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A new classification system of patellar instability and patellar maltracking

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Abstract To date there is no classification of patellar dislocations considering clinical and radiological pathologies. As a result many studies mingle the dislocation's underlying pathologies, so that there are no consistent therapy recommendations. It is this article's objective to introduce a patellar dislocation classification based on the current literature to allow for the application of a structured diagnosis and treatment algorithm. The classification is based on instability criteria as well as on clinical and radiological analyses of maltracking and on loss of patellar tracking. There are five types of patellar instability and maltracking. The rare type 1 is a simple (traumatic) patellar dislocation without maltracking and instability with a low risk of redislocation. Type 2 has a high risk of redislocation after primary dislocation; there is no maltracking. Here, a stabilising operation (in most cases MPFL reconstruction) is indicated and sufficient. Type 3 shows both instability and maltracking. Maltracking is mainly caused by: (a) soft tissue contracture, (b) patella alta, (c) pathological tibial tuberosity–trochlea groove distance, (d) valgus deviations and (e) torsional deformities. Stabilisation by means of isolated MPFL reconstruction is not sufficient in these types and additional osseous corrective surgeries are required to achieve physiological patellar tracking and to prevent redislocation. Type 4 features a highly unstable "floating patella" with complete loss of tracking caused by severe trochlear dysplasia. Therapy of choice is trochleoplasty, and if necessary combined with bony and soft-tissue procedures. Type 5 shows a patellar maltracking without instability. Maltracking can only be fixed by means of corrective osteotomy. The classification is referenced to current literature and each type is introduced by a case example. The resulting treatment consequence is also presented.

Keywords Patella dislocation · Maltracking · Trochlea dysplasia · Genu valgum · Classification

Introduction

The incidence of patellar dislocation comes to approximately 7 in 100,000 of our population and the average age of suffering from primary dislocation is 21.5 years [27]. After primary patellar dislocation 30–50 % of patients complain of a feeling of instability and/or of anterior knee pain [27].

Older studies point out no advantages for the surgical therapy in comparison with the conservative therapy and report on redislocation rates of approx. 20–50 % [16, 48] after 2 years. After 14 years of therapy (surgical versus conservative) redislocation rates of 67 or 71 %, respectively, are stated [48]. According to recent findings, that is because patella instability has a range of various underlying pathologies which are not treatable by either isolated conservative therapy or by a single surgical procedure. This is why in current literature more and more differentiated approaches and therapy concepts are to be found. On these grounds, Hiemstra et al. introduced a classification for patellar dislocation with the objective of categorising patella instabilities analogous to the shoulder in chronic/

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non-traumatic versus traumatic [29]. However, a differentiation between instability and maltracking was not made. It remains to be seen if there may be any therapeutic and surgical consequences at all arising thereby. Our classification, however, is based on clinical and radiological pathologies implying direct therapeutic consequences. In further consequence, this classification shall serve as a decision guidance for both diagnostics and even for conservative or surgical therapy. By analysing the pathologies and also by assigning those to a classification type, inferences can be drawn about the type of surgical care. A further advantage of this classification could be that different studies may become comparable due to the classification's grading into various subtypes. A comparison is currently not possible!

To date, no such similar approach has been described yet in the specialist literature.

Patella instability

To date the term "patella instability" is not accurately defined yet. In our view instability is present if recurrent dislocations or subluxations of the patella occur or if the probability of a redislocation after primary dislocation is very high or if there is a clinically proven significant fear of a redislocation impairing the patients' level of activity. Various attempts have been made to identify factors predicting the risk of patellar redislocation. For this purpose, Balcarek et al. developed a score which allows for risk evaluation of a patellar redislocation [5]. The factors "age", "patellar dislocation on both sides", "extent of trochlea dysplasia", "patella alta", "tibial tuberosity–trochlea groove distance" and "patellar tilt" were used and converted into a point scoring system. If the "Patella Instability Severity Score" encounters four points or more, there is a fivefold increased risk for redislocation [5].

Patella maltracking

From a "physiological perspective", the patella in extension shows a lateralisation of approx. 4 mm [2]. With increasing flexion (from approx. 20°), the patella slides into the osseous groove of the trochlea and is centred in the middle of the trochlea [2, 25].

Maltracking of the patella is present if the tracking of the patella in its slide bearing in flexion and/or extension of the knee joint deviates from physiological kinematics. This can be evoked by soft tissue contractures and cicatrisations, an increased Q angle, an increased tibial tuberosity–trochlea groove distance, a genu valgum, torsional deviations (e.g., inwardly pointing knee), trochlear dysplasia or by a medially inclined knee base line with hypoplasia of the lateral femoral condyle. A distinction must be made between proximal and distal maltracking and also maltracking over the entire motion sequence. Proximal maltracking is evoked by muscular imbalances, pathological tibial tuberosity–trochlea groove distance or pathological Q angle, genu valgum, torsional deviations or trochlear dysplasia. Currently there are no data available, which would lead to an exact definition at which point patellar tracking is being considered pathological; at the moment this can only be evaluated on the basis of clinical and radiological parameters.

The tracking of the patella can be palpated on the lateral edge of the patella in relation to the lateral trochlear ridge. A more objective parameter to measure patella maltracking might be the "patella deviation", measured in 20° of flexion [53]. The risk of dislocation significantly increased with measurements over 10 mm [53].

In many cases, proximal maltracking can clinically become apparent as a clunking or clicking noise at approx. 20°–30° flexion when the knee joint is moved from extension to flexion. From a clinical perspective this can be relatively inapparent. Here, three-dimensional imaging (MRI or CT scan) can provide further information on this matter.

