Influence of Internal and External Imaging Plane Inclination on Assessment of Trochlear Depth, Sulcus Angle, And Facet Asymmetry in the Setting of Trochlear Dysplasia: A Cadaveric Study

Kristel Vranken
Vrije Universiteit Brussel
Seema Doring
Vrije Universiteit Brussel
Nico Buls
Vrije Universiteit Brussel
Johan Vanlauwe
Vrije Universiteit Brussel
Sofie Germonpré
Vrije Universiteit Brussel
Steven Provyn
Vrije Universiteit Brussel
Aron De Smet
Vrije Universiteit Brussel
Michel De Maeseneer (michel.demaeseneer@uzbrussel.be)
Vrije Universiteit Brussel

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Abstract

Purpose

(1) to assess the influence of internal or external imaging plane inclination on measurement of sulcus angle, trochlear depth, and facet asymmetry on transverse cross-sectional images. (2) to assess the effect of measurement level (height) on these respective parameters.

Materials and methods

Twenty dry femurs (9 left, 11 right) were imaged with CT. A 3D dataset was obtained from which axial images were reconstructed in the ideal plane without inclination as well as with 8° of medial and lateral inclination. Sulcus angle, trochlear depth, and facet asymmetry were measured on the 3 image sets. In addition, the measurements were performed at 5 mm and 10 mm from the superior margin of the medial trochlear facet. Statistical analysis consisted of Wilcoxon test and calculation of measurement variation.

Results

There were no statistically significant differences between the indicated measurements on the reference set compared to medial or lateral inclination. All measurements were significantly different depending on measurement height.

Conclusion

Medial or lateral inclination in the transverse imaging plane of 8 ° does not influence the values of typical parameters used for assessment of trochlear dysplasia. The measurement height has a significant influence, and a consensus should be found as to which is the optimal measurement height.

Key Points

-Common parameters and measurements to assess trochlear dysplasia used by clinicians do not change with a typical and common medial or lateral inclination error on cross-sectional imaging.

-The parameters change depending on the level of the height of the trochlea where it is measured.

-The level of measurement should be agreed upon for reproducibility.

Introduction

Patellar dislocation and maltracking are complex multifactorial problems. Factors that may play a role include patellar height (patella alta) and trochlear dysplasia [3, 5, 12, 13]. Although, trochlear dysplasia can potentially be assessed on radiographs, cross-sectional imaging allows a more precise evaluation [10, 11, 14]. Patellar shape, unless severe deformity is present, is no longer regarded as a significant contributor. On cross-sectional imaging several measurements can also be performed. These include mainly trochlear depth, sulcus angle and facet asymmetry [5–7]. Routinely, cross sectional imaging of the knee is performed by MRI. However, in clinical practice the ideal transverse imaging plane is not always obtained and often 'inclination errors' - either medially or laterally - are observed. From our clinical experience we have estimated that this error typically approaches 8°, larger errors being unlikely. We decided to use a CT based cadaveric model because of the ease of obtaining a 3D dataset in dry bone specimens, and thus allowing us to make reconstructions in any chosen plane or at any chosen height. MRI is of course the most commonly performed clinical technique for knee and patella-trochlear assessment. We used CT, also a cross sectional technique, to approximate what would be observed on MRI. The parameters we chose to evaluate are the most commonly used clinical practice, and they may influence clinical decision making. There is no agreement at which height the measurements should be performed and whether this is relevant at all [4,11,14]. The purpose of our work therefore was (1) to determine the influence of typical inclination errors on the commonly obtained trochlear dysplasia measurements. (2) to determine the influence of measurement height on these parameters.

