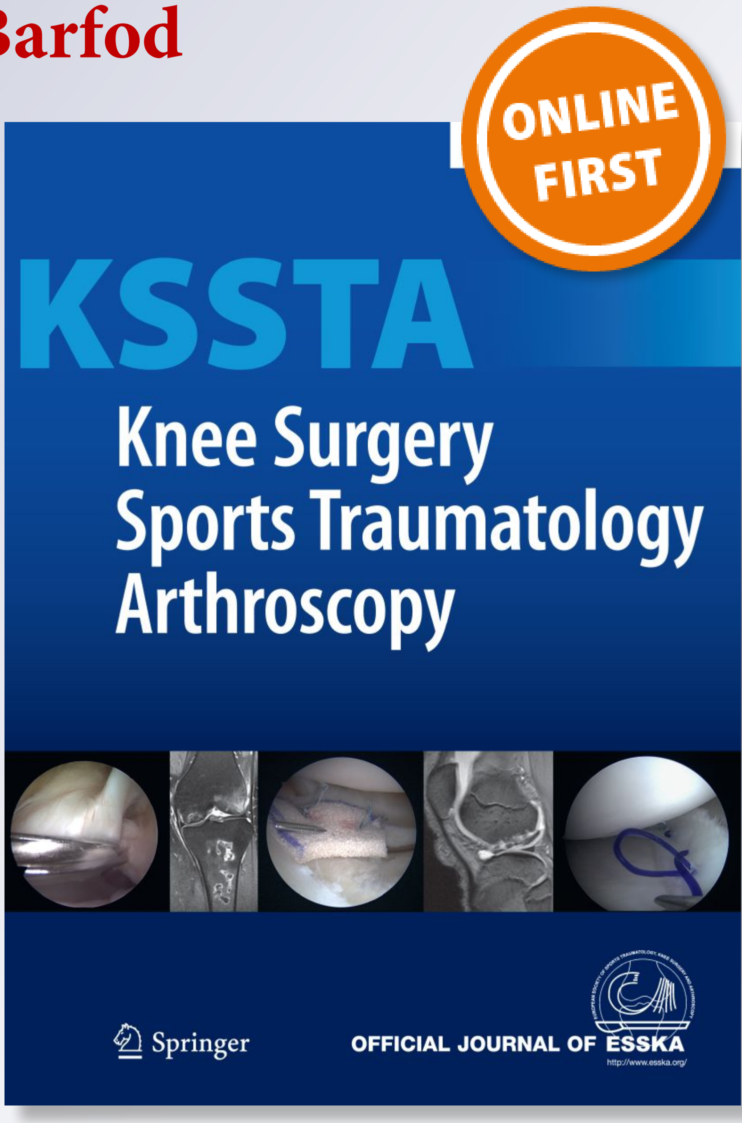
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Quality assessment of radiological measurements of trochlear dysplasia; a literature review

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Abstract
Purpose To make a systematic review with quality assessments of the known measurements used to describe trochlear dysplasia.
Methods A systematic literature search was conducted in the databases PubMed and Embase using the search string "trochlea dysplasia OR trochlear dysplasia". Papers were screened for their relevance based on predefined parameters, and all measurements showing a statistical association between trochlear dysplasia and patellar instability were presented. Four experts evaluated the quality of the measures using a purpose-made quality scale.
Results The search generated 600 papers of which eight were chosen for review. Thirty-three unique measurements were identified and described in order of their date of publication. The lateral trochlea inclination was rated highest by the expert panel. The crossing sign, the trochlea bump, the TT–TG distance, the trochlea depth and the ventral trochlea prominence also had high ratings.
Conclusion Thirty-three unique measurements were identified with the lateral trochlea inclination as the highest rated measurement by the expert panel, and it is recommended for use in assessment of trochlear dysplasia. The crossing sign, the trochlea bump, the TT–TG, the trochlea depth and the ventral trochlea prominence were also rated well and can be recommended for use.
Level of evidence V.

Keywords Trochlear dysplasia · Patellar instability · Patellofemoral · Anterior knee pain · Patellofemoral pain

Introduction

The prevalence of acute patellar dislocation is 6–77 incidents per 100,000 persons per year [22]. Almost half of

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primary dislocations will sustain further dislocation when treated non-operatively [12].

