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Reproducibility of patellofemoral CT scan measurements

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Abstract At least seven parameters have been described for the measurement of patellofemoral malalignment on CT scanning; three of which measure lateral patellar tilt, two lateral patellar shift and two femoral trochlear dysplasia. We studied 22 knees in 18 patients complaining of patellofemoral pain in order to investigate the reproducibility of these methods. CT scans of the patellofemoral joint were performed in each knee at 0° and 20° of flexion. The seven parameters were recorded from each scan by three independent observers in a blind study. The reproducibility was studied by means of the intraclass correlation coefficient (ICC). Parameters measuring lateral patellar tilt showed excellent reliability (ICC>75%). The measurements of lateral patellar shift and femoral trochlear dysplasia showed a fair or poor correlation (ICC<75%). We suggest that parameters for measuring lateral patellar tilt only should be used from CT scanning when planning treatment for patello-femoral malalignment.

Résumé Au moins sept paramétres ont été décrits pour mesurer le désalignement fémoro-patellaire par le scanner. Trois d'entre eux mesurent lìnclinaison laterale de la rotule, deux le déplacement latéral et les deux restant la dysplasie de la trochlée fémorale. Pour connaître la fiabilité de ces méthodes de mesure on a étudié vingt – deux genoux de dix huit sujets avec des douleurs fémoro-patellaire de plus de six mois d'evolution. On fit deux scanners de l'articulation de chaque genou à zéro et vingt degrés de fléchissement respectivement. Chaque scanner fût mesuré en utilisant les sept paramétres, par trois observateurs independants, dans une étude aveugle. Deux mois aprés les mêmes observateurs ont repeté les mesures, à nouveau par la technique aveugle. La reproductibilité des mesures a été etudié par le Coeficient de Correlation Intraclasse (CCI). On trouve une haute fiabilité pour les paramétres qui mesuraient l'inclinaison laterale de la rotule (ICC>75%). D'autre part les differentes mesures du déplacement lateral et la dysplasie de la trochlée fémorale ont demontré une reproductibilité moderée ou mauvaise (ICC<75%). On pense que seuls les paramétres mesurant l'inclinaison laterale de la rotule doivant être pris en compte pour des décisions thérapeutiques.

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Introduction

The commonest source of patellofemoral pain in the young adult is patellar malalignment [3]. Conservative treatment is recommended initially but surgery may be required [3, 4, 13]. Pain, effusion, locking and giving-way in patients with patellofemoral malalignment are not specific for tracking abnormalities [3, 4, 13, 18]. Clinical examination may be unreliable [17], and the diagnosis and treatment is dependent on imaging methods, which may confirm the pathology of tilt, subluxation or dysplasia [5]. A number of radiographic methods, with standard views on X-ray, CT scanning and MRI have been reported [1, 4, 5, 6, 7, 8, 13, 14, 15, 16]. Many authors have indicated that the knee should be placed near full extension when performing any radiographic investigation of the patellofemoral joint. The patellar retinaculum becomes tighter when the knee is flexed and therefore small abnormalities in patellar malalignment can be overlooked in flexion [5, 10, 16].

It has been shown that there is little correlation between measurements from axial radiographs and CT