Distal maltracking mainly occurs in cases of hypoplasia of the lateral condyle with pathological knee base line. Clinically, the patella slips laterally at a bending angle from 50° to 70° (after it moves out of the trochlea). This entity is usually not a case of instability but a case of isolated maltracking.

Loss of patellatracking

Normally the patella can be centralised in the trochlear groove by applying pressure from anteriorly in slight flexion. In case of severe trochlear dysplasia the patella will loose any positional control and "floats" in the slide bearing. A positional control cannot be found at all! The patella can be moved both medially as well as laterally. This can occur in trochlear dysplasia grade B to D according to Dejour [38]. A negative sulcus angle can be another reason for the loss of patellatracking [9] as well as a short trochlea groove. It is not yet fully clarified how severe a trochlear dysplasia must be until patellar tracking is lost and what radiological criteria have to be applied.

Classification

The classification is based on the pathologies "instability", "maltracking" and "loss of patella tracking". The "maltracking" is additionally divided in different subtypes (Fig. 1). The assignment to specific types of the classification system is based on the main pathology.

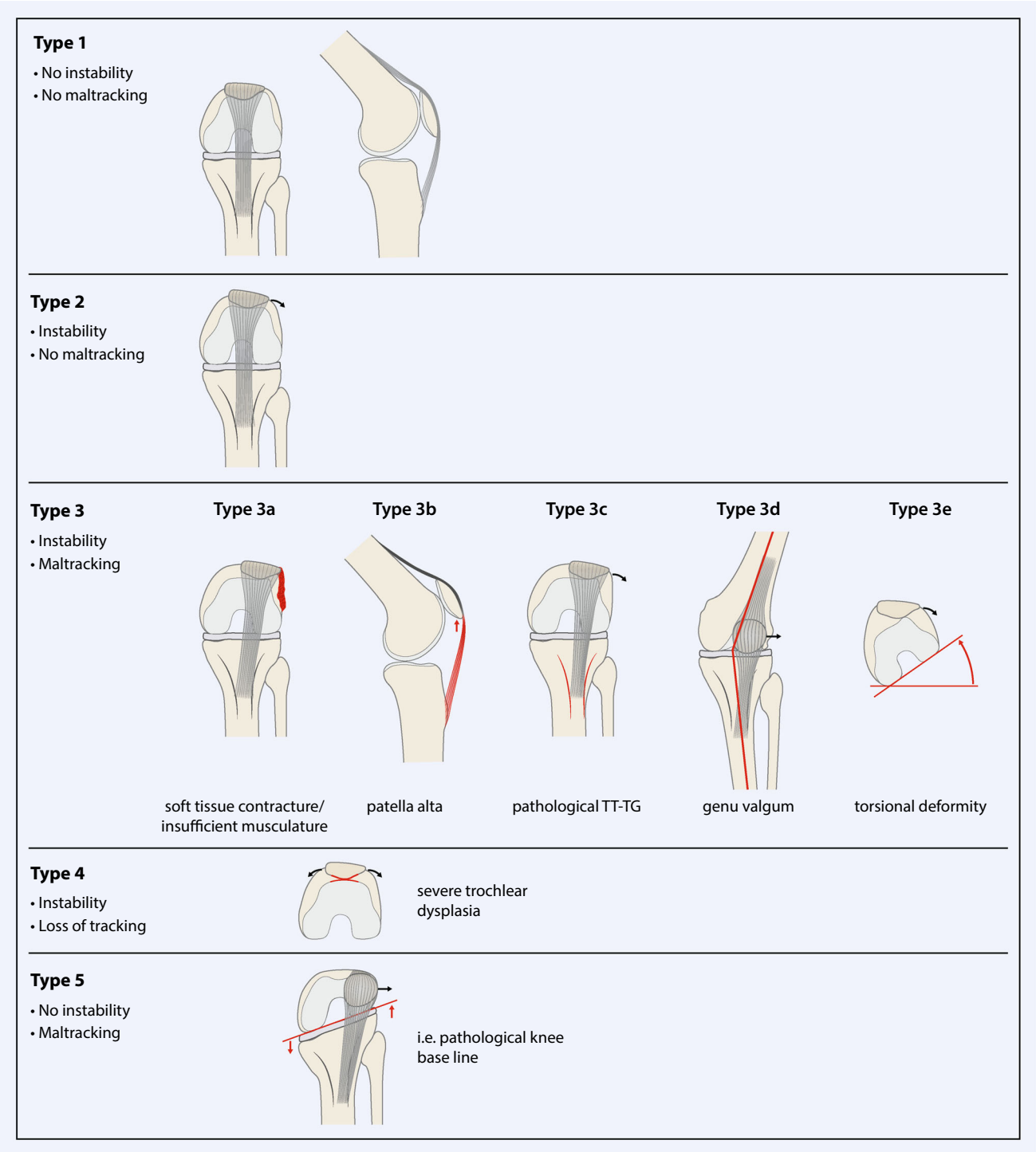

Fig. 1 Classification of patella instability and maltracking. The grading is based on the main pathology, despite instability and maltracking is caused by multiple pathologies in most cases. If there are competing and comparable pathologies, the higher grading is used

Type 1: traumatic patellar dislocation without instability and without patella maltracking

Types 1 are cases of patellar dislocations after adequate trauma. According to the literature only about 7 % of primary patellar dislocations are evoked by adequate trauma [4, 27]. Osseous pathologies are not present or occur in a lower degree of severity only. The risk to suffer from a redislocation is low. According to Balcarek et al. the age of this group of patients should be over 16 years, the tibial tuberosity–trochlea groove distance should be below 16 mm, the Insall–Salvati index (or Caton–Deschamps index) 1.2 or less and the patellar tilt below 20°; no or just a minor trochlea dysplasia should be present and there should be no counter side dislocation (oder instability) [5].