Patella instability is a clinical condition often caused by pathomorphologic changes involving the patellofemoral joint, resulting in an increased likelihood of the patella to dislocate laterally. The main predisposing factors include patella alta, increased tibial tubercle, trochlear groove distance and trochlear dysplasia [9]. Trochlear dysplasia is the most significant predisposing factor for patellar instability [24] and also predisposes patients to cartilage degeneration [14, 16, 26].

Many measurements describing trochlear dysplasia have been developed and presented, and there is no consensus concerning which measurements should be used to diagnose trochlear dysplasia or guide its treatment.

Some authors characterize trochlear dysplasia using the following measurements: lateral condyle index, lateral trochlear inclination and trochlear facet asymmetry [16]. Others use only the Dejour classification or a modified Dejour classification to describe trochlear dysplasia [5, 24], and some use the lateral trochlear inclination as the only measure to discriminate dysplastic knees from healthy knees [13].

The purpose of the present study was to perform a systematic review of the literature presenting the known measurements of trochlear dysplasia and perform a standardized assessment of the measurements quality. The study adds an overview and assessment of the known radiological measurements to the literature and a recommendation of a set of measurements based on a quality assessment.

Materials and methods

This systematic review follows the PRISMA (preferred reporting items for systematic reviews and meta-analysis) guidelines [17].

The systematic review is based on a protocol that can be obtained by request to the authors. Based on the PRISMA guidelines, the following research questions were established:

- Which radiological measurements for trochlear dysplasia can be found in the English literature in the search engines PubMed and Embase from 1990 and forward?
- Can some measurements, based on predefined questions, be said to be superior to others in terms of finding the correct diagnosis, guiding the choice of treatment and predispose recurrent dislocation and pain?
- What is the intra- and inter-rater reliability of the measurements?

A systematic review of the literature was completed on 26 January 2017 using the search engines PubMed and Embase with the search line: “Trochlea dysplasia OR trochlear dysplasia”. Due to the limited amount of literature, it was possible to make a broad search minimizing the possibility missing important studies. The search string was developed in cooperation with a librarian. All papers describing measurements related to the morphology of the trochlea were included in the study. Papers that did not present new measurements, but only measurements that had already been presented in previous papers, were excluded. Only radiological *measurements* were included in the study. Classifications were not evaluated. Measurements showing a statistical difference between people with and without trochlear dysplasia or patellar instability were included in the qualitative synthesis. The intra- and inter-rater reliability for the measurements were extracted if possible. No sample size calculation was performed as quantitative synthesis of data was performed.

Quality assessment of the measurements was performed by an expert panel according to a purpose-made quality assessment scale. The experts were chosen to represent both orthopaedic surgeons and musculoskeletal radiologists, experienced in diagnosing and treating trochlear dysplasia. The expert panel consisted of three orthopaedic surgeons from three different continents and one musculoskeletal radiologist. Their individual views of the radiological measurements were unknown prior to the assessment. The validity of the purpose-made questionnaire was assessed by the author group as all authors were asked whether they believed the questionnaire did measure quality of the measurements and whether they had suggestions for further questions to be added. No formal validation of the measurements was performed.

The selected experts individually evaluated the measurements based on the six questions listed in Table 1. Possible answers where “yes”, “maybe” or “no”. From

Table 1 Questions for the assessments of the measurements quality

Questions for quality assessment
Is the measurement easy to learn and perform?
Is the measurement reliable?
Is the measurement useful for diagnosis of trochlear dysplasia?
Is the measurement useful for planning of treatment of trochlear dysplasia?
Does the measurement predict future risk of patellofemoral pain?
Does the measurement predict future risk of patella dislocation?

Possible answers were “yes”, “maybe” or “no”. From this, a sum core was calculated: “yes” gave 2 points, “maybe” 1 point and “no” 0 points. The sum score ranged from 0 to 12 with 0 indicating the worst quality and 12 the best this, a sum score was calculated: "yes" gave 2 points, "maybe" 1 point and "no" 0 points. The sum score ranged from 0 to 12 with 0 indicating the worst quality and 12 the best. Each measurement was ranked by the average score of the four experts.

Results

The search generated 600 papers (Fig. 1), which were reduced to 375 after removal of duplicates. The paper titles were screened in terms of relevance, and 330 were excluded due to topics related to surgery, paper comments, treatment of trochlear dysplasia, epidemiology of trochlear dysplasia, effects of having trochlear dysplasia and for not being directly related to trochlear dysplasia. Forty-five papers were assessed for eligibility. Three were excluded as they were written in a language other than English and 34 as they reported measurements that had been reported previously. Eventually eight papers presenting 46 unique measurements were included in the study. Of those, 33 measurements showed statistical differences between people with and without trochlear dysplasia or patellar instability and were thus included in the qualitative analysis. The 13 measurements excluded from the qualitative analysis are listed in Table 2.