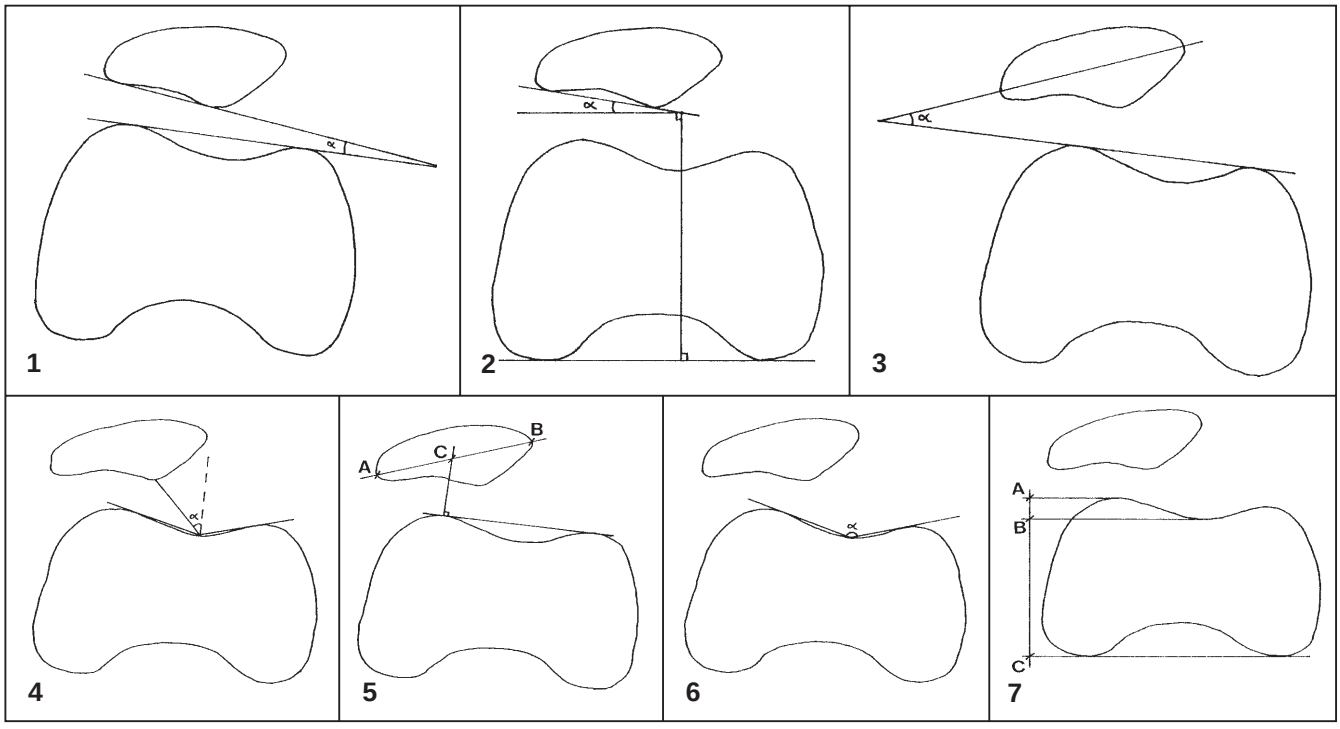

Fig. 1 Measurement of the lateral patellofemoral angle (alpha), as described by Laurin et al. [10]

Fig. 2 Measurement of the patellar tilt angle (alpha), as described by Schutzer, Ramsby and Fulkerson [16]

Fig. 3 Measurement of the tilting angle (alpha), as described by Sasaki and Yagi [14]

Fig. 4 Measurement of the congruence angle (alpha), as described by Merchant et al. [12]

Fig. 5 Measurement of the lateral shift. As described by Sasaki and Yagi [14], is distance AC/BC multiplied by 100 (in %). As modified by Delgado-Martínez [1] is AC/AB and multiplied by 100 (in percentage)

Fig. 6 Measurement of the femoral trochlear angle (sulcus angle)(alpha), as described by Schutzer, Ramsby and Fulkerson [16]

Fig. 7 Measurement of the femoral trochlear depth (percentage) as described by Schutzer, Ramsby and Fulkerson [16] and modified by us: distance AB/AC and multiplied by 100 (in percentage)

scans [13, 19]. Thus a CT scan of the patellofemoral joint should be performed in patients with patellofemoral pain or instability and normal axial X-rays, whose symptoms do not improve after a period of conservative treatment [13]. There has been some debate as to whether the quadriceps should be relaxed or contracted when the CT scan is performed. We have previously shown that contraction of the quadriceps may not be necessary [1].

If surgery is to be considered lateral patellar tilt and lateral patellar shift should be recorded on CT. Three methods of measuring tilt [6, 14, 16], and two of measuring shift [14, 16] have been described. Three patterns of malalignment as recorded in the transverse plane have likewise been suggested : Type I, subluxation without tilt; Type II, subluxation with tilt; and Type III, tilt without subluxation [15, 16]. Femoral condylar dysplasia predisposes to patellar instability, and the shape of the femoral trochlear may be recorded as femoral trochlear depth or angle [15].