Therapy of type 1 is primarily conservative unless refixable osteochondral flakes are present. Even in cases of slightly increased tibial tuberosity–trochlea groove distance (14 mm on average) and mild trochlea dysplasia Balcarek et al. could not register any redislocation within 37 months after conservative therapy [5].

Type 2: patella instability without patella maltracking

Those patients have a high risk of redislocation or are already redislocated without clinical or radiological patellar maltracking. Osseous pathologies can be present; however, they are not in need of therapy. According to the patellar instability severity score those patients have 4 or more points [5] and, in further consequence a five-time higher redislocation risk. Most influencing factors with regard to the redislocation risk are patient age, trochlea dysplasia and bilateral instability [5]. Similarly, Nikku et al. [45] have reported that female patients with open growth plates and bilateral instability are most at risk for subsequent instability episodes. Due to those recurrent dislocations or the high redislocation risk surgical treatment is recommended. Patients can be treated with soft-tissue stabilising surgery as no maltracking is present. MPFL reconstruction with autologous flexor tendon has become established as the most suitable procedure [11, 38]. In a prospective randomised study, Ma et al. could demonstrate that MPFL reconstruction has a significant advantage over medial duplication of the retinaculum [38]. To date only MPFL reconstruction, when compared with conservative therapy in prospective randomised studies, could demonstrate its significant advantages for the treatment of primary patellar dislocation [11]. After 2 years both the clinical result and also the redislocation rate outclassed the conservative therapy. Up to now, this has not been described yet for any other procedure. In addition, a mild realignment of the patella due to MPFL reconstruction was postoperatively observed [31]. Steiner et al. demonstrated that even in cases, where a mild trochlea dysplasia is present, good clinical results and low redislocation rates can be achieved by means of MPFL reconstruction only [60]. No other procedure has been described featuring such low redislocation rates of approx. 5 % [59].

Type 3: patella instability and patella maltracking (Fig. 1)

Besides the high risk of redislocation (instability) patients belonging to this type additionally show clinical and radiological signs of patellar maltracking. Radiologically measured parameters for maltracking are not definitely determinable as the maltracking can be induced by a combination of various pathologies. In addition muscular factors can also be an issue there. This type's therapy principle consists of correction of the maltracking by means of soft tissue or osseous procedures. In addition, instability is usually treated by MPFL reconstruction with autologous flexor tendon.

Type 3a: instability and maltracking because of soft tissue contractures or muscular imbalances

It is a fact that the quadriceps power has a considerable influence on patellar tracking [34, 71]. It is interesting that the patellar tilt is significantly affected by it [34]. A strengthening of the vastus medialis in particular leads to an improved tracking of the patella in near-extended position and to a reduced retropatellar pressure, especially in the area of the lateral facet [71].

It is, however, quite often the case in type 3a that contracted soft tissue is present, for example, after previous surgery (particularly lateral release) which causes maltracking of the patella to lateral due to soft tissue contraction to the lateral side (Fig. 1). This is also the case after delayed diagnosis of a chronically persistent patellar dislocation [43]. After appropriate analysis of causes, is this one of a few cases where (apart from other measures) lateral release or better lateral retinaculum extension in the form of Z-Plasty [9, 47] should be carried out to reposition the patella. It should be considered that lateral release should be reluctantly performed, only in special cases and only in combination with other stabilizing procedures.

Type 3b: instability and maltracking in case of patella alta

After distalisation of the tibial tubercle redislocation rates between 0 and 4.9 % with an osteoarthritis rate below 15 % (follow up 4.5–9.6 years) are described in the literature [37]. This is why the meta-analysis of Magnussen

et al. [37] concluded that the patella instability can be successfully treated by means of distalisation of the tibial tubercle and by restoration of the physiological patella height. However, it does not conclusively arise from literature at which point of time distalisation is appropriate. Wagner et al. could not observe any increased redislocation rates or poorer clinical results after MPFL reconstruction with an Insall–Salvati index (ISR) ranging from 1.2 to 1.3 than in patients with physiological patella height [70]. Some authors recommend in cases of an ISR greater than 1.4 distalisation of the tibial tubercle in addition to MPFL reconstruction. Tsuda et al. detected that the patella alta was the significant predictor for persistent instability after Fulkerson osteotomy [64]. In the redislocation group the Insall–Salvati ratio came to an average of 1.35, the ISR in the group without redislocation amounted to 1.16 [64]. A more reliable parameter to measure the patella hight is the Canton–Deschamps index. In case of a Caton–Deschamps index of greater than 1.2 combined with patella instability a distalisation of the tibial tuberosity is recommended in the current literature [37, 41]. A physiological Caton–Descamps index of 1.0 is postoperatively recommended [37].

Type 3c: instability and maltracking in cases of pathological tibial tuberosity–trochlea groove distance