Materials And Methods

Approval from the ethical board of the hospital was obtained for this study as well as approval from the anatomy department for the use of cadaveric specimens. Our data set included 20 dry femurs (9 left, 11 right) from the anatomical laboratory. It was not known if they belonged to male or female subjects, and the age at death was also unknown. An anatomist, unaware of the purpose of the study, collected randomly dry specimens from the anatomical collection. The specimens were examined visually by an experienced knee surgeon (JVL) and anatomist (MDM), and it was subjectively determined that none of the specimens showed major deformity, degenerative changes, and no signs of prominent trochlear dysplasia. The specimens were positioned in the CT scan in neutral position and transverse images were obtained. (Fig. 1). The CT system was a Somatom Definition (Siemens, Erlangen, Germany). The imaging parameters are shown in Table 1. The native images were used to obtain reconstructions in the standard transverse plane that served as reference, and two additional offset reconstructions with an inclination of 8° medially as well as laterally. Images were also reconstructed in the coronal and sagittal plane (IMPAX 6.5.3–3009: Agfa, Mortsel, Belgium) (Fig. 2). Using the sagittal image set as guidance, transverse images were obtained at the level of the highest point of the medial condyle facet, denoted as 0-, 5- and 10-mm inferior to that specific level. Sulcus angle was measured by drawing a line parallel to the medial and lateral trochlear facet and measuring the obtained angle. Facet asymmetry was measured by obtaining the length of the lateral and medial facet and determining the percentage of the medial facet relative to the lateral facet. Trochlear depth was obtained by drawing a line connecting the most anterior aspect of the trochlear borders and drawing a perpendicular line up to the deepest point of the trochlea (Fig. 3–4). All measurements were performed by an experienced reader in MSK imaging after a training session in 10 unrelated cases. For each measurement, mean and standard variation are reported for the three considered height levels. Statistical analysis was performed with a Wilcoxon signed rank test (IBM Statistics 2.0). The significance level was set as $p < 0,05$. To determine the variability of the measurements, all measurements were repeated 10 times in a single specimen. Percentage of difference in measurements was calculated, and confidence intervals were derived.

Results

The obtained values for sulcus angle, trochlear depth and facet asymmetry are shown in Tables 2–4. The values at the different heights and comparing standard view, medial and lateral inclination are shown in Table 5. The measurement error for height measurements, and for medial and lateral inclination images was 1%. This difference is actually below the CT resolution, indicating that repeatability is excellent.

Table 1: CT parameters

Measurement	0 mm	5 mm	10 mm	P-value	
	(M +- SD)	(M +- SD)	(M +- SD)	0–5 mm	5–10 mm
Sulcus angle (°)	154 +- 9	139 +- 11	129 +-11	0,000	0,000
Trochlea depth (mm)	3,1 +- 1,0	4,5 +- 1,7	6,6 +- 1,9	0,000	0,000
Facet-asymmetry (%)	63 +- 17	56 +- 13	66 +- 11	0,298	0,001

• Statements

Table 2
Data-analysis sulcus angle (°)

CT scannerl	Tube voltage (kV)	Tube current(mAs)	Detector collimation	Pitch	Reconstruction thickness and increment (mm)	FoV (mm)	Scan length (mm)
Siemens SOMATOM Definition AS	120	250	16 x 0,6 mm	0,85	1,0 / 0,5	120	125

Table 3
Data-analysis CT trochlea depth (mm)

Sulcus angle (°)	Ideal transverse plane	8° Medial inclination	8° Lateral inclination	P-value	
	(M +- SD)	(M +- SD)	(M +- SD)	Ref-Med	Ref-Lat
0 mm	154 +- 9	153 +- 9	154 +- 11	0,243	0,763
5 mm	139 +- 11	140 +- 13	140 +- 12	0,383	0,189
10 mm	129 +-11	129 +- 9	129 +- 9	0,855	0,921

Table 4
Data-analysis CT facet-asymmetry (%)

Trochlea depth (mm)	Ideal transverse plane	8° Medial inclination	8° Lateral inclination	P-value	
	(M +- SD	(M +- SD)	(M +- SD)	Ref-Med	Ref-Lat
0 mm	3,1 +- 1,0	3,1 +- 0,9	2,9 +- 1,1	0,989	0,146
5 mm	4,5 +- 1,7	4,2 +- 1,4	4,6 +- 1,7	0,103	0,446
10 mm	6,6 +- 1,9	6,3 +- 1,7	6,6 +- 1,9	0,012	0,522

Table 5
Data-analysis CT: difference for different measurement levels

Facet-asymmetry (%)	Ideal transverse plane	8° Medial inclination	8° Lateral inclination	P-value	
	(M +- SD)	(M +- SD)	(M+- SD)	Ref-Med	Ref-Lateral
0 mm	63 +- 17	62 +- 16	64 +- 18	0,686	0,337
5 mm	56 +- 13	59 +- 14	61 +- 16	0,072	0,001
10 mm	66 +- 11	68 +- 9	65 +- 11	0,059	0,316

There was no statistically significant difference for the measurements when performed in the reference transverse plane and with medial and lateral inclination of 8 ° ($p > 0.05$). There was a statistically significant difference ($p < 0.01$) for the measurements at different heights. As expected, the values increased as the measurement was obtained more inferiorly. Facet asymmetry increased by respectively 13 and 45% (5, 10 mm), and trochlear depth by 18 and 47% respectively (5, 10 mm). For sulcus angle the increase was 11 and 8% respectively (5, 10 mm).

