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ORIGINAL ARTICLE

Galeazzi's modified technique for recurrent patella dislocation in skeletally immature patients

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Abstract
Background A large number of surgical techniques have been proposed for the treatment of recurrent patellar dislocation in adolescents, one of the most famous being Galeazzi's semitendinosus tenodesis as modified by Baker. The aim of this study was to verify the mid-term results of this technique, the effectiveness of restoring the patellofemoral congruency, by both static and dynamic computed tomography (CT), and to determine whether the preoperative type of patellofemoral relationship affects the results.
Methods The study included 14 patients (16 knees), with a mean age of 11.6 years, Tanner stage $\leq$3, with at least two to three episodes of patellar dislocation. The patients underwent surgery using Baker's modification of Galeazzi's technique. All 14 patients were evaluated preoperatively and at least 4 years afterward by static and dynamic CT. Clinical evaluation at follow-up was performed using the criteria described by Crosby and Insall.
Results Clinical results at follow-up were excellent in 62.5% and good in 37.5%. As preoperative evaluation showed a high patella in 7 out of 16 knees, two groups were considered: A, high patella; B, not high patella. The data obtained with static CT show that the patella reached a satisfactory congruence in all knees. The data obtained with dynamic CT showed different results between group A and B. A preoperative high patella remains high with quadriceps contraction and again shows the change of tilt and subluxation. In group B, the data obtained with dynamic CT are comparable with those obtained with static CT.
Conclusions This technique produces good mid-term clinical results. However, the dynamic CT showed that in those patients with high patellas, semitendinosus tenodesis alone is not enough to stabilize the patella.

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Introduction

Patellar instability is one of the most common musculoskeletal disorders encountered in children and adolescents, with patellar dislocation being the most severe degree. The incidence of primary patellar dislocation is 5.8 per 100,000, increasing in adolescence to 29 per 100,000 [1, 2].

Redislocation rates following non-operative treatment range from 15 to 71% [3–5]. In younger patients the rate of recurrent dislocation is higher than in patients over 20 years of age [6]. However, many patients have pain and mechanical limitation after the initial dislocation [7]. High patella, trochlear dysplasia, hyperlaxity, an increased quadriceps angle due to various torsional deformities of both the femur and the tibia, female gender, and a positive family history have all been associated with the condition [3, 8–10]. A complete medical history and careful clinical examination are essential to define the type of dislocation and should be supplemented with imaging. In the literature, many methods have been described for the investigation of patellofemoral malalignment. Some authors suggest standard X-ray, including posteroanterior weight-bearing views of both knees at 45° flexion, lateral views and Merchant views [11–13]; others prefer static computed tomography (CT) [14], or static and dynamic CT [15], and magnetic resonance imaging (MRI) is now considered a reliable means of identifying risk factors for chronic patellar

instability [16]. In many published reports, the first treatment of acute primary patellar dislocation is nonoperative, focusing on early joint motion and quadriceps muscle strengthening, except in the presence of osteochondral lesions [3].

Several techniques have been proposed for the surgical treatment of recurrent patellar dislocation in adolescents. The distal bony realignment of the tibial tubercle should not be used in skeletally immature patients because it can induce premature physeal closure and subsequent genu recurvatum [17, 18]. However, some authors have utilized distal periostal patellar tendon realignment, either partial [19] or total [20].

Another surgical technique is the reconstruction of the medial patellar-femoral ligament (MPFL). In fact, biomechanical research has demonstrated that the MPFL accounts for 50–60% of the medial soft tissue restraining force against lateral patellar subluxation or dislocation [21]. In recent years increasing interest has been observed in the literature for surgical reconstruction of the MPFL [22, 23], showing good results.

Among the techniques utilizing soft tissue, one of the most famous is semitendinosus tenodesis, published by Galeazzi [24] in 1922, for reconstructing the medial patellotibial ligament (MPTL). This technique was adopted and modified by Fiume (1954), who added lateral retinacular release and medial retinacular reefing [25]. In 1972, Baker [26] adopted this technique, but made an oblique tunnel across the patella in the line of the tenodesis through which he passed the semitendinosus tendon from the medial to the lateral side. The tendon was under tension, drawing the patella medially and downward. Several studies reported unsatisfactory results in about 25% of cases of patellotibial reconstruction using Baker's modification of Galeazzi's semitendinosus tenodesis technique [26–29].