Standard values for the tibial tuberosity–trochlea groove (TT-TG) distance are 10 mm for men and approx. 9 mm for women [49]. A TT-TG greater than 15 mm significantly increases the risk of patella dislocation [53], however, a number of authors see a tibial tuberosity–trochlea groove distance of over 20 mm as pathological and relevant for therapy [41, 70]. With reference to our clinical experience a TT-TG of over 20 mm is usually accompanied by a clinical maltracking of the patella. This usually can be observed during dynamic testing of the patellar tracking under arthroscopic visualisation, when the patella does not centralise in the trochlea's sulcus during knee flexion. Care has to be taken during this testing not to use high fluid pressure. In cases of recurrent patellar dislocations good clinical results can be achieved by means of (antero) medial tibial tubercle transfer with a redislocation rate of 6.5 % after 115 months on average [64]. After nearly 10 years a follow up examination could not register any significant signs of osteoarthritis in cases of physiologically restored TT-TG [64]. And yet, the patients had a pathological preoperative tibial tuberosity–trochlea groove distance of an averaging 23 mm (15–33 mm). Those have been normalised to a distance between 10 and 15 mm with surgery [64]. Similar results are reported on utilising the Elmslie–Trillat procedure; here, the redislocation rates range between 8.6 and 15.2 % [7, 62, 64]. Nakagawa et al. [42], Endres et al. [24], and Carney et al. [14] established a time-related decrease in knee function after Elmslie–Trillat procedures with 91 % good-to-excellent results at 45 months toward 54 % after 26 years. They also reported on 42 % of advanced patellofemoral OA and of a 7 % redislocation rate [14, 24, 42]. Some of those long-term course high osteoarthritis rates [69] found in the specialist literature are, to our knowledge, studies where the TT-TG distance was not measured preoperatively and hence, a completely untargeted medial tibial tubercle transfer was carried out [42, 69].

Saranathan et al. demonstrated that the contact pressure on the lateral facet can be reduced by 15 % almost across the entire motion sequence by means of medial tibial tubercle transfer [52].

In cases of pathological TT-TG of over 20 mm associated with a clinical patellar maltracking we therefore indicate a physiological recovery of the tibial tuberosity-trochlea groove distance. In so doing we combine the medial tibial tubercle transfer with MPFL reconstruction (Fig. 2). Simultaneously, in patients with a high TT-TG distance also severe trochlear dysplasia, axis and torsional deformities have to be ruled out!

Type 3d: instability and maltracking in case of genu valgum

Biomechanical studies revealed that a varus- or valgus alignment of the leg axis has significant influence on patellar tracking [40]. Valgus alignment of the leg by just a few angular degrees leads to a lateralisation of the patella and also to a modified patellar tilt [40]. Currently there are no studies with a larger number of cases available. However, a number of case reports point out successful treatment of patellar maltracking by means of combined surgery consisting of soft-tissue stabilising surgery, distal closed-wedge femoral osteotomy and transfer of the tibial tubercle [33, 50]. However, nearly all of the cases described in the literature show severe valgus deformity [32, 33, 50]. In accordance with our own experience it intraoperatively became apparent that valgus correction alone is not sufficient in order to normalise patellar tracking in most cases (Fig. 3). Often we additionally carried out medial soft-tissue stabilising surgery and medial tubercle transfer (Fig. 2). To date it has not been described yet from which angular degree onwards an axis correction should be carried out in cases where lateral patellar maltracking and instability are present. More recent studies on over 5000 knee joints reveal that a valgus leg axis of more then 3° leads to a 2.5 times higher risk for degenerative changes and induces a 5.9 times higher risk of suffering from cartilage damages in the lateral knee joint compartment [26]. Where degenerative changes in the lateral compartment are

Fig. 2 22-year-old male patient with recurrent patellar dislocations, left side. Clinical instability and lateral patellar maltracking type 3c. Straight leg axis, no torsional deformity, tibial tuberosity–trochlea groove distance 22 mm, Insall–Salvati ratio 1.3. Medial tibial tubercle transfer by 10 mm, additional MPFL reconstruction with autologous gracilis tendon. One year postoperative normal tracking and stable patella

already present there is a significant risk of "disease progression" in cases of a valgus alignment of 1.1°–3° [26]. In cases of lateral patellar maltracking with patellar instability and valgus alignment we rather more generously indicate closed-wedge femoral osteotomy with additional soft-tissue stabilising surgery; those measures are dependent on individual patient factors and on the symptoms of the patient.

Type 3e: instability and maltracking in cases of torsional deformity

Standard values for internal femoral torsion are specified as 24.1° (±17.4°) and 34.9° (±15.9°) for external tibial torsion [61]. In our own experience pathological torsions of the lower limb are often overseen. In our own series all 23 patients underwent surgery because of a patellar problem. Torsional deformity was primarily not found in any of the patients. It is known, however, that torsional deformities of the femur and the tibia can lead to anterior knee pain, patellar maltracking and recurrent patellar dislocations [21]. Dickschas et al. indicate that in 12 % of all patients with patellar maltracking torsional deformity could be identified as the cause [21]. The current term for the typical deformity, namely "inwardly pointing knee" was described by Cooke et al. [18]. He postulates five criteria for the diagnosis of an "inwardly pointing knee":

1. Inwardly turned knee during standing.
2. Chronic patellar pain.
3. Patellar dislocation or subluxation.
4. "Retropatellar induced instability (giving way)".
5. Genu varum et recurvatum.