The included measurements are described in Table 3 along with the results of the quality assessment. Normal values were identified for all 33 measurements, whereas reliability values were only identified for eight measurements.

The highest rated measurements were the lateral trochlear inclination, the crossing sign, the trochlear bump, the TT–TG, the trochlear depth and the ventral trochlear prominence. The detailed quality assessments are found in online Annex.

For better understanding of the measurements, the anatomical landmarks for each individual measurement are shown in Figs. 2, 3, 4 and 5.

Discussion

The most important finding of this study was an agreement on six measurements of good quality that can be recommended for assessment of trochlear dysplasia.

These measurements were the lateral trochlear inclination [6], the crossing sign, the trochlear bump, the trochlear depth, the TT–TG [8] and the ventral trochlear prominence [20].

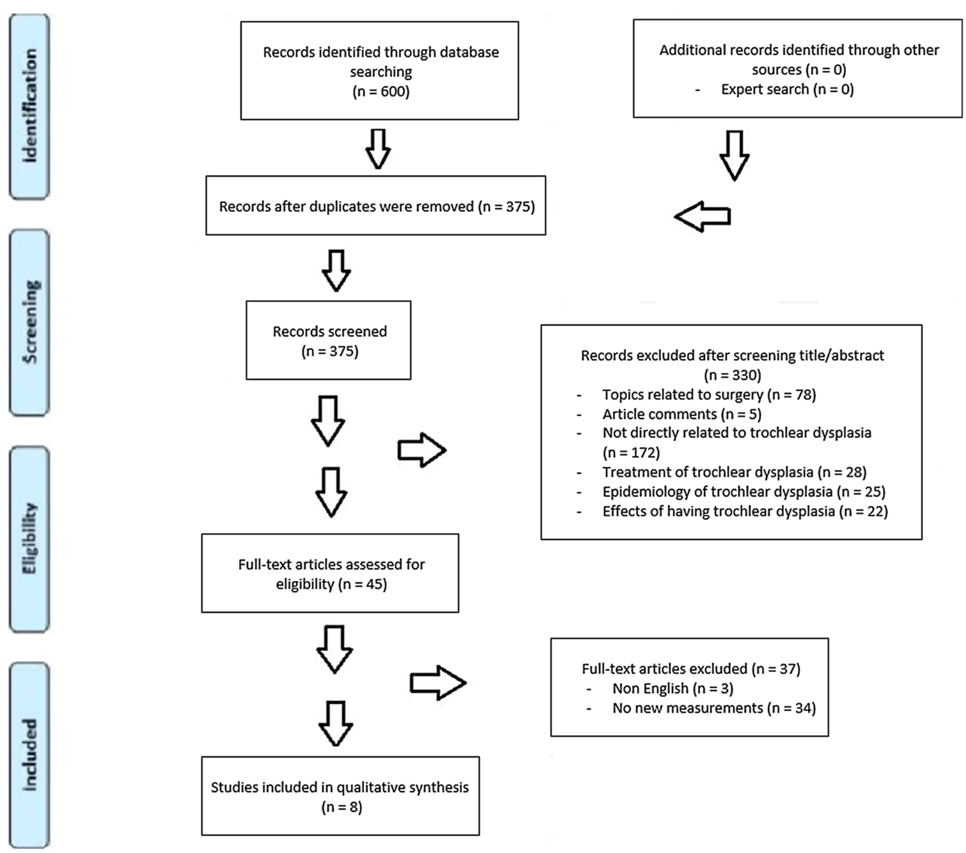

Fig. 1 Literature search

Table 2 Overview of all the excluded measurements

Paper	Measurement	Reason for exclusion
Dejour et al. [8]	1. Mean patella height index	Not relevant to trochlear dysplasia
	2. Lateral subluxation	No significant difference
Pfirrman et al. [20]	3. Condyle asymmetry (1 cm)	No significant difference
	4. Condyle asymmetry (2 cm)	No significant difference
	5. Condyle asymmetry (3 cm)	No significant difference
Fucentese et al. [10]	6. Thickness	No significant difference
	7. Lateral facet	No significant difference
	8. Cartilaginous Wiberg angle	No significant difference
	9. Subchondral Wiberg angle	No significant difference
	10. Facet curvature	No significant difference
	11. Cartilaginous angle	No significant difference
	12. Cartilaginous length	No significant difference
Biedert et al. [4]	13. Lateral condyle height	No significant difference