Furthermore, we have not found any studies that evaluated the patellofemoral relationship both preoperatively and at follow-up by static and dynamic CT examination.

The aim of this study was to verify:

- The mid-term clinical results of surgery using Baker's modification of Galeazzi's technique (at least 4 years of follow-up);
- The effectiveness of restoring patellofemoral congruency by both dynamic and static CT at follow-up.
- Whether the preoperative patellofemoral characteristics affect the results at follow-up.

Materials and methods

Between 1998 and 2004, 24 patients (7 male and 17 female) with a mean age of 11.6 years (range 9.2–13.7) were treated by Baker's modification of Galeazzi's technique for recurrent dislocation of the patella. Four patients underwent bilateral surgery. Fourteen of the 24 patients (4 male and 10 female; mean age 11.1 years, range 9.2–13.1; 16 knees, 2 female patients suffered from bilateral dislocation) who met the criteria listed below were enrolled in the study:

1. Recurrent patellar dislocations (at least 2–3 episodes);
2. Tanner stage ≤ 3; [30]
3. Signs of subluxated and tilted patella assessed by CT [31];
4. Clinical and instrumental evaluation by static and dynamic CT [15] after at least 4 years of follow-up;
5. No associated meniscal or cartilaginous injuries.

All the procedures described in this investigation were approved by our local ethics committee.

All the patients and their parents gave written informed consent prior to the surgical procedure and agreed to be included in this study.

All patients were evaluated preoperatively with measurement of the *Q*-angle of the knee and assessment of ligamentous laxity using the Carter-Wilkinson criteria [32]. The clinical evaluation at follow-up was performed using the criteria described by Crosby and Insall [33] (Table 1). CT scans were performed without (static) and with (dynamic) quadriceps contraction [15], and the following parameters were considered:

(1) Type of patellofemoral relationship: tilted, subluxated, subluxated and tilted patella.
(2) The distance in millimeters between the apex of the tibial tuberosity and the bottom of the trochlear groove (TAGT).
(3) The sulcus angle (SA).
(4) The patellar tilt angle (PTA).
(5) The patellar tilt angle with quadriceps contraction (PTAc).
(6) The patellar height (PH) is the position of the patella with respect to the femoral intercondylar notch. It is considered normal (PH = 0) when the complete

Table 1 Crosby and Insall's criteria (1976)

Grade	
Excellent	No pain, normal activity including all sports, full range of movement, knee subjectively normal
Good	Occasional discomfort, feeling of stiffness or instability, no participation in contact sports, slight loss of flexion, knee considered improved or normal by the patient
Fair to poor	Pain most of the time, symptoms altered but including recurrent subluxation or significant loss of flexion, further surgical treatment required in some instances
Worse	Pain increased, subluxations more frequent

morphology of the patella can be observed in the same CT scan as the complete femoral intercondylar notch. We considered a high patella when PH was ≥2 mm. We measured the patellar height taking into consideration the number of CT scans necessary to visualize the notch in respect to the complete morphology of the patella. The scans each measure 2 mm.

(7) The patellar height with quadriceps contraction (PHc).
(8) The femoral patellar distance (FPD), which is the distance in millimeters between the lateral margin of the femur and the lateral margin of the patella.
(9) The femoral patellar distance with quadriceps contraction (FPDc).

Preoperative arthroscopic evaluation to assess the presence of meniscal or cartilage defects was performed in all patients. The surgical technique used was Baker's modification of Galeazzi's semitendinosus tenodesis based on the reconstruction of the medial patellotibial ligament with adequate lateral release and medial retinacular reefing. The operation was performed by one senior surgeon (GV). The surgical technique required placement of the patients in a supine position; a pneumatic tourniquet was applied to the proximal thigh, and the surgeon then made a medial longitudinal parapatellar incision exposing the extensor apparatus. A lateral release was performed taking care to avoid tearing the synovial membrane. The semitendinosus tendon was identified and divided at the muscle-tendon junction. The tendon must be at least 12–13 cm long. An oblique 4-mm hole was drilled through the patella from the infero-medial to the supero-lateral side, and the tendon was passed through it from the medial to the lateral side. The tendon was sutured under considerable tension, firmly drawing the patella medially and downwards to reposition it in the trochlea (Fig. 1). The lax medial retinaculum was reefed. After the operation, the knee was positioned in a 20° flexion brace for 3 weeks. Postoperative CT scans were routinely performed to check for overcorrection, which could lead to development of a medial patellar subluxation [28]. Isometric muscle exercises of the quadriceps were started in a brace the day after the operation. Once the immobilization device had been removed, continuous passive motion of the knee and volitional exercises combined with neuromuscular electrical stimulation were begun, as well as exercises to strengthen the quadriceps and hamstring muscles. One month after surgery, the patient could begin knee flexion of more than 90° and progressive weight-lifting until complete. Sports activities were restricted for 4–6 months.