Discussion

Trochlear dysplasia is a complex multifactorial problem that can lead to recurring episodes of patellar dislocation [4]. During such episodes an important reinforcing structure in the medial retinaculum, the medial patellofemoral ligament may tear. Initial treatment is often conservative, but if this fails more invasive procedures may be necessary. Many potential treatments have been described. Such treatments in recalcitrant cases can include MPFL reconstruction, condyloplasty, and tibial tuberosity transposition [11,2,8].

In trochlear dysplasia the trochlear groove may exhibit an abnormal shape or depth. Abnormal shapes have been previously reported by Dejour, who proposed a classification in 4 types (A, B,C,D) (Fig. 5)[10] .The trochlear groove deepens more distally compared to the more proximal level. The lateral trochlear facet anatomically reaches slightly higher than the medial facet. Hence, when moving from superior to inferior in the transverse plane, the first level where measurements can realistically be obtained is where both facets become visible, the medial in addition to the lateral.

With knee flexion the patella enters the trochlear groove. It is in the initial stages of flexion that dislocation occurs, a fact that is underappreciated by radiologist and clinicians. The dislocation can be due to a too high position of the patella, or an undeep or deformed trochlea, or a combination of both. With higher degrees of flexion, the patella enters an area where the trochlea is much deeper, hence the patella does not dislocate in the more flexed position or may even relocate after initial dislocation [13].

There is no consensus what the best imaging method is in the setting of trochlear deformation and dislocation. A number of signs have been described according to the Dejour classification on radiography. These may however be subjective, also in our opinion, and also an assessment of trochlear depth may be difficult on projection radiography [9]. It may also be difficult to obtain strict lateral radiographs. Interobserver variation also is reported to be poor with the Dejour classification [9,7,6]. CT may be used to measure trochlear dysplasia parameters. It is then limited to an assessment of the bony surfaces. With CT arthrography, which is invasive, or MRI, which is noninvasive, the soft tissue (cartilaginous) contours can be taken into account. MRI can also assess the medial retinaculum, in particular the medial patellofemoral ligament, which is a structure of importance in surgical considerations.

Many measurement parameters have been described to assess trochlear dysplasia on transverse cross sectional images. We chose three parameters which are more commonly used in our hospital, either formally measured or by ‘eye-balling’.

Treatments may also vary but generally address one of the three parameters. The surgeon may attempt to change the insertion angle of the quadriceps femoris by tibial transposition. This is radiologically assessed by the so called TAGT measurement. Another parameter that may be addressed is the MPFL, which may be reconstructed after injury. The inclination angle of the lateral femoral condyle-trochlea may also be increased, to augment lateral support of the patella. With a majorly deformed trochlea, a trochlear deepening procedure-trochleoplasty may be performed [2].

In our investigation we studied the effect of changes in inclination of the transverse imaging plane. This aspect has not been studied before, which is somewhat surprising, as a potential cause of measurement error of the trochlear dysplasia parameters. We observed that in our clinical practice such errors were commonly made by the technician on MRI. However, they never appeared to exceed 8 °, hence we arbitrarily chose this value for our investigation. Our results are somewhat surprising as there is not statistically significant different for any of the selected parameters with such inclination errors. Thus, our results suggest that such inclination mistakes do not affect diagnostic reliability. To our knowledge, no other studies investigated this aspect, hence comparisons with other work are not immediately possible.

In another part of our study, we aimed to determine the effect of the height at which the measurements are performed. In previous studies, evaluating trochlear dysplasia measurements, the measurement height is as a rule not clearly defined. This is surprising as the trochlear groove shape and depth is quite variable from superiorly to more inferiorly. In our investigation, we found that there are significant differences in measurements at the 0, and 5 mm as well as the 10 mm level. In some studies, the measurement height is defined at a certain distance from the femorotibial joint space [6–8], but this is very dependent on the individuals constitution. Previous studies have used different heights in their assessment. Some studies do not even report at which height the measurements were performed. From our data, it thus seems difficult to interpret and especially compare the results of such studies. From our study results we cannot specifically determine the optimal measurement plane, as this was not our goal. The measurement height, as we showed, shows very different results. Nevertheless, we suggest from our observations that the highest level where both medial and lateral facet become visible should be used, or a level just a few mm below that.

