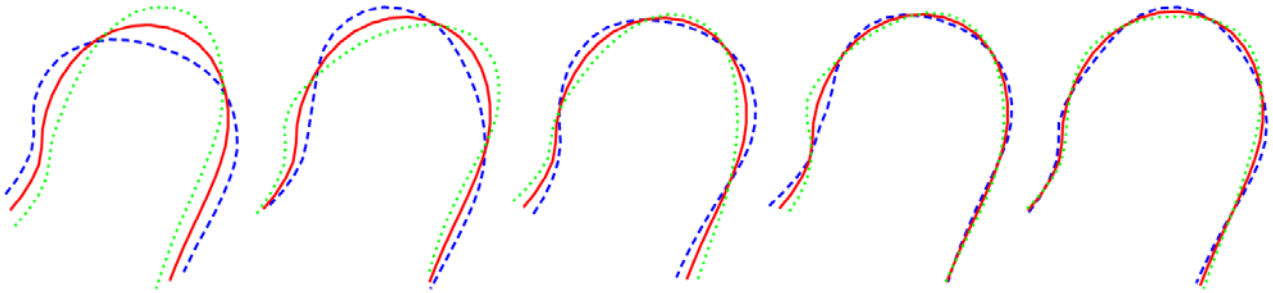
Mode 8

Conclusion:
The main mode of variation across all subjects is between an elongated oval shape and a flattened round condyle shape.

The second main mode of variation is between the condyle being crooked and a angled condylar shape.

Gender Analysis

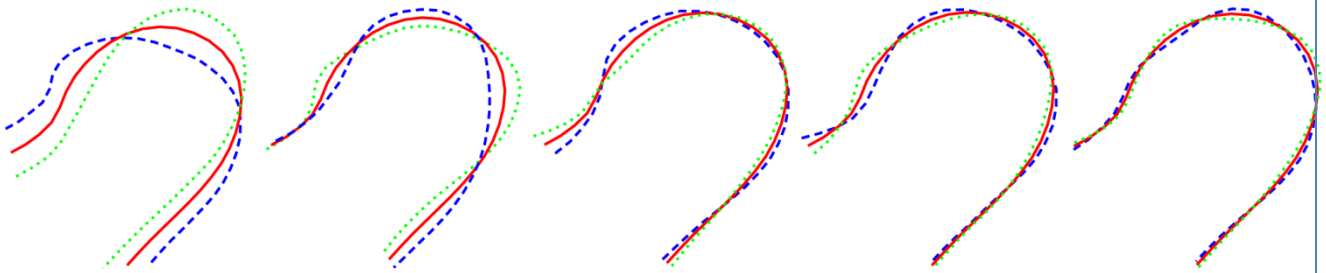
Female shape model (n=67, two sides each):
5 modes explain 95% of shape variation.



Mode 1 (53.2%) Mode 2 (23.7%) Mode 3 (10.7%) Mode 4 (4.9%) Mode 5 (2.7%)

[The brackets () above give the amount of shape variation explained per mode.]

Male shape model (n=33, two sides each):
5 modes explain 95% of shape variation.

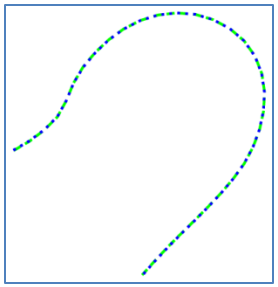


Mode 1 (65.9%) Mode 2 (17.9%) Mode 3 (6.1%) Mode 4 (3.7%) Mode 5 (2.1%)

[The brackets () above give the amount of shape variation explained per mode.]

- These five shape modes suggest that the variation across males and females is very similar
- The general tendency of shape variation in terms of different classes is consistent across gender.
- The first shape mode explains significantly more of the shape variation in males than in females.

Overlaying the mean shape of the female and male models does not show any visible differences:



Correlation analysis between first five shape modes and gender

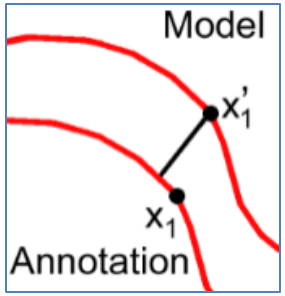
Ntests GENDER:	5				
p-value for significance:	0.010				
Nsamples:	200				
Correlation with GENDER:	-0.0733	-0.0518	0.0654	-0.0103	-0.1259
p-value for GENDER:	0.3025	0.4667	0.3578	0.8854	0.0758

Conclusions:

There is no significant correlation between any of the first five shape modes and either gender (analysed using Pearson correlation analysis).