Materials and methods

22 knees in 18 patients with symptoms of patellofemoral pain for more than 6 months were randomly selected for this study. The age ranged from 11 to 31 years. Patients with previous knee surgery were excluded. In eight knees there had been at least one episode of patellar dislocation. The knees were investigated by means of a transaxial CT scan that focussed on the central area of the patella. Tomographic images of 5 mm width were obtained with parameters of bone window (W=1500; C=150), with the quadriceps relaxed. For each knee, two scans were carried out: one in full extension and one in 20° of flexion [11].

The measurements performed on the 20 CT scan slices were : a) Lateral patellofemoral angle of Laurin (PFA) (Fig. 1); b) Patellar tilt angle (PTA) (Fig. 2); c) Tilting angle (TA) (Fig. 3); d) Congruence angle of Merchant (CAM) (Fig. 4); e) Lateral shift (LS) (Fig. 5); f) Femoral trochlear angle (FTA) (Fig. 6); g) Femoral trochlear depth (FTD) (Fig. 7). Each measurement was recorded independently by three surgeons without knowledge of clinical data. The intraclass correlation coefficient (ICC) and its 95% confidence interval, as described by Fleiss [2] was used. Intraobserver variability was calculated by the ICC between measurements made by the same observer on the same CT scan twice. Interobserver variability was calculated by the ICC between the measurements of the 3 observers.

Results

Sasaki and Yagi [14] who described the measurements of lateral shift, did not indicate how to record this measurement when the patella was displaced so far laterally that the distance BC was inverted (Fig. 5). There was one such case in this study and this measurement was there-

Table 1 Values of ICC (Intraclass Correlation Coefficient). *PFA* Lateral patellofemoral angle of Laurin; *PTA* Patellar tilt angle; *TA* Tilting angle; *CAM* Congruence angle of Merchant; *LS* Lateral shift; *FTA* Femoral trochlear angle; *FTD* Femoral trochlear depth (percentage)

a) Intraobserver ICC values

	At 0° knee flexion	A 20° knee flexion
PFA	0.95 (0.93;0.97)	0.94 (0.91;0.96)
PTA	0.95 (0.92;0.97)	0.95 (0.92;0.97)
TA	0.92 (0.87;0.95)	0.90 (0.84;0.94)
CAM*	0.80 (0.69;0.87)	0.81 (0.70;0.88)
LS**	0.63 (0.45;0.76)	0.23 (–0.01;0.46)
FTA	–0.02 (–0.25;0.22)	0.86 (0.79;0.92)
FTD	0.60 (0.41;0.73)	0.84 (0.76;0.90)

b) Interobserver ICC values

	At 0° knee flexion	At 20° knee flexion
PFA	0.92 (0.87;0.95)	0.93 (0.88;0.96)
PTA	0.78 (0.66;0.87)	0.76 (0.65;0.85)
TA	0.88 (0.81;0.93)	0.85 (0.77;0.91)
CAM*	0.63 (0.47;0.77)	0.64 (0.49;0.77)
LS**	0.29 (0.08;0.51)	0.06 (–0.11;0.28)
FTA	0.15 (–0.02;0.36)	0.84 (0.75;0.90)
FTD	0.40 (0.20;0.60)	0.56 (0.39;0.71)

(*) The congruence angle of Merchant was impossible to be measured accurately on six (out of 132) times. Calculations excluded these measurements

(**) One CT scan could not be measured because the author who described the LS method did not explain the system required in the case of extremely displaced patellae. On 4 times (out of 126 times) it was impossible to be measured accurately. Calculations on LS excluded that particular CT scan and the failed measurements

fore excluded; moreover on 4 occasions (out of 126 measurements) the observer was not able to obtain reliable reference points and therefore unable to record a measurement. These calculations were excluded but the cases considered in the discussion.

In 6 cases (out of 132 measurements) it was not possible for the observer to record the congruence angle, as described by Merchant et al. [12], because of lack of reliable reference points. Thus, in further calculations of this angle these cases were excluded, but considered in the discussion.