Statistical methods

The paired Student's *t* test was used to analyze preoperative and postoperative values when the data were parametric, and Pearson's correlation was used to compare preoperative with postoperative values. Outcome data for each group are presented as the mean and standard deviation, and the mean difference between groups and 95% confidence interval is provided. A p value of <0.05 was considered significant.

Statistical analysis was performed using a GraphPad prism 5 computer program.

Results

Fourteen patients satisfied the inclusion criteria and had a mean follow-up of 4.4 years (range 4.1–5.8). According to Crosby and Insall's criteria, 62.5% of knees showed excellent results, 37.5% had good results, and no cases showed poor or worse outcomes (Table 2). The only reported complication was a transient saphenous nerve

Fig. 1 **a** Galeazzi's semitendinosus tenodesis modified by Baker. The semitendinosus tendon was passed through the patella in an oblique tunnel and **b** was sutured to itself. After finding the right tension and obtaining a repositioning of the patella medially and downward, the operation is completed by lateral release and medial retinacular reefing

Table 2 Results of 16 knees

Grade	Knees	%
Excellent	10	62.5
Good	6	37.5
Fair to poor	0	0
Worse	0	0

sensory deficit in four knees. The mean *Q*-angle was 19.4° (range 17.4–22.3). Ligamentous laxity was found by the Carter-Wilkinson test in ten patients (62.5%) and was not correlated with any other parameter evaluated.

As preoperative evaluation showed a high patella (PH ≥2 mm) in 7 out of 16 knees, two subgroups of patients were considered: those with a high patellas (subgroup A) and those without (subgroup B) before surgery. The type of patellofemoral malalignment was characterized by subluxated and tilted patellas in all knees by static CT, being more marked in dynamic CT; PTA (Fig. 2a) and FPD (Fig. 3a) were the parameters used for this evaluation.

The mean TAGT value was 21.5 mm (range 18–25) and did not change after surgery.

The measurement of PTA in all cases showed a statistically significant difference between preoperative static and dynamic CT values ($p = 0.01$), but conversely no difference at follow-up ($p = 0.25$). There was a statistically significant difference ($p = 0.0001$) between preoperative static PTA and static PTA at follow-up, and between preoperative dynamic PTA and follow-up dynamic PTA ($p < 0.0001$) (Fig. 2a). In subgroup A, the p value was also significant at follow-up between static PTA and dynamic PTA ($p = 0.003$) (Fig. 2b). In subgroup B, it is interesting to note that there was no statistically significant difference between static PTA and dynamic PTA either preoperatively ($p = 0.072$) or at follow-up ($p = 0.169$) (Fig. 2c). The measurement of FPD in all cases showed a statistically significant difference between preoperative static and dynamic CT values ($p < 0.0001$), but conversely no difference at follow-up ($p = 0.096$) (Fig. 3a). This result was much more significant in subgroup A ($p = 0.0002$) (Fig. 3b) than in subgroup B ($p = 0.013$) in preoperative evaluation (Fig. 3c). The measurement of PH in all knees showed a statistically significant difference between preoperative static and dynamic CT values ($p = 0.0014$) and values at follow-up ($p = 0.0055$) (Fig. 4a). Furthermore, this result