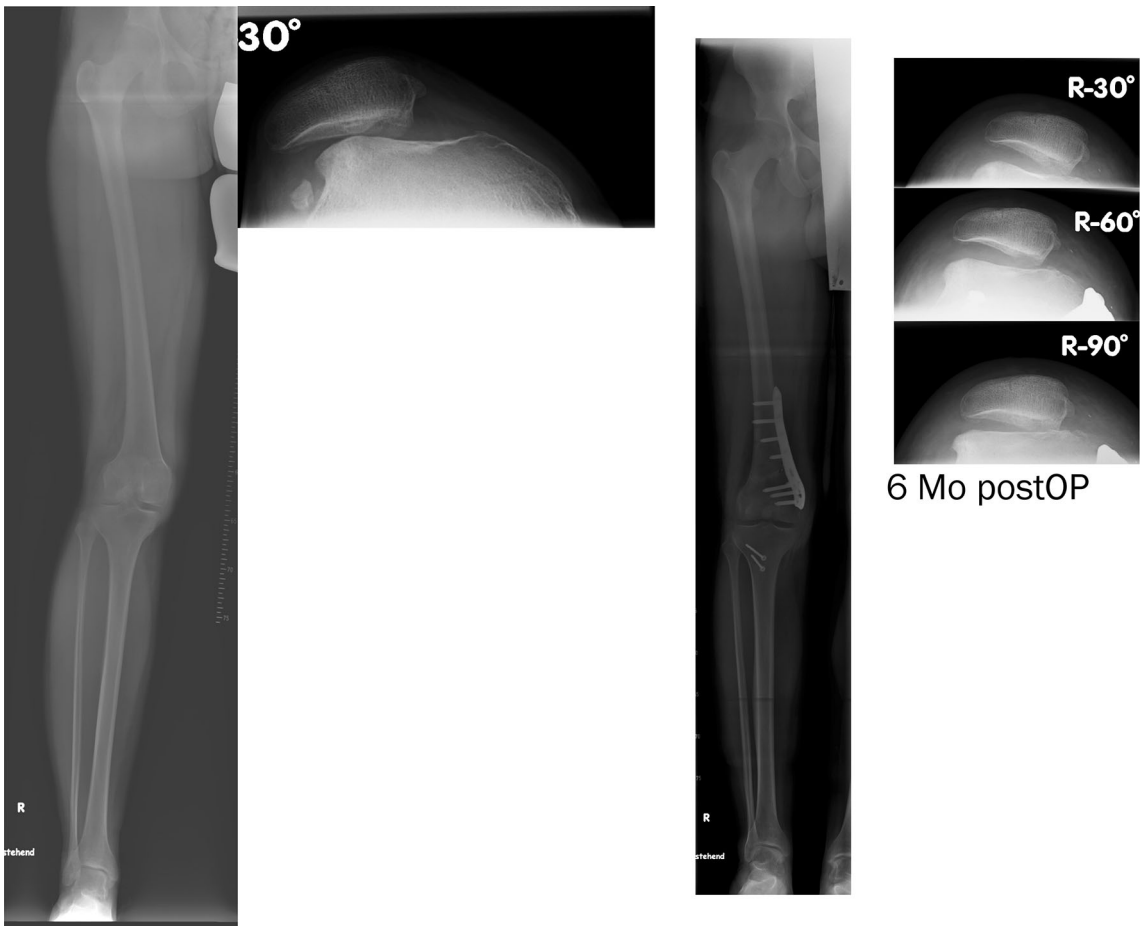

Fig. 3 19-year-old male patient with recurrent patellar dislocations, *right side*. Clinical instability and lateral patellar maltracking type 3d. Leg axis 9° valgus, no torsional deformity, tibial tuberosity–trochlea groove distance 17 mm, Insall–Salvati ratio 1.2. Closed-wedge supracondylar osteotomy and medial tibial tubercle transfer by 6 mm, additional MPFL reconstruction with autologous gracilis tendon. 3 years postoperatively regular tracking and stable patella. Minor complaints due to already existing degenerative changes

Torsional osteotomies have a significant and effective influence on patellar tracking [44], particularly in near-extension angles. Interstingly the femoral torsion seems to have a higher influence as a risk factor for patella dislocation than the tibial torsion [53]. High success rates with torsional osteotomies are reported in the literature [21, 23, 58]. Accurate values at what torsional deviation a correction should take place are not known. This is not only dependent on absolute values but also on accompanying pathologies (trochlea dysplasia, patella alta, genu valgum and others) and on clinical symptoms. Torsional deformities from 10° onwards are discussed in cases of corresponding clinical symptoms [21, 23]. However, it should be taken into account that combined deformities are often present. Dickschas et al. [21] carried out 11 femoral, 19 tibial and two bifocal corrective osteotomies on 32 patients. At the same time accompanying valgus correction was carried out on 18 of those 32 patients; two patients were additionally treated with a varus correction. However, only in 12 patients maltracking and additional patella instability could be observed (type 3e). 20 patients showed isolated maltracking without instability (type 5). In our own patient population we additionally carried out MPFL reconstruction on all type 3e-patients (Fig. 4). However, this is usually not required in cases of type 5 because of the lacking instability.

Type 4: maltracking with loss of patella tracking (severe trochlear dysplasia)

Type 4 describes a highly unstable patella with complete loss of the proximal patellar tracking due to a high degree of bony dysplasia of the proximal trochlea (Fig. 5). Here, intact medial restraints cannot preserve the patella from lateralisation. Correction of trochlea geometry can be seen as a causal treatment [6, 12, 20, 22, 43, 46, 54, 65, 67, 68].