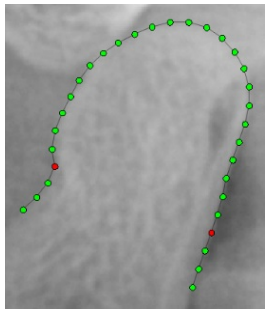
Symmetry Analysis

Mean point-to-curve distance (averaged over all 32 points per image):

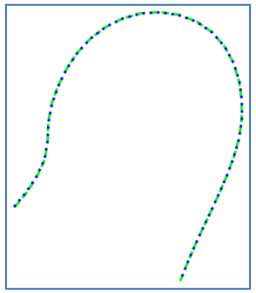


Analysis of *mean point-two-curve distances* between left and right sides of each subject:
Median: 3.1 pixels
90%ile: 6.0 pixels
95%ile: 8.0 pixels (i.e. for 95% of images the average distance between left and right over all points is 8 pixels.)

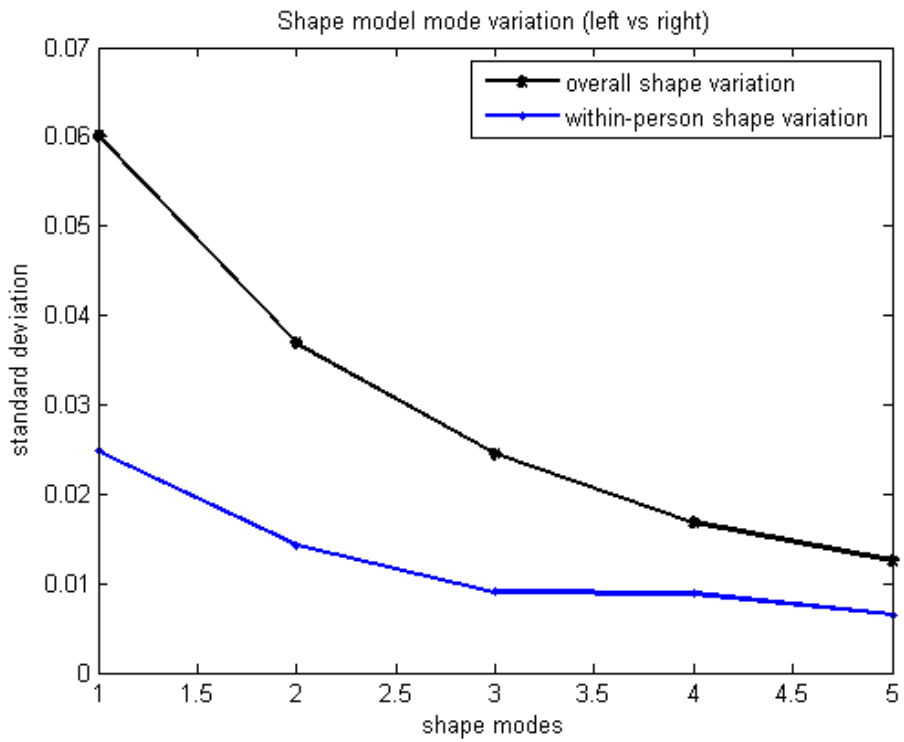
For reference, average distance between points 3 and 28 (red points): 128 pixels



Overlaying the mean shape of the left and right sides does not show any visible differences:



The shape variation between the left and right sides per subject is small compared to the overall shape variation in the dataset:



Conclusion:
The left and right condyles of an individual are highly symmetric.

Future Work

- More training data for the automatic BoneFinder search model
- Exploration of automatic classification into previously identified subgroups
- Inclusion of more subjects into the shape analysis
- Investigation of correlation between shape and age
- Investigation of correlation between shape with other clinical parameters like malocclusion, habits etc.
- Shape analysis in patients with osteoarthritis

References:

[1] C. Lindner, S. Thiagarajah, J.M. Wilkinson, The arcOGEN Consortium, G.A. Wallis and T.F. Cootes. "Fully Automatic Segmentation of the Proximal Femur using Random Forest Regression Voting", *IEEE Transactions on Medical Imaging*, Vol. 32, No. 8, pp. 1462-1472, 2013. DOI: 10.1109/TMI.2013.2258030

[2] C. Lindner, P.A. Bromiley, M.C. Ionita and T.F. Cootes. Robust and Accurate Shape Model Matching using Random Forest Regression-Voting. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 37, No. 9, pages 1862-1874, 2015. doi:10.1109/TPAMI.2014.2382106

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