Column 1 presents the paper describing the measurement. Column 2 presents the excluded measurements chronologically numbered. Column 3 presents the reason for exclusion

The lateral trochlea inclination scored highest in the quality assessment. According to the expert panel, the measurement is useful for the diagnosis of trochlear dysplasia, the planning of treatment of trochlear dysplasia and the prediction of future risk of patellar dislocation. The role of the lateral trochlea inclination in predicting future patellofemoral pain was uncertain by the expert panel. Furthermore, the lateral trochlea inclination rated highly in terms of its reliability and simplicity to perform.

The mean value of the lateral trochlea inclination is reported to be 16.9° in knees without trochlear dysplasia. Using a diagnostic threshold of 11°, the measure has shown a sensitivity of 93% and a specificity of 87% for trochlear dysplasia [6]. Nelitz et al. have investigated the lateral trochlear inclination's correlation with the Dejour classification, which is the most common classification system of trochlear dysplasia dividing affected knees into type A, B, C and D [7]. It was found that the measurement correlated well with higher grades of trochlear dysplasia but related more poorly to lower grades of trochlear dysplasia [18].

The crossing sign scored the second highest in the quality assessment. The crossing sign rated well by the expert panel in terms of its reliability and simplicity to perform. The panel found it to be useful for the diagnosis of trochlear dysplasia, planning the treatment of trochlear dysplasia and the prediction of future risk of patellar dislocation. The importance of the crossing sign in predicting patellofemoral pain was uncertain. The crossing sign is frequently used to diagnose the presence of trochlear dysplasia, in both adults and children [15, 19] but has been reported to give inconsistent results regarding the trochlear shape [21]. The crossing sign is low cost and low tech as only a lateral plain radiograph is needed.

The TT–TG was found to be useful for planning the treatment of trochlear dysplasia and the prediction of future risk of patellar dislocation by the expert panel. The importance of the TT–TG in the diagnosis of trochlear dysplasia and prediction of future risk of patellofemoral pain was uncertain. The TT–TG was rated well by the panel in its reliability and simplicity to perform. The measurement is widely used in the literature and has a high intra- and inter-reliability for both orthopaedic surgeons and musculoskeletal radiologists [23].

The trochlea bump was found to be useful for the diagnosis of trochlear dysplasia, but the panel was not certain of the measurements role in the treatment of trochlear dysplasia, prediction of patellofemoral pain and risk of patella dislocation. The reliability and the simplicity of the measurement were assessed well by the expert panel.

The trochlea depth by Dejour was assessed as a useful diagnostic tool for trochlear dysplasia and for predicting future risk of patella dislocation. As the only measurement, the expert panel also found it useful in the prediction of future risk of patellofemoral pain. Theoretically, a shallow trochlea might increase the contact pressure in the patellofemoral joint, a condition already known for trochlear dysplasia [7]. The increased contact pressure will elevate the stress in the subchondral bone of the patellofemoral joint, which is hypothesized to be a cause for patellofemoral pain [11]. The role of trochlea depth in planning treatment is uncertain, and the expert panel questioned its reliability.

Finally, the ventral trochlea prominence rated well for the diagnosis of trochlear dysplasia as well as for its simplicity and reliability by the expert panel. Its role in planning treatment and predicting future risk of