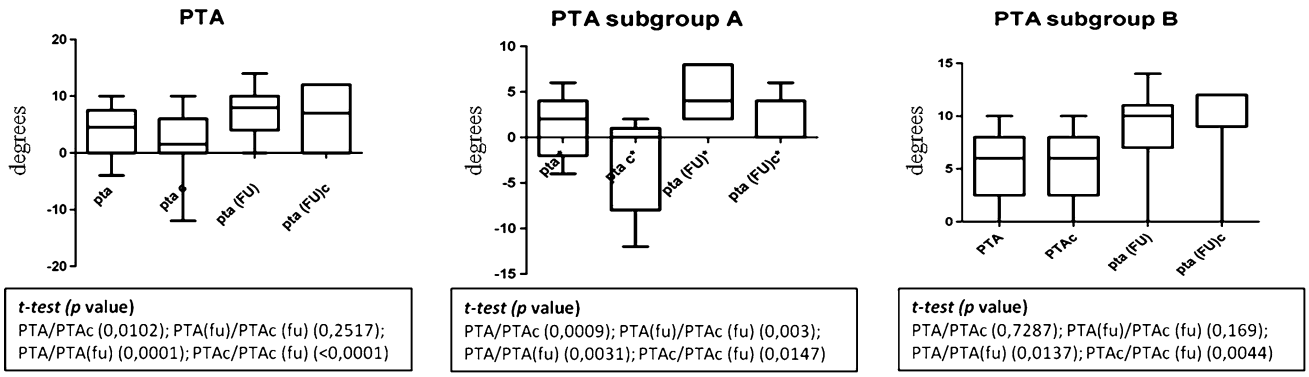

Fig. 2 The patellar tilt angle (PTA) measurements of all knees and of subgroups A and B. Patellar tilt angle (PTA) with quadriceps contraction (PTAc) and at follow-up [PTA(fu) and PTAc(fu)]

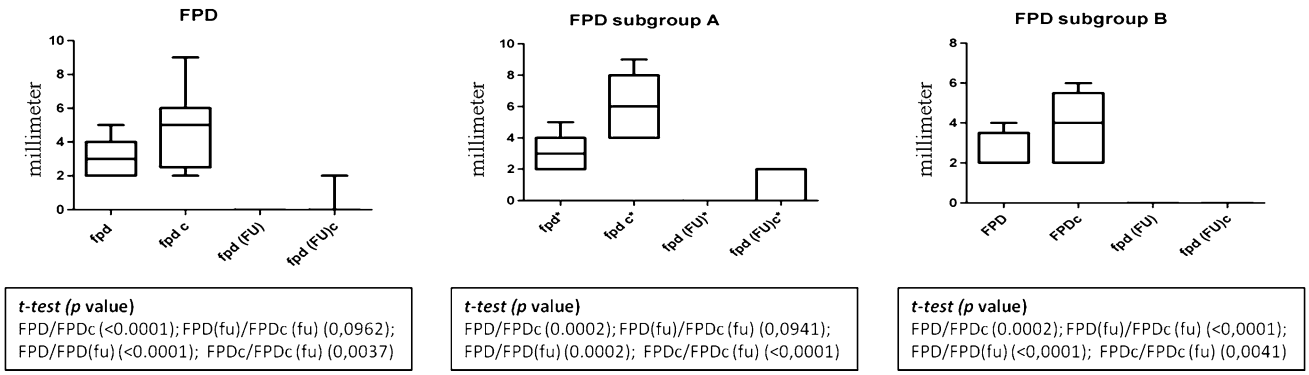

Fig. 3 The femoral patellar distance (FPD) measurements of all knees and of subgroups A and B. Femoral patellar distance (FPD) with quadriceps contraction (FPDc) and at follow-up [FPD(fu) and FPDc(fu)]