Our study has several limitations. First, we used a CT dry bone model to simulate the MRI context. On MRI, however the soft tissues rather than bone can be used to obtain these measurements. Nevertheless, the bone contours form a good approximation, and only in atypical situations there would be a major difference with the soft tissue contours. The CT model simplified our investigation compared to a possible MR model. We limited our investigation to three parameters to evaluate the trochlea. Other parameters exist, such as for example inclination of the lateral trochlear facet, but the ones we used represent the most commonly performed ones. The inclination angle and measurement height were arbitrarily chosen, but approximate what occurs in clinical practice, according to our experience. To assess variability, only a selected number of measurements were repeated. Performing the standardized measurements is simple and straightforward. Another limitation is that we imaged femora with rather normal, than dysplastic trochlea. We believe, however, that the findings could be extrapolated to abnormally shaped trochlea. With major trochlear deformities, such as a convex shaped trochlea, the measurements are not necessary to obtain.

In conclusion medial and lateral inclination simulating a commonly made error by technicians in daily MR practice have no influence on the typically measured trochlear dysplasia parameters. The measurement height changes the obtained parameters very significantly and a consensus is certainly needed as to which measurement height should be chosen in clinical practice.

Declarations

Statements

Ethics approval and consent to participate: ethical board approval and written consent was obtained

