Trochlear Development In Children One Month To 10 Years Of Age an MRI Study

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Trochlear Development: Purpose

• To perform an MRI-based evaluation of the femoral trochlea in a series of pediatric cadaveric knees, aged from 1-month to 10-years-old.

• When available, age matched specimens were separately analyzed. The biometric analysis encompasses parameters previously reported. (Wanner, 1997 and Glard et al., 2005)
Trochlear Development: Methods

- The study population consisted of 24 knees (12 M /12 F) from pediatric cadavers, aged 1 month to 10 years (Allosource, Inc.) An IRB waiver approval applied.

- MR Sequence: 3D-GRE sequence for Susceptibility-Weighted Magnetic Resonance Imaging: a non-invasive technique allowing precise distinction between cartilage vs. osseous morphology.
Trochlear Development: Methods

- 2 one-month-old male knees
- 2 three-month-old female knees
- 1 four-month-old male knee
- 2 nine-month-old male knees
- 3 one-year-old knees (2 female and 1 male)
- 2 two-year-old female knee
- 2 three-year-old knees (1 male and 1 female)
- 4 four-year-old knees (2 males and 2 females)
- 1 five-year-old male knee
- 2 seven-year-old knees (1 male and 1 female)
- 1 eight-year-old female knee
- 2 ten-year-old knees (1 male and 1 female)

4 samples (both two-year old female samples, the 5-year old male & the 10 year-old female) were excluded due to the low quality of the images acquired.
Trochlear Development: Methods

• For each sample, the MRI biometric analysis was conducted on the axial/sagittal/coronal views analyzing three slices; the most proximal slice corresponding to the location of full cartilage trochlear groove coverage.

• Patellar measurements were not performed due its absence in many specimens.
For each specimen, the MRI biometric analysis was conducted on the axial view analyzing three cuts

• Cut 1 corresponds to first cut where the intercondylar notch is recognized.

• Cut 3 is the most cranial cut corresponding to the full cartilage coverage of the trochlear groove (medial cartilage hard to distinguish from periosteum)

• Cut 2 was recorded as halfway between the first and the third cuts, and two methods were used to double-check the proper cut.

**Figure 1**: image showing the 3 different cuts analyzed
Figure 2: Image showing the 3 different cuts analyzed in each sample for Axial and coronal cuts.
Trochlear Development: Methods

- Biometric analysis included lateral/media/central trochlear height, cartilaginous sulcus angle (CSA), osseous sulcus angle (OSA), trochlear depth (TD), and trochlear facet length asymmetry (TFA).

- Sex comparisons were considered when one or more specimens from both sexes of the same age were available; 12 knees total spanning 4 age groups (ages 1, 3, 4 and 7 years).
**Figure 3:** Measurements performed on each sample

**Trochlear Depth (TD):** $[(A+B)/2]-C$ is not shown.

Measurements made on both cartilaginous & osseous surfaces.
Figure 4a: Illustration of the progression of lateral (A) and medial (B) trochlea condylar heights from cut 1 (distal) to cut 3 (proximal) in a 3 y/o male knee.

LFCH: 3.4 cm in cut 1, 3.8 cm in cut 2, 4.1 cm in cut 3.
MFCH: 3.4 cm in cut, 3.6 cm in cut 2, 3.7 cm in cut 3.

Mean LFCH > MFCH among the overall series / all cuts analyzed. Both LFCH & MFCH increased by 12% from cut 1 to cut 2.
Figure 4b: Illustration of the progression of both lateral (D) and medial (E) Trochlear Facet Length (TFL) from cut 1 (distal) to cut 3 (proximal) in a 3 y/o male knee.

Lateral TFL decreased: 1.8 cm in cut 1, 1.6 cm in cut 2, 1.5 cm in cut 3. Medial TFL decreased: 1.3 cm in cut 1, 1.1 cm in cut 2, 1.0 cm in cut 3.

Lateral TFL was always > Medial TFL, largest between cut 2 and cut 3. The discrepancy between lateral and medial TFL was more evident in older samples: in the younger ages, medial and lateral TFL had = widths.
Figure 5: the progression of both lateral (F) and medial (G) TF angles from cut 1 to cut 3 in a 3-year-old male knee. (measured on cartilage – C)

Lateral CTF angle: 29.1° in cut 1, 22.5° in cut 2, 20.3° in cut 3.
Medial CTF angle: 33.4° in cut 1, 18.3° in cut 2, 10.5° in cut 3.

Mean lateral & medial CTF angles decreased from cut 1 to cut 3. Medial CTF angles decreased > lateral CTF
(60% and 25% respectively)
Figure 6: CSA values in cut 2 among 3 different samples: 3-month-old female, 4-year-old female and 8-year-old female.

Cartilage Sulcus Angle values are stable across all of the samples independent of the age.
Figure 7: thickness of the cartilage (cut 2) among 3 different male samples: 9-month-old male, 4-year-old male, and 10-year-old male. Cartilage thickness was not measured in those samples under 4-year-old, because it was challenging to recognize distinct from bone.
Trochlear Development: Results

- The shape of the osseous center evolves from
  - round (1 month) to
  - oval (9 month) to
  - square (2 years) to
  - Aviator glasses (5 years) (Fig. 8)

There is no distinct osseous trochlear sulcus in the early years, although a well formed cartilaginous sulcus already is in place.

At 5 years the osseous shape begins to suggest a sulcus.

The bony contour of the adult distal femur resembles the cartilaginous contour at 7-8 years.
Distal femoral epiphysis at the level of the trochlea. Representative stages of development of the secondary ossification center (SOC) at 1 month (male), 9 month (female), 2 years (male), 5 years (male), 7 years (male). The shape of the SOC is evolving from round at 1 month of age, to oval (9 month), to square (2 years), to aviator glasses shapes (5 years) to finally follow the contour of the adult distal femur (7-8 years).
Comparative trends between male and female samples

4 age/sex matched specimens were compared
(n=4: ages 1, 3, 4 and 7-year-old)

- All the values were higher in males than in females, with the exception of both the CSA and the OSA.

- Females had higher CSAs and OSAs with respect to males in the three cut analyzed, thereby demonstrating a shallower trochlea representing more trochlear dysplasia.
Trochlear Development: Discussion

• From the earliest stage of the development, the female trochlea is flatter with less groove depth than that of males.

• The development of the shape of the OSA does not follow that of the CSA, suggesting that other forces (possibly from the patella) dictate the contour of the mature bony trochlear groove.
Trochlear Development: Conclusions

Our sample suggests:

1) a developmental tendency for females to have shallower grooves;

2) the lateral trochlea is higher (trochlear height) and wider (trochlear facet length) during growth than the medial in both sexes;

3) the development of the osseous sulcus shape lags behind the development of the cartilagenous sulcus shape in our sample population.
Future thoughts

• The anatomic findings in this study are consistent with clinical studies on trochlear dysplasia in females, and suggests that trochlear development plays a critical role in sexual dimorphism in patella instability.

• The development of the osseous sulcus does not appear to dictate the development of the cartilagenous sulcus.

  What is the primary driver of this development?

  How does this change in Trochlear Dysplasia?

• Trochlear dysplasia is mainly defined by the elevation of the central trochlear height, and at times a reduction of the medial trochlear height. How is the central groove height dictated in early development.
Thank you