Original Article

Imaging findings and clinical function after combined surgery for recurrent patella dislocation: a comparative study

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Background: Limited research has evaluated imaging results following a combination of operations for recurrent patella dislocation (RPD) based on medial patellofemoral ligament (MPFL) reconstruction. Therefore, this study aimed to retrospectively compare the imaging and clinical results of RPD following 2 types of combined surgical techniques.

Methods: Patients who underwent combined surgery for RPD from January 2008 to December 2019 were enrolled in the study and allocated into 2 groups. MPFL reconstruction combined with lateral retinacular release (LRR) was performed in groups A and B, and an additional tibial tuberosity transfer (TTT) was performed in group B only. Patients in group A with a tibial tuberosity trochlear groove (TT-TG) distance greater than 15 mm were included in subgroup A*. Congruence angle (CA), patellar tilt angle (PTA), lateral patellofemoral angle (LPA), lateral patellar displacement (LPD), TT-TG, Insall-Salvati Index (ISI), the Dejour type of trochlear dysplasia, and knee function were assessed. All groups were followed up in the short-term (1–2 years), and group B was also followed up in the mid-term (over 5 years).

Results: A total of 40 knees (36 patients) were included in group A, 26 knees (24 patients) in subgroup A*, and 27 knees (26 patients) in group B. In group A, CA, PTA, and LPD had increased at the short-term follow-up, yet LPA had decreased compared to the results 3 days after surgery. In group B, at the mid-term follow-up, PTA (12.54±6.88 *vs.* 15.23±6.10; P=0.002) increased while LPD (7.08±6.48 *vs.* 4.69±6.28; P=0.049) decreased compared with the short-term outcomes. The more severe the femoral trochlear dysplasia, the lower the mid-term Kujala scores in group B (P=0.007). The short-term TT-TG (17.32±4.288 *vs.* 12.84±3.758; P<0.001) and ISI [1.25 (1.1075, 1.300) *vs.* 1.06 (1.00, 1.16); P<0.001] in group B were lower than those in group A, who had a higher Kujala score (P<0.001). The CA, LPD, ISI, TT-TG, and Kujala score in subgroup A* were higher than those in group B at the short-term follow-up (P<0.05).

Conclusions: Both types of combination treatments were successful in altering the patellofemoral joint in a satisfactory manner, and the knee function improved in both groups. A TTT might not be necessary for patients with a TT-TG distance greater than 15 mm.

Keywords: Recurrent patella dislocation; imaging measurement value; knee function score

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Introduction

Recurrent patella dislocation (RPD) is a common condition among adolescents, particularly females aged 10–17 years (1). Dysplasia of the trochlear, increased tibial tuberosity trochlear groove distance (TT-TG), and patella alta have been identified as independent factors that contribute to the high incidence of secondary dislocation (2). For first-time dislocators without intra-articular loose bodies or chondral damage, conservative therapies are recommended; nonetheless, 15–45% of patients still experience recurrent patella instability after non-operative care (3). Currently, surgical management of RPD still remains controversial, with a lack of gold standardized protocols. Operative techniques on the knee extension apparatus can broadly be classified into 4 categories: (I) proximal realignment; (II) distal realignment; (III) trochleoplasty; and (IV) a combination of the above (4). Realignment at the proximal part often involves internal patellar retinaculum plication, medial patellofemoral ligament (MPFL) reconstruction, and lateral retinacular release (LRR). Distal realignment requires transfer of the tibial tuberosity (TTT) to improve the function at the patellofemoral joint in the presence of addressing the patellofemoral line of force and the anatomical Q angle (4). However, this procedure is inappropriate for patients with unclosed epiphyses due to the risk of affecting subsequent growth and development. TTT is also not recommended in individuals with medial meniscus resection or significant osteoarthritis in the knee (5).

During the past decade, reconstruction of the MPFL has become the predominant surgical therapy for RPD and is the standard approach to proximal realignment. The MPFL is the major medial restraining structure in patellar stability and contributes over 50% of the total medial restraining forces (6-10). MPFL reconstruction yields satisfactory outcomes in reducing the rate of re-dislocations, restoring patellar stability, and improving patients' quality of life (11). Although no research has demonstrated definite surgical indications, combined surgery centered on MPFL reconstruction has grown in popularity. Feller *et al.* (12) suggested that MPFL reconstruction taken as the main method of recurrent patella instability surgery could provide satisfactory results in the short- or mid-term, whether performed alone or in conjunction with other surgical procedures.

LRR is primarily applicable to patients with a tight lateral retinaculuma in the presence of clearly identified lateral patella compression syndrome (13), based on the effect of reducing the high pressure on the lateral side of the patella, balancing the medial and lateral forces, and re-centralizing the patella on its physiological axis (11). However, a decrease of pressure in the lateral patellar compartment following isolated LRR might lead to an increase in patellar instability (11). Isolated lateral release for patellar instability has been highly discouraged in the literature (13). In a study by Zhao *et al.* (5), MPFL reconstruction and LRR were combined based on the conviction that this would reduce the pulling force on the lateral patella, thus stabilizing the knee joint, and provide an improved biomechanical environment for the reconstructed medial structure to heal and remodel. However, the role of MPFL reconstruction and LRR in combination appears controversial, and the indications have not been entirely clarified.