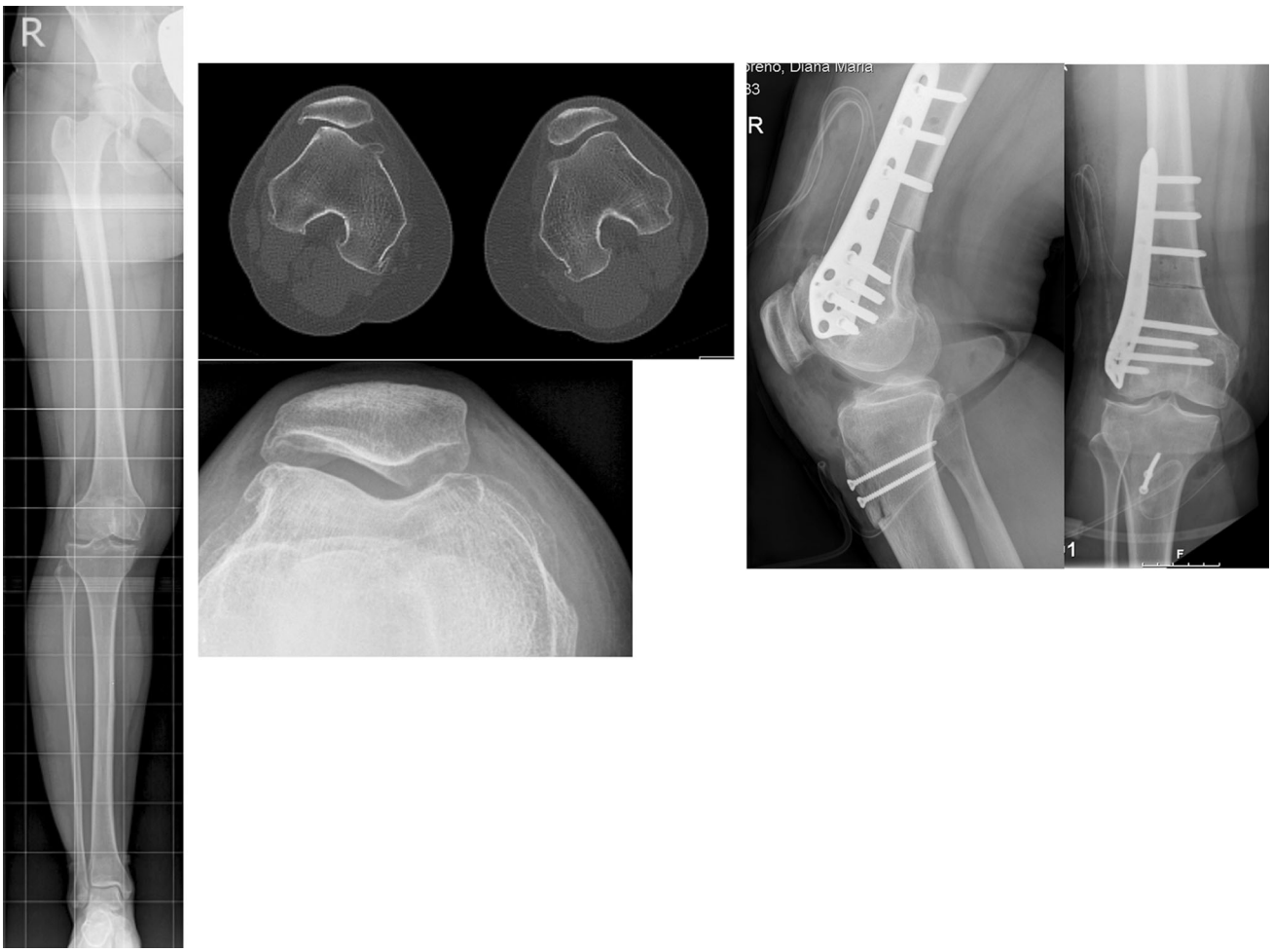

Fig. 4 27-year-old female patient with recurrent patellar dislocations, *right side*. Clinical instability and lateral patellar maltracking type 3e. Straight leg axis, internal torsion of the femur 40°, external torsion of the tibia 39°, tibial tuberosity–trochlea groove distance 17 mm, Insall–Salvati ratio 1.2. External torsional osteotomy of the distal femur by 12°. Medial tibial tubercle transfer by 5 mm, additional MPFL reconstruction with autologous gracilis tendon. Postoperatively stable patella and normal tracking. Free of complaints after 1 year

Since the patellar tilt, shift and the patella alta are caused by a dysplastic trochlear geometry, a correction of the trochlea positively influences these risk factors. Dysplasia of the trochlea is not synonymous with an isolated flattened or dysplastic lateral femoral condyle. It is rather defined by a hypoplastic medial femoral condyle, which shifts the sulcus trochleae medially and thereby flattens the lateral slope at a normal high condyle. As a result, the trochlea sulcus is reduced and the lateral trochlea is no longer a ledge, but rather more of a guideway for the patella. Additionally a missing proximal patellofemoral overlap caused by a short trochlea and not by patella alta can be a cause of the loss of patellar tracking.

Therefore the goal of trochleaplasty in most cases must be to steepen and raise the lateral facet in relation to the trochlea without increasing patellofemoral pressure. This can only be achieved by deepening the central parts of the trochlea and not by raising the lateral trochlear facet. Similarily TT-TG can be adressed by positioning the trochlea sulcus.

Different surgical techniques exist [19, 28]. We prefer Bereiter's technique [8, 57]. Additional medial stabilisation is usually recommended. Here, MPFL-reconstruction with a free gracilis graft has shown to be reliable. Further, in most cases a lateral tightness exists, whereas a lengthening of the lateral retinaculum as recommended by Biedert is indicated [9, 10].

Thus a trochleoplasty is able to correct multiple risk factors of patellofemoral instability in one step:

- Dysplasia (bony geometry) of the trochlea.
- Lateralisation of the trochlea sulcus and thus normalisation of the TT-TG.
- Minimal reduction of patella alta.
- Normalisation of patella tilt and -shift.