Table 1 summarises the results of ICC for each measurement performed by the same observer (intraobserver variability) and by different observers (interobserver variability) both with the knee at 0° of flexion and at 20° of flexion.

An ICC>75% in intra- and interobserver correlation was found when recording lateral patellar tilt (PFA, PTA, and TA). When recording Merchant's congruence angle (CAM) the intraobserver correlation was 0.80 but interobserver correlation only 0.63. Six inaccurate measurements were excluded. When recording lateral shift (LS) 4 unreliable measurements were excluded. The intraobserver and interobserver correlation was moderate to poor. When measuring trochlear angle on straight knee the correlation was poor. On flexed knee both the inter- and intraobserver correlation was >0.80. The same was the case when measuring femoral trochlear depth (FTD).

Discussion

The accuracy and reproducibility of imaging methods in the assessment of the patellofemoral joints are essential when planning treatment [13, 18]. Tomsich et al. reported that clinical assessment and measurements of patellofemoral alignment are unreliable [17]. This study suggests that the most reliable measurement is of lateral patellar tilt; the trochlear angle can be fairly reliably measured; and the other measurements are less reliable.

Lateral patellar tilt

The difference between the three methods used to calculate the lateral patellar tilt are in the reference lines used for the measurements. Lateral patellofemoral angle, as described by Laurin et al. [10] (Fig. 1), requires one line passing through the anterior margins of the femoral condyles and the other through the margins of the lateral facet. The angle formed by these lines is positive when open laterally.

The patellar tilt angle, as described by Schutzer, Ramsby and Fulkerson [16] (Fig. 2) requires reference to the posterior margins of the femoral condyle with the same patellar reference. lt has been suggested that reference to the posterior margins of the femur is more reliable as patients with patellofemoral pain may have a hypoplastic lateral femoral condyle [1, 5]. However, we found measurements of the posterior femoral margins unreliable.

The tilting angle, as described by Sasaki and Yagi [14] (Fig. 3), has its patellar reference point on a line passing through the centre of the patella and we found this line less reliable than that through the margins of the lateral patellar facet. However, the ICC for these measurements shows all to be reproducible (>75%); the most reproducible results being those of the lateral patellar angle.

Lateral patellar shift

The value of the congruence angle (as described by Merchant et al. [12] (Fig. 4), initially increases rapidly with small patellar deviations, but increases less when the deviations become greater. This angle relies on correct measurement of the sulcus angle, which may be difficult; and some authors have therefore abandoned it [1, 6, 18]. However, Schutzer, Ramsby and Fulkerson [16] recommended the congruence angle as it also records the orientation of the trochlea; and Kujala et al. [8], also found it to be satisfactory. We found an excellent intraobserver reliability but a moderate interobserver reliability for this parameter (Table 1). However, in six cases

the measurement could not be made and we believe that measurements of the congruence angle are not reliable.

The lateral shift, as described by Sasaki and Yagi [14] (Fig. 5), measures the same as the congruence angle; however, unlike the congruence angle, its value increases very little with small patellar deviations but increases rapidly with greater deviations. The true parameter cannot be measured when the patella lies lateral to the apex of the lateral femoral condyle. A modification of this measurement whereby it becomes over 100% when the patella is lateral to the femoral condyle has been described [1]. Laurin also described lateral patellar displacement [9, 18] which is similar to lateral shift. However this is an absolute index and is dependent on the magnification of the CT scans; and, for this reason, it was not included in our study. We noted a poor interobserver variability for lateral shift, and in four cases it was not possible to obtain a reliable value. We therefore believe that parameters of lateral shift should not be used and that there is no accurate method, on CT scanning, for calculating lateral patellar displacement.

Trochlear dysplasia

Some authors have reported difficulty in obtaining a measurement of sulcus angle at 0° of flexion [1, 6]. On MRI, at 0°, the sulcus angle is greater than at 20° [8]. These angles on CT scan are more difficult to measure at 0° and we found a much lower ICC value at 0° than at 20° (Table 1).