Consent for publication: approved by test subjects and authors

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Authors' contributions

Kristel Vranken: data collection, first manuscript, literature

Seema Doring: manuscript revision

Nico Buls: statistics, manuscript revision

Johan Vanlauwe: anatomical study, analysis

Sofie Germonpré:study design

Steven Provyn: anatomical study, manuscript revison

Aron De Smet: anatomical research

Michel De Maeseneer: study design, data analysis, final manuscript

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Figures

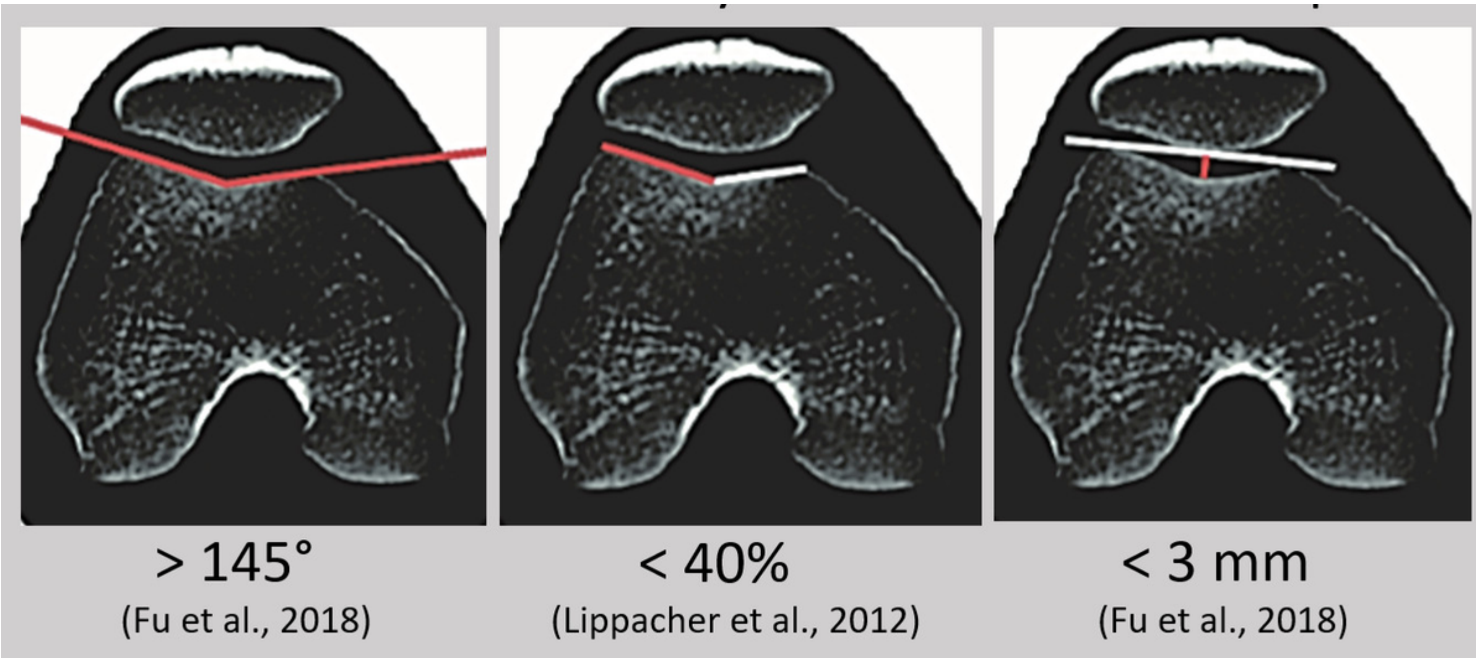

Figure 1

CT images show trochlear dysplasia parameters used. Sulcus angle (left), facet asymmetry (middle, and trochlear depth (right).

Figure 2

Positioning of the dry femur specimen in the CT scan. Native transverse images were obtained.

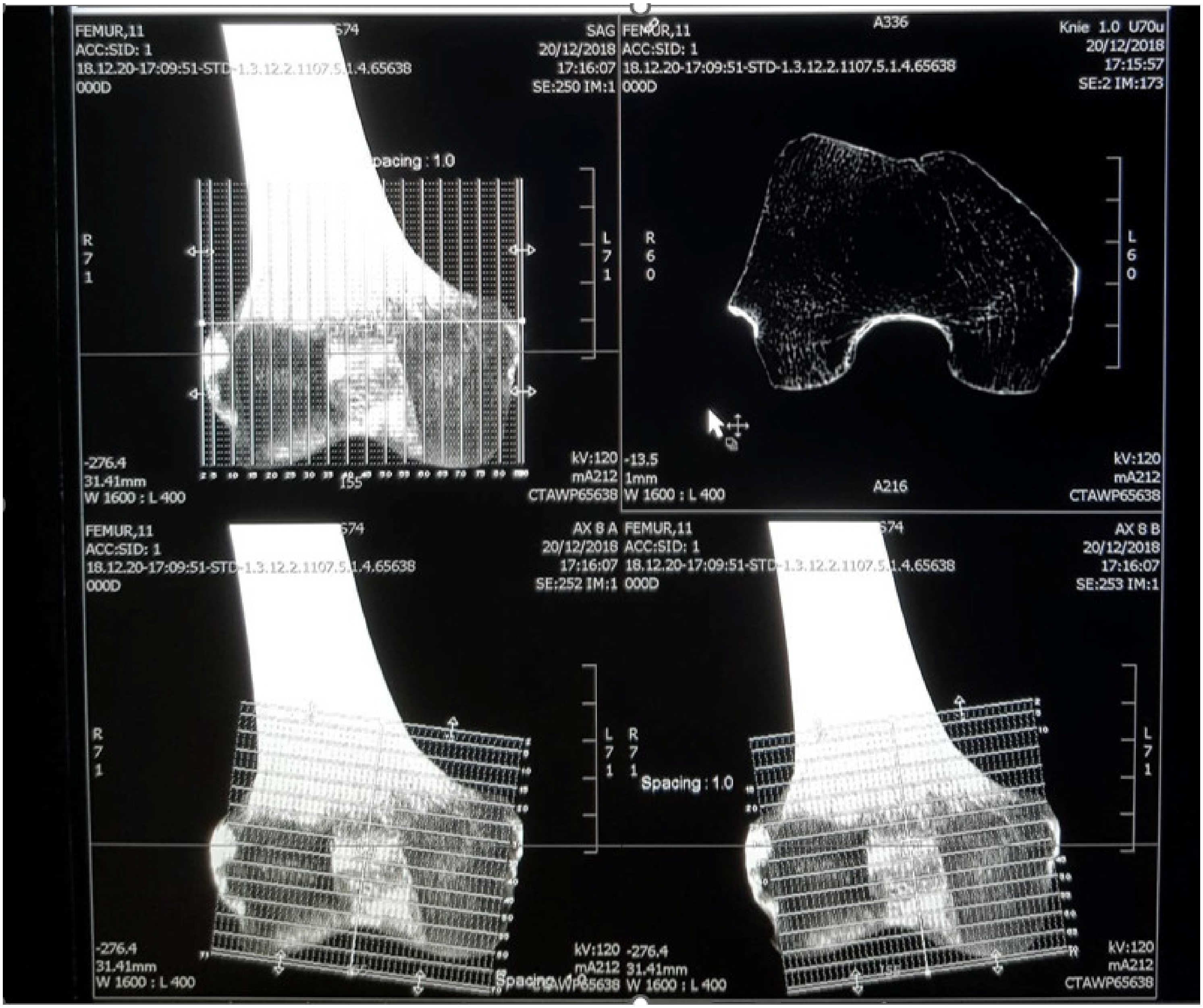

Figure 3

Coronal CT reconstructions. Reconstruction planes for the ideal transverse plane and with inclination of 8 ° medially and laterally are shown.