For some patients with enlarged TT-TG and patella alta, additional procedures such as TTT should be considered to rearrange the distal knee device and change the Q angle and the force line of lower limbs, as well as reduce the height of the patella. Distal realignment could be added to some participants with increased patellar lateral tracking caused by a high TT-TG (5). Overcorrection may lead to medial instability and cartilage overload (14). A TT-TG >20 mm has always been considered abnormal (15). However, whether TTT is suitable for knees with TT-TG over 15 mm should be discussed, considering that patients with RPD consistently exhibit femoral trochlear and lateral condyle dysplasia, which results in reduced bony constraint of the patella. Additionally, a report showed that the Q angle was positive even when the TT-TG distance was 0 mm, indicating a propensity for lateral patellar excursion (5).

Even though many alternative surgical methods for RPD are discussed in the literature, limited studies have quantified and compared imaging results following combination operations based on medial patellofemoral ligament reconstruction. Research has shown that proximal and/or distal realignment on the knee extension apparatus produces positive outcomes. This study compared the results of a combination of MPFL reconstruction and LRR with or without TTT. The purpose of this retrospective study was to compare the computed tomography (CT) imaging manifestations and clinical scores following 2 combined surgeries of RPD centered on MPFL reconstruction. The hypothesis was that both combined techniques would positively impact the outcomes during follow-up. We present the following article in accordance with the GRRAS reporting checklist (available at https://qims.amegroups.com/

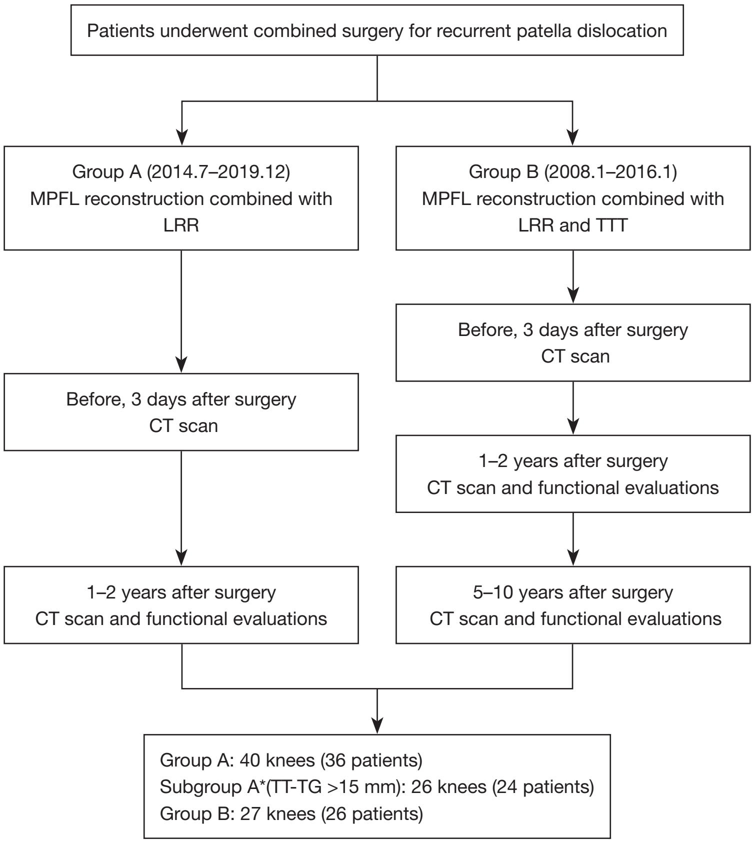

Figure 1 The flow chart of the research showing the process of screening patients. MPFL, medial patellofemoral ligament; LRR, lateral retinacular release; TTT, transfer of the tibial tuberosity; CT, computed tomography; TT-TG, tibial tuberosity trochlear groove distance.

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Methods

Patients

In this retrospective study, patients who had undergone combined surgery of RPD admitted to the Shanghai Sixth People's Hospital were selected and divided into 2 groups. Patients in group A admitted from July 2014 to December 2019 underwent the combination of MPFL reconstruction and LRR (proximal realignment). Patients admitted from January 2008 to January 2016 underwent an extra TTT in addition to proximal procedures and were enrolled in group B (proximal and distal realignment). The indication of TTT was TT-TG >15 mm according to the surgical technique described by Zhao *et al.* (5). Among group A, patients with TT-TG >15 mm were enrolled in subgroup A*. All groups received short-term results (1–2 years), and group B also received mid-term results (over 5 years). The imaging and clinical results were compared in group A, subgroup A*, and group B (*Figure 1*).