The height of the lateral femoral condyle was defined by Schutzer, Ramsby and Fulkerson [16] as an absolute value calculated from lines drawn parallel to the posterior margin of the femoral condyles, one in relation to the superior border of the lateral femoral condyle and another in the deepest aspect of the sulcus. However, this parameter depends on the magnification of the radiograph. Thus, in our study, we divided this value by the width of the lateral femoral condyle. Moderate to excellent intraobserver reliability and a moderate interobserver reliability were obtained with these measurements. These results were less reliable at 0° of flexion as has previously been recorded [1, 6]. In summary measurements of lateral patellar tilt are reliable when planning treatment for patellofemoral disorders. Measurements of lateral patellar shift and trochlear dysplasia are less reliable.

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References

1. Delgado-Martínez AD, Estrada C, Rodríguez-Merchán EC, Atienza M, Ordóñez JM (1996) CT scanning of the patellofemoral joint. The quadriceps relaxed or contracted? Int Orthop 20:159–162
2. Fleiss JL. (1986) The design and analysis of clinical experiments. Wiley, New York
3. Fulkerson JP, Kalenak A, Rosenberg TD, Cox JS (1992) Patellofemoral pain. Instr Course Lect 41:57–71
4. Fulkerson JP, Shea KP (1990) Disorders of patellofemoral alignment. J Bone Joint Surg [Am] 72:1424–1432
5. Grelsamer RP, Newton PM (1994) Patellofemoral imaging. Sports Med Arthros Rev 2:226–236
6. Inoue M, Shino K, Hirose H, Horibe S, Ono K (1988) Subluxation of the patella. Computed tomography analysis of patellofemoral congruence. J Bone Joint Surg [Am] 70:1331–1337
7. Koskinen SK, Taimela S, Nelimarkka O, Komu M, Kujala UM (1993) Magnetic resonance imaging of patellofemoral relationships. Skeletal Radiol 22:403–410
8. Kujala UM, Österman K, Kormano M, Komu M, Schlenzka D (1989) Patellar motion analyzed by magnetic resonance imaging. Acta Orthop Scand 60:13–16
9. Laurin CA, Dussault R, Levesque HP (1979) The tangential x-ray investigation of the patellofemoral joint: x-ray technique, diagnostic criteria and their interpretation. Clin Orthop 144: 16–26
10. Laurin CA, Lévesque HP, Dussault R, Labelle H, Peides JP (1978) The abnormal lateral patellofemoral angle. A diagnostic roentgenographic sign of recurrent patellar subluxation. J Bone Joint Surg [Am] 60:55–60
11. Martínez S, Korobkin M, Fondren FB, Goldner JL (1983) A device for computed tomography of the patellofemoral joint. Am J Radiol 140:400–401
12. Merchant AC, Mercer RL, Jacobsen RH, Cool CR (1974) Roentgenographic analysis of patellofemoral congruence. J Bone Joint Surg [Am] 56:1391–1396
13. Ordóñez JM, Delgado-Martínez AD (1995) Dolor femoropatelar: diagnóstico y tratamiento. Rev Ortop Traumatol 39:370–382
14. Sasaki T, Yagi T (1986) Subluxation of the patella. Investigation by computerized tomography. Int Orthop 10:115–120
15. Schutzer SF, Ramsby GR, Fulkerson JP (1986) Computed tomographic classification of patellofemoral pain patients. Orthop Clin North Am 17:235–248
16. Schutzer SF, Ramsby GR, Fulkerson JP (1986) The evaluation of patellofemoral pain using computerized tomography. A preliminary study. Clin Orthop 204:286–293
17. Tomsich DA, Nitz AJ, Threlkeld AJ, Shapiro R (1996) Patellofemoral alignment: reliability. J Orthop Sports Phys Ter 23: 200–208
18. Vähäsarja V, Lanning P, Lähde S, Serlo W (1996) Axial radiography or CT in the measurement of patellofemoral malalignment indices in children and adolescents?. Clin Radiol 51: 639–643
19. Walker C, Cassar-Pullicino VN, Vaisha R, McCall IW (1993) The patellofemoral joint: a critical appraisal of its geometric assessment utilizing conventional axial radiography and computed arthro-tomography. Br J Radiol 66:755–761