Table 3 A description of the measurements included in the qualitative assessment

Paper	Measurement	Description of measurement	Modality	Reliability	Normal values	Quality assessment
Dejour et al. [8]	1. Trochlea depth	The measurement is performed on a true lateral view on X-ray. A tangent to the posterior femoral cortex and a perpendicular line at the most proximal part of the posterior condyles is drawn. A line subtended 15 degrees from the perpendicular line is now used to measure the trochlea depth (|LK| in Fig. 2)	X-ray	Inter-class correlation coefficient = 0.38	7.8 ± 1.5 mm	8.7
	2. Trochlea angle	The measurement is performed on an axial view on X-ray and is measured as the angle made by the trochlea (angle I in Fig. 3)	X-ray		Mean—130°	6
	3. Crossing sign	The sign is seen on a lateral view X-ray as the line of the trochlea floor crossing the anterior part of the lateral condyle making the trochlea flat	X-ray		–	9
	4. Trochlea bump	The measurement is made on a lateral X-ray view as a prominent anterior extension of the trochlea groove in relation to the distal anterior cortex of the femur (|M| in Fig. 2)	X-ray		−0.8 ± 2.4 mm	9
	5. Femoral anteversion	The angle between the line joining femoral neck and head and a line tangential to the posterior condyles (angle A in Fig. 4a)	CT		10.8° ± 8.7°	7.7
	6. TT–TG	The tibial tuberosity–trochlear groove distance is measured by drawing a line from the centre of the tibial tuberosity and another line from the bottom of the trochlear groove subtended perpendicular to the posterior condylar line. The tibial tuberosity–trochlear groove distance is then measured as the distance between these lines (|A| in Fig. 4b)	CT	Measured on MRI: Intra-observer reliability ICC ≥ 0.86 Inter-observer reliability ICC = 0.85	12.7 ± 3.4 mm	9
	7. External patella tilt	The patella tilt is measured as the angle between a line trough the mid pole of the patella and a line tangent to the posterior condyles (angle between lines J and C in Fig. 3).	X-ray/CT		16° ± 3.3°/10° ± 5.8°	6.3
	8. Mean patella tilt	Measured as the external patella tilt but calculated as the average value with and without contracted quadriceps	CT		10.8° ± 5.4°	4.7
	9. External tibial torsion	Measured as the angle between a line tangent to the posterior plateau of tibia and a line trough the bimalleolar axis (A in Fig. 4c)	CT		Mean—35°	4
Carrillon et al. [6]	10. Lateral trochlear inclination	One line is made by crossing adjacent to the posterior edges of the condyles, and another line is made by drawing a tangential line to the lateral trochlear facet. The lateral trochlear inclination is the angle between these two lines (angle between lines C and E in Fig. 3)	MRI		16.93° (SD, 4.76°)	10.7

Table 3 continued

Paper	Measurement	Description of measurement	Modality	Reliability	Normal values	Quality assessment
Pfirrmann et al. [20]	11. Trochlea depth (1 cm)	The measurement is calculated as the average height of the medial and lateral condyle minus the distance from the deepest point of the trochlea groove to a line parallel to the posterior outline of the condyles [(A + B/2) − D in Fig. 3]. The measurement was performed on a transverse image 1 cm above the femorotibial joint space	MRI		Mean: 9.0 mm Range −1.6 to 13.2 mm	8
	12. Trochlea depth (2 cm)	The measurement is calculated as the average height of the medial and lateral condyle minus the distance from the deepest point of the trochlea groove to a line parallel to the posterior outline of the condyles [(A + B/2) − D in Fig. 3]. The measurement was performed on a transverse image 2 cm above the femorotibial joint space	MRI		Mean: 6.6 mm Range 2.7–10.0 mm	8.7
	13. Trochlea depth (3 cm)	The measurement is calculated as the average height of the medial and lateral condyle minus the distance from the deepest point of the trochlea groove to a line parallel to the posterior outline of the condyles [(A + B/2) − D in Fig. 3]. The measurement was performed on a transverse image 3 cm above the femorotibial joint space	MRI		Mean: 5.2 mm Range 2.4–10.5 mm	8
	14. Facet asymmetry (1 cm)	The length of the medial (G in Fig. 3) and lateral (F in Fig. 3) condylar facet was measured. Then, the asymmetry was calculated by a ratio: F/G × 100%. The measurement is performed on a transverse image 1 cm above the femorotibial joint space	MRI		Mean: 80% Range 59–96%	7.3
	15. Facet asymmetry (2 cm)	The length of the medial (G in Fig. 3) and lateral (F in Fig. 3) condylar facet was measured. Then, the asymmetry was calculated by a ratio: F/G × 100%. The measurement is performed on a transverse image 2 cm above the femorotibial joint space	MRI		Mean: 65% Range 47–82%	6.3
	16. Facet asymmetry (3 cm)	The length of the medial (G in Fig. 3) and lateral (F in Fig. 3) condylar facet was measured. Then, the asymmetry was calculated by a ratio: F/G × 100%. The measurement is performed on a transverse image 3 cm above the femorotibial joint space	MRI		Mean: 57% Range 17–93%	6
	17. Lateralization of patella	The measurement is performed on a transverse image as the shortest distance between the most lateral point on patella and a line parallel to the lateral side of the femur condyle (|H| in Fig. 3)	MRI		Mean: 2.5 mm Range 0–11.2 mm	6
	18. Ventral trochlear prominence	The distance between a line parallel to the ventral cortical surface of the distal femur and the most ventral cartilaginous point of the femoral trochlea floor (|I| in Fig. 2)	MRI	Inter-class correlation coefficient = 0.62	Mean: 5.0 mm Range 0–10.5 mm	8.7
	19. Nipple	The length of a local nipplelike anterior prominence on the superior part of the trochlea (|J| in Fig. 2)	MRI		Mean: 0.1 mm Range 0–1.0 mm	8