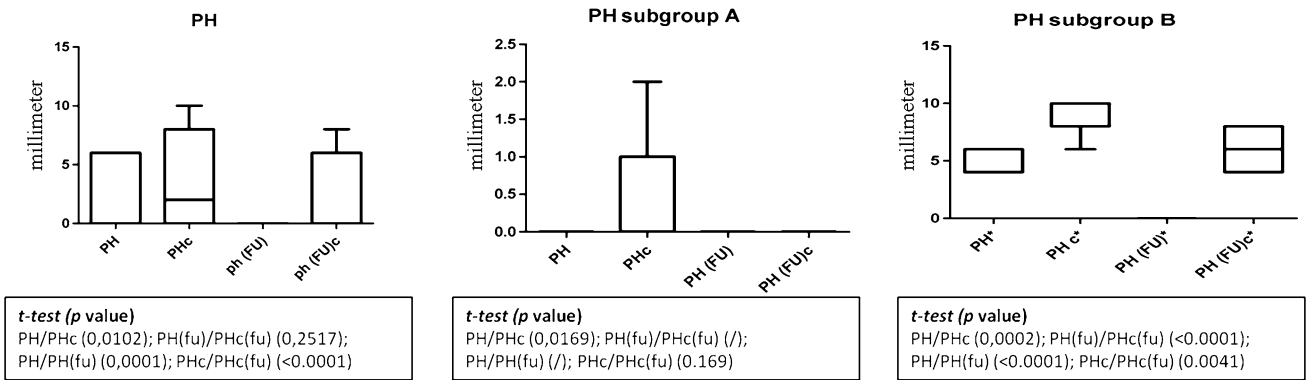

Fig. 4 The patellar height (PH) measurements of all knees and of subgroups A and B. Patellar height (PH) with quadriceps contraction (PHc) and at follow-up ([PH(fu) and PHc(fu)]

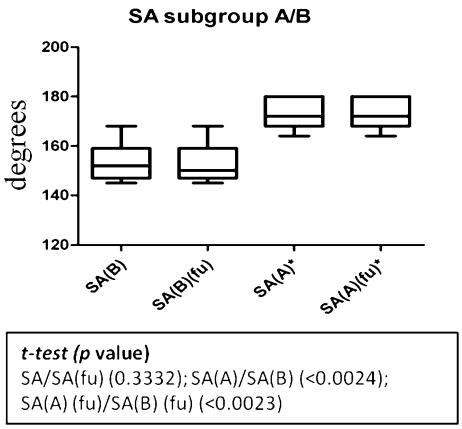

Fig. 5 The sulcus angle SA measurements of subgroups A and B

was much more significant in subgroup A, characterized by a high patella ($p = 0.0002$ preoperatively, $p < 0.0001$ at follow-up) (Fig. 4b). In subgroup B, characterized by a normal patella height, the data showed no statistically significant difference (Fig. 4c). The measurement of SA, with a preoperative mean of 162.1°, showed no statistically significant difference at follow-up ($p = 0.333$). However, there were statistically significant differences between subgroup A and subgroup B ($p = 0.0024$ preoperatively and $p = 0.0023$ at follow-up) (Fig. 5). In fact the mean SA value for subgroup A was 173.4° and for subgroup B, 153.2°.

Discussion

Clinical data at follow-up of at least 4 years confirm that Galeazzi's semitendinosus tenodesis, with adequate lateral release, medial retinacular reefing and modified by Baker, can produce good clinical mid-term results in skeletally immature patients with recurrent patella dislocation. Analysis of the data obtained with static CT showed that the patella reached a satisfactory congruence with the trochlea in all knees subluxated and tilted prior to surgery. The PTA, the index of patellar tilt, was normal in all cases, as was the FPD, the index of patellar subluxation. In addition, the PH was normalized also in patients with preoperatively high patellas. Analysis of the data obtained with dynamic CT showed a difference in results between subgroup A and subgroup B.

In the preoperative high patella subgroup A, the patella remained high with quadriceps contraction, but showed the change in PTA and FPD with lower values compared to preoperative data (Fig. 6). In subgroup B (not high patella) the data obtained with dynamic CT were comparable to those obtained with static CT (Fig. 7). Therefore, Galeazzi's modified technique normalized the high patella in static CT, but the correction was not maintained in the dynamic assessment.

The study documented that, in the reconstruction of MPTL in patients with preoperative high patellas, the semitendinosus tendon alone cannot counteract the force of the quadriceps. However, the maintenance of an abnormal patellofemoral relationship was never seen to be associated with a new dislocation at follow-up at least 4 years after surgery.

The study allows us to maintain that the presence of a preoperative high patella affects the instrumental (CT scan) outcome of this surgical technique used for recurrent dislocation of the patella in adolescents.