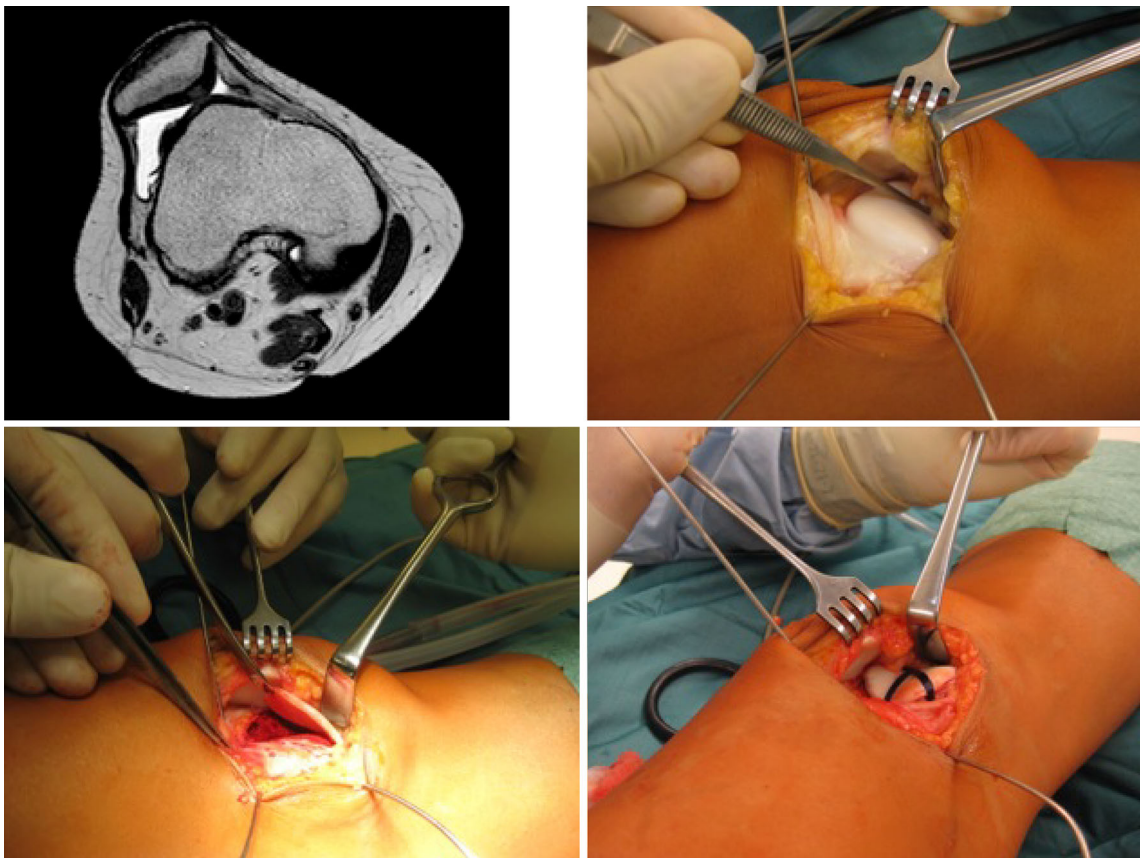

Fig. 5 Female patient with patella instability and loss of patellar tracking, *right side*. After trochleoplasty and MPFL reconstruction normal tracking and stable patella

Follow-up examinations of the initial detached and then readapted cartilage and the underlying bone have shown an intact and, according to the criteria of the ICRS, normal cartilage [55].

Short and midterm results after trochleaplasty show good and encouraging results in which a significant improvement in function is described [6, 12, 20, 22, 43, 46, 54, 65, 67, 68]. This is consistent with the observation in our own patients, especially a high subjective patient satisfaction as well as a significant gain in quality of life is observed.

Further studies have to show to what extent long-term degenerative changes can be avoided by correcting the trochlea.

Indication for trochleaplasty is the high grade trochlear dysplasia of type B and D according to Dejour with complete loss of the proximal patellar tracking. But limits here are gradual. In order to determine an objective parameter, where an isolated MPFL reconstruction is no longer sufficient, the group around Bereiter [8] has postulated that a less than 10° lateral trochlear inclination could be an indication for trochleoplasty. For this purpose, an objective method of measurement of the proximal trochlea on the basis of MRI cross-sectional images was developed [13].

Trochleoplasty represents a technically demanding surgical procedure with a longer learning curve and requires careful patient selection and indication. In the future more and decisive factores have to be defined to characterise trochlear dysplasia and to define more exactly surgical indications for trochleoplasty.

Type 5: maltracking without instability

Patellar maltracking without instability can typically be observed in approx. 60 % of "inwardly pointing knee"-cases [21] or in case of a pathological, laterally inclined knee base line with hypoplasia of the lateral femoral condyle. Both entities are rather rare and often overlooked so that patients most commonly underwent various previous surgical procedures and therefore have a long period of suffering already put behind them (Fig. 6).