Table 3 continued

Paper	Measurement	Description of measurement	Modality	Reliability	Normal values	Quality assessment
Fucentese et al. [10]	20. Baseline (BL)	Measured as the distance between the most medial and lateral edge of the patella (|AB| in Fig. 5)	MRI		Mean: 42.00 mm SD: 4.50 mm	3.7
	21. LBC	The distance from the most lateral part of the patella to the beginning of the perpendicular line from the baseline to the cartilaginous posterior patellar edge (|BD| in Fig. 5)	MRI		Mean: 14.20 mm SD: 2.09 mm	3
	22. LBS	The distance from the most lateral part of the patella to the beginning of the perpendicular line from the baseline to the subchondral posterior patellar edge (|BF| in Fig. 5)	MRI		Mean: 10.60 mm SD: 1.46 mm	3
	23. Medial facet	The length of the medial facet	MRI		Mean: 22.82 mm SD: 4.17 mm	3.7
	24. Facet ratio	The facet ratio is calculated as (lateral facet)/(medial facet)	MRI		Mean: 1.15 SD: 0.23	4
	25. Cartilaginous Wiberg index	The index is calculated as (LBC)/(BL)	MRI		Mean: 0.54 SD: 0.08	2
	26. Subchondral Wiberg index	The index is calculated as (LBS)/(BL)	MRI		Mean: 0.57 SD: 0.08	2.7
	27. Distal cartilaginous Wiberg angle	A cartilaginous Wiberg angle measured on the most distal image where the patella is still covered with cartilage	MRI		Mean: 135.45° SD: 9.45°	2
Biedert et al. [2]	28. The patellotrochlear index	The patellotrochlear index is calculated as the ratio between the vertical distance between the most superior aspect of the trochlea articular surface and the most inferior aspect of the patellar articular cartilage and the distance between the most superior and inferior aspect of the patellar articular cartilage (|HG|/|EF| in Fig. 2)	MRI		0.33 ± 0.1	6
Biedert et al. [4]	29. Central height	The height of the lowest point of the trochlea compared to the width of the femoral condyle (most lateral part to the most medial part) and expressed as a percentage of the width (|D|/|C| × 100% in Fig. 3)	MRI	Intra-observer agreement 75%	Mean: 73% SD: 0.04	7.7
	30. Medial condyle height	The height of the medial condyle compared to the width of the femoral condyle (most lateral part to the most medial part) and expressed as a percentage of the width (|B|/|C| × 100% in Fig. 3)	MRI	Intra-observer agreement: 75%	Mean: 76% SD: 0.04	5.7
Biedert et al. [3]	31. Lateral condyle index	A tangent line is drawn at 90 degrees to the central longitudinal axis and the length from the most anterior (|AC| in Fig. 2) and posterior (|BD| in Fig. 2) aspect of cartilage is then measured. The lateral condyle index is defined as the ratio: |AC|/|BD|	MRI	Inter-observer reliability: ICC = 0.94	Mean: 93 ± 7%	3.7
Van Haver et al. [25]	32. Medial inclination angle of the trochlea	One line is made by crossing adjacent to the posterior edges of the condyles, and another line is made by drawing a tangential line to the medial trochlear facet. The medial trochlear inclination is the angle between these two lines (angle between lines C and K in Fig. 3)	3D models made by arthro-CT scans	Intra-class correlation coefficient = 0.99	13.4° ± 2.6°	4.3