In the 1990s, different anatomical and biomechanical studies highlighted the primary role of the MPFL as a restraint among the medial static patellar stabilizers. Conlan [34] reported that "the MPFL had 53% of the total medial restraining force." Hautamaa and Desio reported that "the MPFL contributes an average of 50% of the total medial restraint and 60% of the total restraining force" [35–37]. The percentage contribution of MPTL resistance to lateral dislocation has been found to be 13% [38]. However, our focus on reconstruction of the MPTL concerns its role in opposing for pulling force of the quadriceps muscle and not on the lateral patellar dislocation as

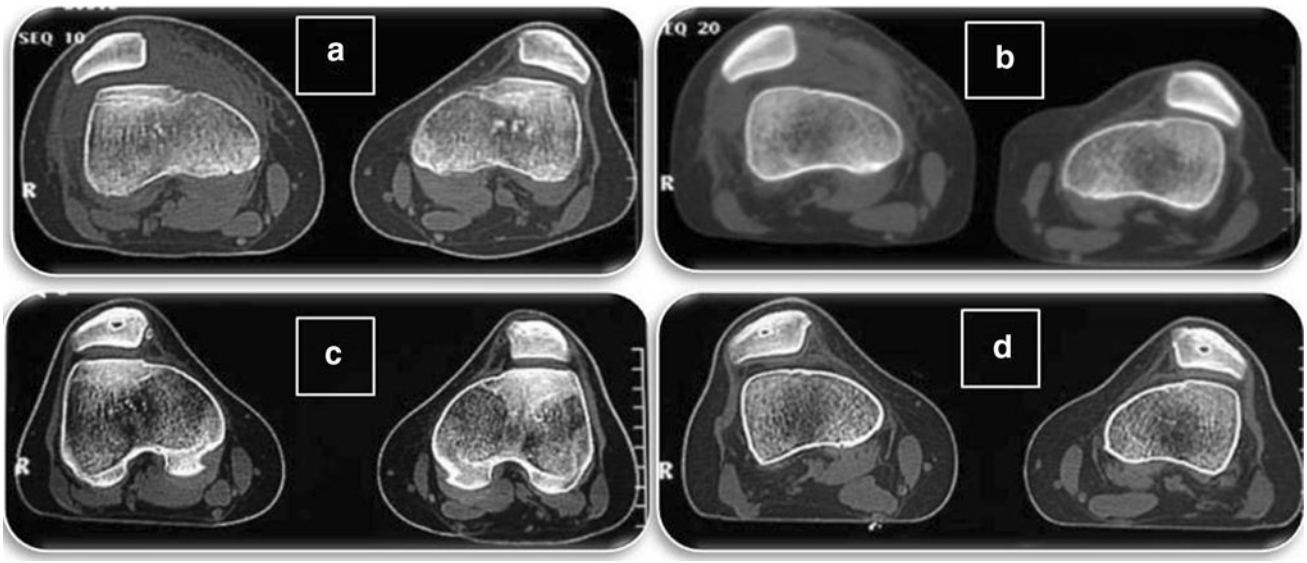

Fig. 6 Female 13.5 years old, Tanner stage 3. The patient has experienced three episodes of patellar dislocation. Preoperative CT. The high patella does not permit simultaneous visualization of the complete patellar morphology and the intercondylar notch with both static (**a**) and dynamic (**b**) examination of the right and left knees. **c** Static CT at 5-year follow-up of the right knee and at 6-year follow-up of the left knee: the patellofemoral congruence is satisfactory, and the complete patellar morphology and the intercondylar notch are simultaneously visible. The presence of trochlear dysplasia is shown. **d** Dynamic CT at 5-year follow-up of the right knee and at 6-year follow-up of the left knee: the high patella tendency is bilaterally confirmed, contrary to the satisfactory bilateral patellofemoral congruency shown by the static CT exam