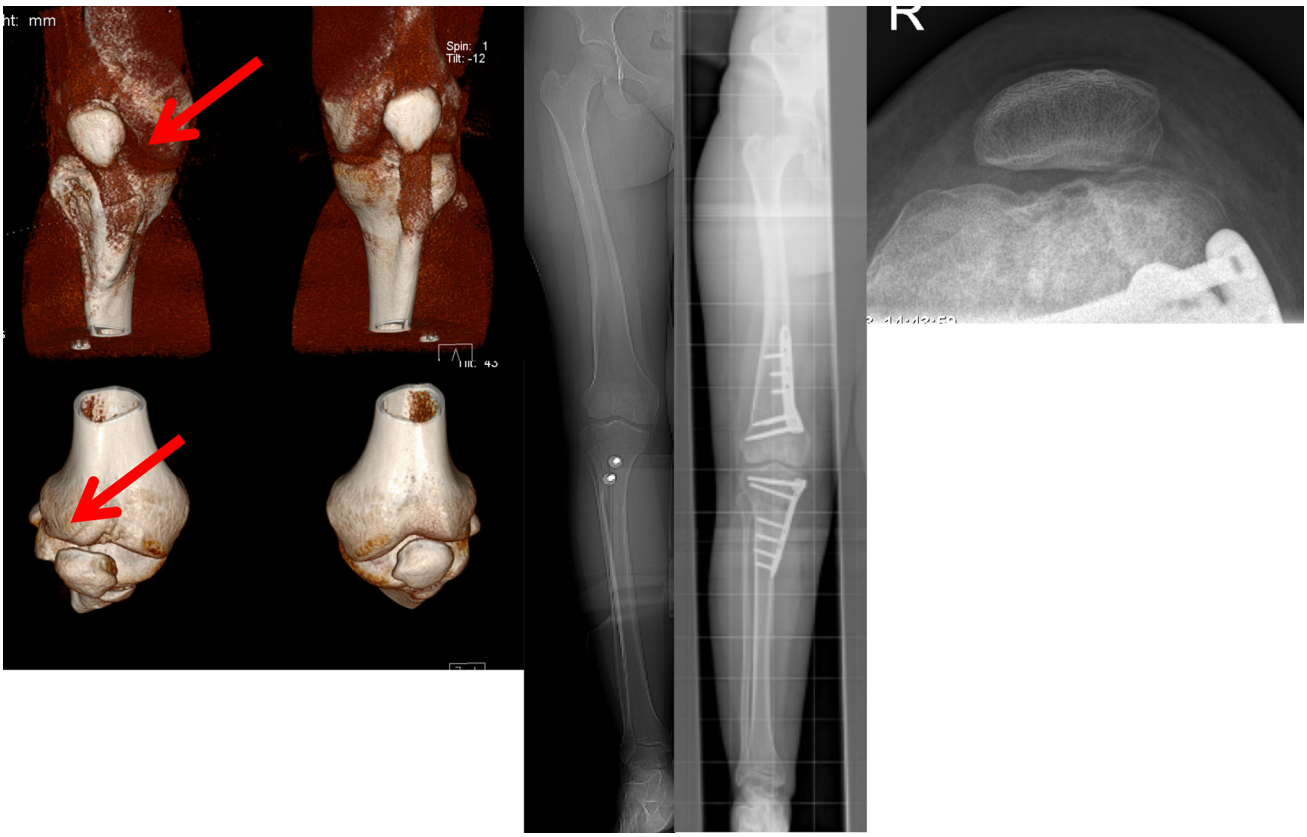

Fig. 6 27-year-old female patient with lateralisation of the patella and maltracking after 50° of flexion; type 5. No previous dislocation. Straight leg axis, however 9° deviation of the knee base line to medial, regular torsion, Insall–Salvati ratio 1.1, tibial tuberosity–trochlea groove distance 8 mm after medialization surgery with unsuccessful overcorrection a number of years ago. Centralised patella after double osteotomy of tibia and femur and reconstruction of the knee base line

Discussion

Patellofemoral instability represents a multifactorial pathophysiology. There is always a coincidence of different risk factors, which influence each other. The often preclaimed "individual" approach to therapy [17, 66, 70]—depending on the underlying pathology—accommodates the present classification, which should be helpful in decision-making in everyday clinical routine.

Since the risk factors never occur isolated, but always in variable expression, this classification is based on the graduation of the main pathology into different types. As a consequence, an individual and accurate clinical examination and adequate imaging is obligatory. Here, an MRI with determination of the TT-TG and the lateral trochlear inclination are of outstanding importance. If clinically suspected torsional deformity of lower extremity is present, further torsional measurement (MRI or CT scan) of the lower extremity is indicated. Beside adequate measured parameters, the existing cartilage status and history of previous operations has to be additionally considered.

Our experience has shown that many patellar instabilities which require surgical intervention can be treated by means of MPFL reconstruction with good to very good results. This surgical technique is easy to perform and provides—at a suitable indication—reliable results. As a consequence of increasing quantity of MPFL reconstructions, an increased rate of revisions can be noticed. The main reason for revision is a misplaced femoral insertion point. To ensure correct femoral insertion, the insertion point should be determined intraoperatively by fluoroscopy [51, 56]. Another reason for failed MPFL-reconstruction is inaccurate indication. Especially an overseen maltracking is a common reason for failure after MPFL reconstruction. Hence, the present classification should remind the physician of the possibility of an existing maltracking or possibly of a loss of patellar tracking and it should encourage him to conduct specific clinical and radiological exam for an exact evaluation of the patella tracking.

When which procedure should be used derives from the present classification to some extent already, but there still is a leeway in individual decision making for the surgeon.

A further advantage of this classification may lie in a better chance to compare clinical studies. At the moment almost all clinical studies concerning patella dislocation presented in the literature contain a mixture of different pathologies, which makes it impossible to compare these studies. That may be one reason, why so many different results and so many different clinical pathways for the treatment of patella instabilities are reported in the literature. The presented classification system could have the potential to serve as a basis for a better understanding and better comparability of future clinical studies.

Further more all cases of patella instability und maltracking can be described by this classification. In this respect there has not been a single case in our clinic over the past 6 years, which would not have been ascertained by this present classification.

The above, however, poses a limitation at this point in time as the intraobserver and interobserver reliability is not yet scientifically evaluated. Time will tell if this classification has potential for broad clinical application.

Further limitations of this present classification are that there are occasional borderline cases, which are difficult to be clearly assigned to a specific type because not all parameters are explicitly defined with a pathological score value (e.g., torsion) through current literature yet. However, this classification might prove beneficial in years to come as it allows for "learning" and for transferring improved knowledge into it. In doing so each type of the classification can be further refined and more accurately distinguished from each other without having to change them. Especially the parameters for the terms "instability", "maltracking" and "loss of tracking" should be more precisely defined in the future, which could significantly improve the clinical and scientific value of the classification without the need to change it.

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