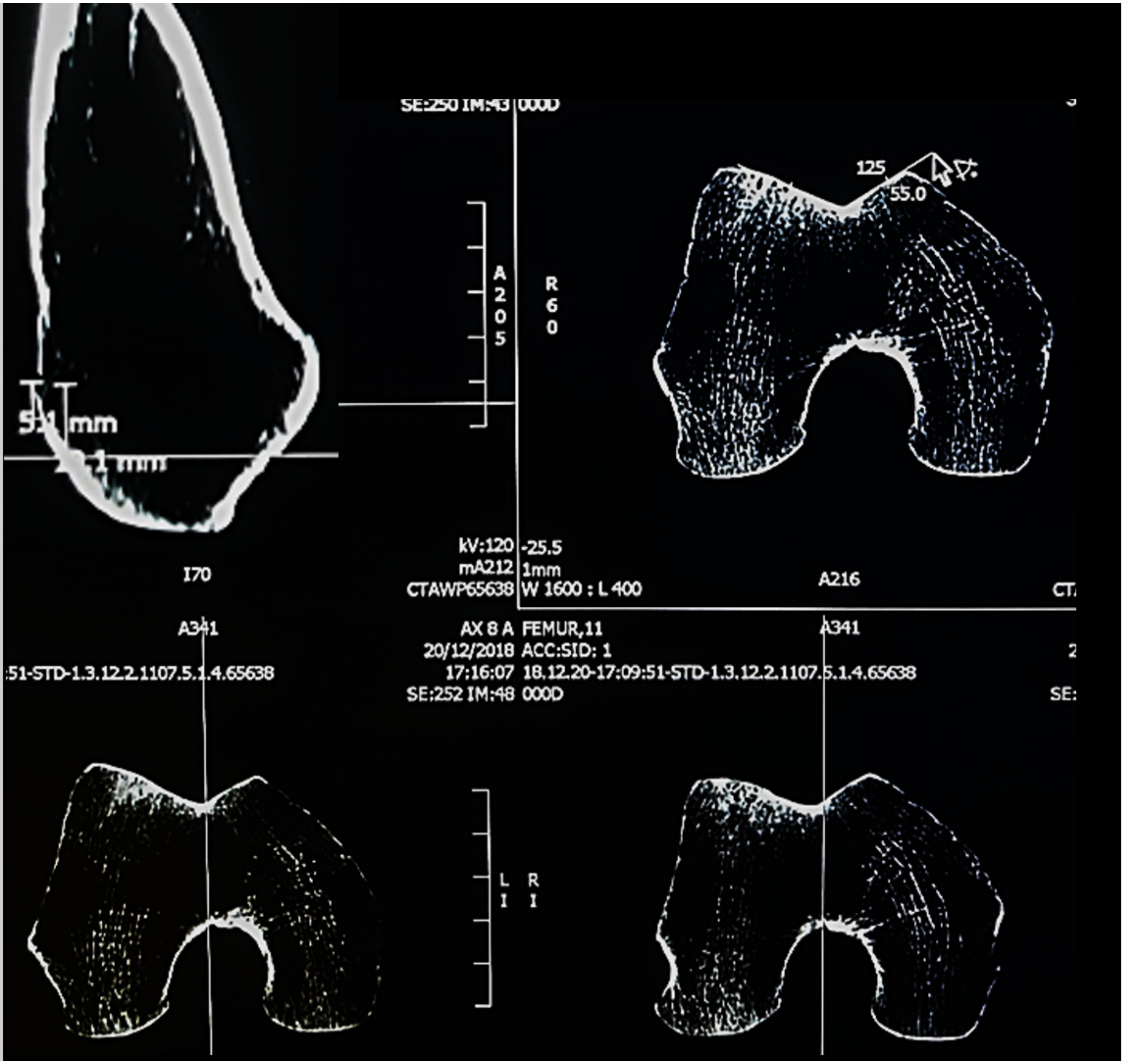

Figure 4

Illustration of sagittal CT reconstruction and method for obtaining the transverse sections at 0, 5, and 10 mm from the highest point of the medial trochlea facet.