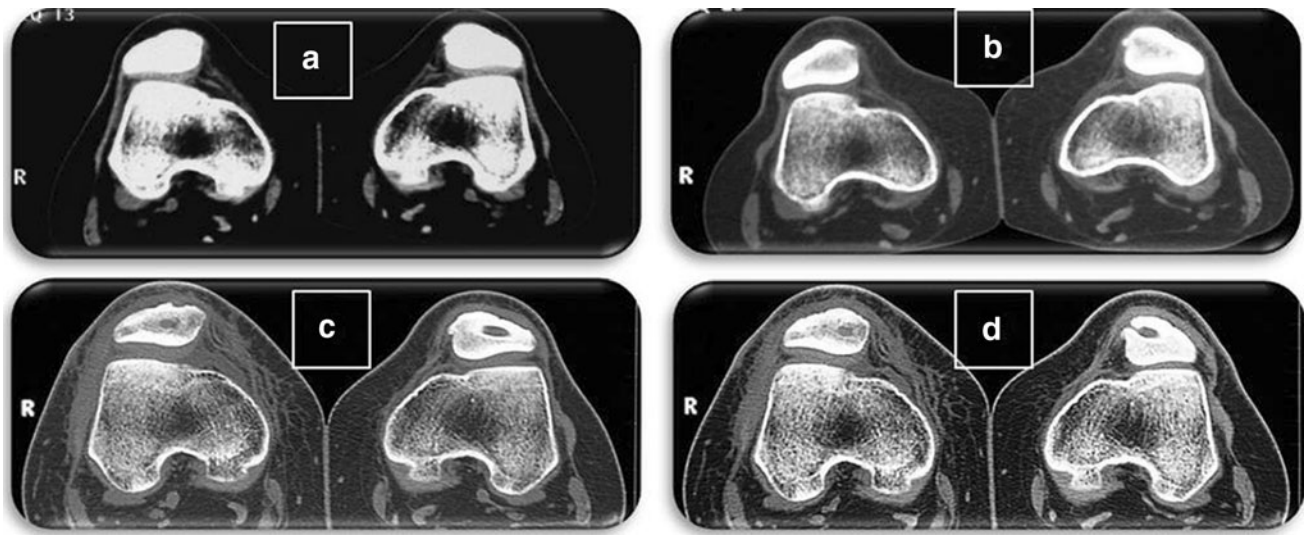

Fig. 7 Female, 13 years old, Tanner stage 3. The patient has experienced three episodes of patellar dislocation. Preoperative static (**a**) and dynamic (**b**) CT scan. **c** Static CT at 4-year follow-up of the right knee and at 5-year follow-up of the left knee showed a satisfactory bilateral patellofemoral congruence even in the presence of trochlear dysplasia. **d** Dynamic CT confirmed the satisfactory bilateral results of the static examination

amply highlighted in several studies. In the absence of predisposing factors, the reconstruction of the MPFL alone might be indicated. However, the indications for reconstruction of the MPFL are not yet fully clarified [39]. In fact, especially in adolescents, different anatomical abnormalities or constitutional factors may facilitate and sustain the lateral dislocation of the patella. The presence of an excessive *Q* angle or a high patella may invalidate the outcome of medial patellofemoral ligament reconstruction, as suggested by Mountney, who reported that problems with stability of the patellofemoral joint are rarely straightforward and may be influenced by other factors such as articular geometry, alignment of the lower limb, rotational deformities, patellar height and ligamentous

laxity [40]. Because of these considerations, in the presence of a high patella or a high *Q* angle, to achieve real stability of the extensor mechanism, we agree with other authors who have published and suggested the reconstruction of both the MPFL and MPTL in order to avoid bad results at follow-up [3, 21, 41, 42].

In the literature various studies have reported the results of semitendinosus tenodesis using this technique. Baker et al. [26] reported 81% excellent or good results in 53 patients and a 5% recurrence rate. Hall et al. [27] described only 62% excellent or good results in 26 operated knees. Letts et al. [28] reported 82% excellent or good results, and 8% recurrence in 26 cases. Other studies [29, 43] on this procedure reported good results. The most frequent complications mentioned in the literature are persistent pain due to chondromalacia, infections, limitation of the range of motion, transient saphenous nerve sensory deficit and wound healing [28]. In our study, failures did not occur, but we had four cases of transient saphenous nerve sensory deficit. However, three important factors that may influence results have been reported in the literature: appropriate tension before suturing the tendon to the patella, adequate lateral release and normal conditions of the joint surface of the patella at the time of surgery [44].

The strong points of this study are: the static and dynamic CT study, the follow-up of at least 4 years and the surgery being performed by one senior surgeon (GV). The limitation of the study is the small number of cases.

In conclusion, this study shows that semitendinosus tenodesis can resolve the functional problem of patellar dislocation and attains satisfactory patellofemoral congruence in all knees as evidenced by static CT. However, dynamic CT showed that this technique is unable to counter the tendency of upward displacement of the patella, and to prevent subluxation and tilting of the patella in patients with high patellas preoperatively.

The limitation of this operation was seen on CT assessment with quadriceps contraction [15]. The maintenance of this malalignment in dynamic conditions could entail a risk of chondromalacia. These results led to improvements being made to this technique by strengthening the semitendinosus resistance and/or having more anchor points in the patella [3], especially in knees with high patellas preoperatively.

Conflict of interest The authors declare that they have no competing interests.

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