Table 3 continued

Paper	Measurement	Description of measurement	Modality	Reliability	Normal values	Quality assessment
	33. Trochlear cartilage height	The measurement is performed by using three-dimensional computer models. It is measured as the angle between a plane through the bone-articular cartilage border of the inter-condylar notch and a plane through the most proximal edge of the articular cartilage	3D models made by arthro-CT scans	Intra-class correlation coefficient = 0.99	33.7 ± 3.4 mm	2.3

Column 1 presents the paper describing the measurement for the first time in relation to trochlear dysplasia. Column 2 presents the included measurements chronologically numbered. Column 3 contains a short description of the measurement. Column 4 presents the radiological modality used in the first description of the measurement. Column 5 presents the intra- and inter-rater reliability if described in the literature. Column 6 presents the normal values of the measurements. Column 7 presents the average quality assessment performed by the expert panel. The score ranges from 0 to 12 with 0 indicating the worst quality and 12 the best

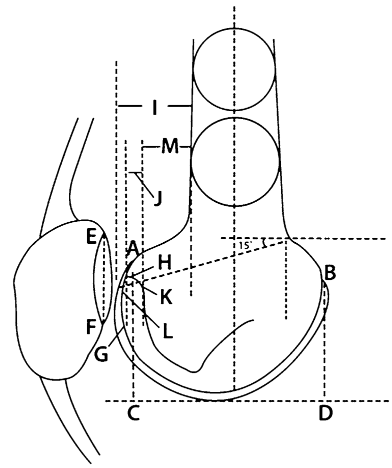

Fig. 2 A sketch of the knee joint on a lateral view. *A* is the most superior aspect of the anterior cartilage. *B* is the most superior aspect of the posterior cartilage. *C* and *D* are the crosspoints between the baseline of the distal condyle (perpendicular to the longitudinal axis) and the perpendicular line from *A* and *B*. *E* and *F* are the most superior and inferior aspects of the patellar articular cartilage. *G* is the most inferior aspect of the patellar articular cartilage but represented on the femur. *H* is the most superior aspect of the trochlea articular surface. *I* is the distance between a line parallel to the ventral cortical surface of the distal femur and the most ventral cartilaginous point of the femoral trochlea floor. *J* is the length of the prominence on the superior part of the trochlea. *K* and *L* are the points where the line subtended 15° from the perpendicular line to the tangent of the posterior femur cortex crosses the trochlea floor and femur condyles. *M* is the distance from the prominent anterior extension of the trochlea groove to the anterior cortex of the femur

patellofemoral pain and dislocation was uncertain. Some studies have suggested that the ventral trochlear prominence is the most reliable measure in terms of identification of the trochlear dysplastic shape [21].

The controversy of different methods to approach trochlear dysplasia is illustrated by the assessment results. The panel agreed on most assessments, but some measurements were assessed very differently, such as the facet asymmetry 1 cm above the femorotibial joint space. These differences were also caused by the inaccurate definitions of how some measurements should be performed and the lack of an international consensus.

The consequence of using different measuring methods regarding trochlear dysplasia has several aspects. It can be useful to use multiple measures to increase the knowledge of a specific knee and thereby individualize patient treatment. Individualized treatment using a la carte treatment algorithms is gaining popularity [1]. The purpose of those is to give the individual patient the best possible correction of anatomical deformities. But for those algorithms to be transferable and valid between institutions, surgeons should use the same set of measurements in order not to complicate exchange of information. Using

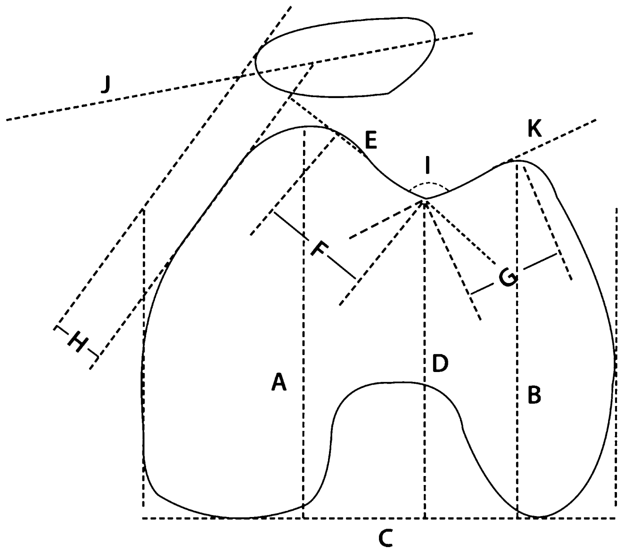

Fig. 3 A sketch of the knee joint seen on an axial view. *A* and *B* are the heights of the lateral and medial condyles. *C* is the width of the femoral condyle adjacent to its posterior edges. *D* is the height of the lowest point of the trochlea. *E* is the tangential line to the lateral facet. *F* and *G* are the lengths of the lateral and medial facets. *H* is the distance between the most lateral point on patella and a line parallel to the lateral aspect of femur. *I* is the angle between the lateral and medial facets. *J* is a line through the mid pole of the patella. *K* is the tangential line to the medial facet

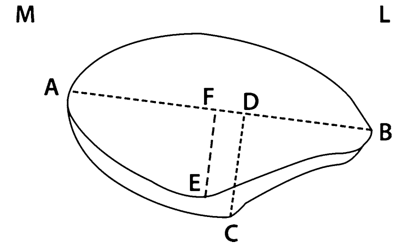

Fig. 5 A sketch of the patella. *A*, *B* are the most medial and lateral points of the patella. *C* is the cartilaginous posterior patella edge. *D* is the perpendicular projection of *C* to the mid pole (*AB*) of the patella. *E* is the subchondral posterior patella edge. *F* is the perpendicular projection of *E* to the mid pole (*AB*) of the patella

different approaches to assess trochlear dysplasia is the consequence of not having an international consensus on which measurements or classifications to use. In the treatment of trochlear dysplasia, some surgeons are primarily guided by specific measurements and some by classification systems such as the Dejour classification. This study is clinically relevant as a standard set of validated measurements could support the strengths of the classification systems and unify the tools used to assess and treat trochlear dysplasia.

The study possesses some limitations. The literature search was conducted by the first author alone. The quality assessment was based on a purpose-made non-validated score. As such, misinterpretation of both questions and answers may have been present. To minimize the risk of misinterpretation, the score was built over six short and simple questions with standardized and simple possibilities for responding. There is no reason to believe misinterpretation was present. The small size and composition of the expert panel also constitute a potential bias as different experts might prefer different measurements based on their clinical practice and research merits. The experts were chosen to be neutral representatives of both orthopaedic surgeons and radiologists, and we are not aware of bias due to the composition of the panel. Due to the size of the expert panel, further research and evaluation are recommended.

The literature search was limited by its search string, but the strength of the search string was increased by asking the members of the expert panel whether they knew any further measurements to add to the search—no measurements were suggested. Three studies were excluded due to language. They were evaluated by the first author and did not present new measurements. Finally, classifications of the trochlea such as the trochlear morphology [24] and the classification by Dejour et al. [7] are widely used to diagnose and treat trochlear dysplasia. This review only included the measurements dealing with trochlear dysplasia, and as such, the classifications were not included.

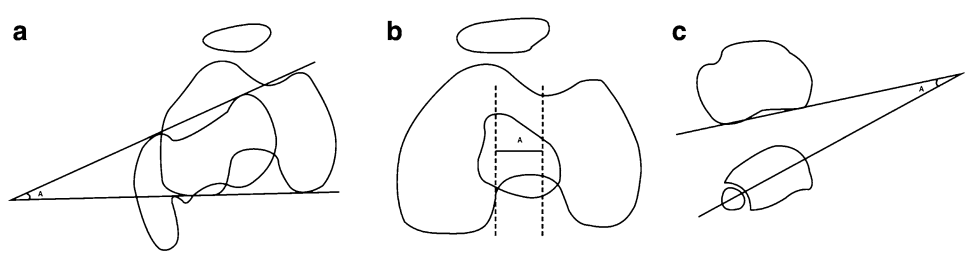

Fig. 4 **a** A sketch of dashed femur condyles projected into the femoral neck and head. *A* is the angle formed between the line joining femoral neck and head and a line tangential to the posterior condyles. **b** A sketch of the tibial tuberosity projected into the femur condyles. *A* is the distance between the trochlea groove and the tibial tuberosity. **c** A sketch of the tibia plateau and the bimalleolar axis

Conclusion

Thirty-three unique measurements were identified with the lateral trochlea inclination as the highest rated measurement by the expert panel, and it is recommended for use in assessment of trochlear dysplasia. The crossing sign, the trochlea bump, the TT–TG, the trochlea depth and the ventral trochlea prominence were also rated well and can be recommended for use.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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Ethical approval This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all the individual participants included in the study.

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