The inclusion criteria were as follows: (I) patients diagnosed with RPD on admission with at least 2 episodes of dislocation or 1 episode of dislocation plus multiple episodes of instability, positive fear sign, Q angle >15°, and CT examination showing patellar subluxation or dislocation; and (II) patients who had experienced arthroscopy-controlled combined surgery during hospitalization. The exclusion criteria were as follows: (I) patients with a previous history of knee surgeries, rheumatoid arthritis, joint cavity infection, tumors, or other diseases; and (II) patients who underwent trauma or reoperation in the knee during follow-up.

CT parameters and clinical scores

Knee joints with flexion of 0° were scanned by a 64-row CT scanner (GE LightSpeed VCT; GE

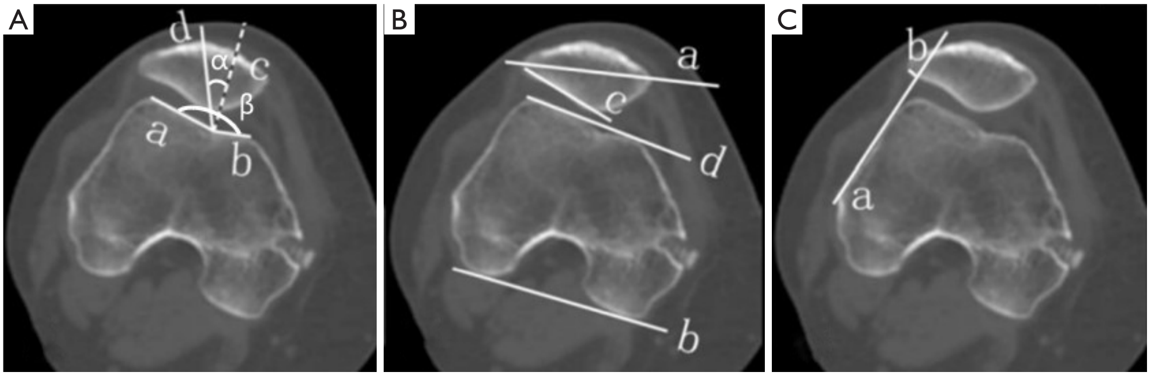

Figure 2 Methods of measuring the congruence angle, patellar tilt, lateral patellofemoral angle, and patellar lateral displacement. Select the slice with maximum patellar width. (A) Congruence angle: the sulcus angle (β) was determined by identifying the highest points of the medial and lateral condyles and the lowest point of the intercondylar sulcus. An angle bisector of the sulcus angle (dotted line c) was established. A line (d) was drawn from the lowest point of the intercondylar sulcus to the vertical ridge of the patella. The angle (α) formed by dotted line c and line d was a congruence angle. (B) Patellar tilt angle: a line parallel to the long axis of the patella (a) and a line passing through the media and lateral posterior condyle (b) were drawn. The patellar tilt angle was established by line a and line b. (B) Lateral patellofemoral angle: A line parallel to the lateral patellar facet (c) and a line across the posterior femoral condyles (d) were drawn. The angle formed by line c and line d was the lateral patellofemoral angle. (C) Lateral patellar displacement: A line parallel to the lateral margin of the trochlea was drawn (a). Lateral patellar displacement (b) was established as the distance between the most lateral margin of the patella facet and line a.

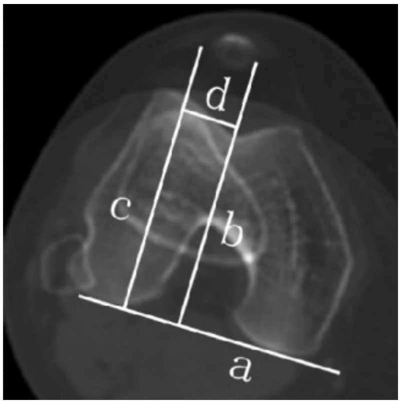

Figure 3 Method of measuring TT-TG. Overlay the slice showing the proximal trochlear groove of the femur with the slice showing the tibial tuberosity. Line a was drawn across the posterior margins of the medial and lateral condyles. Line b was perpendicular to line a and crossed the deepest point of the trochlear groove. Line c was perpendicular to line a and crossed the most anterior point of the tibial tuberosity. The distance (d) between line b and line c was TT-TG. TT-TG, tibial tuberosity trochlear groove distance.

Healthcare, Chicago, Il, USA) and 3D reconstructed. All data were measured by 2 independent examiners with perennial experience in imaging diagnosis. A total of 8 factors were measured: (I) Congruence angle (CA) (*Figure 2A*): the angle medial to the angle bisector of the sulcus angle is designated as negative, and the lateral one is designated as positive. The normal angle is <(-)6. The more positive the angle, the more severe the lateral subluxation of the patella (15). (II) Patellar tilt angle (PTA) (*Figure 2B*): generally, patellar tilt should be addressed when the PTA is >20°, and the patella cannot be everted to neutral on examination (16). (III) Lateral patellofemoral angle (LPA) (*Figure 2B*): the normal angle is >11 degrees opening laterally. (IV) Lateral patellar displacement (LPD) (*Figure 2C*): the most lateral margin of the patella facet medial to the lateral margin of the trochlea is designated as negative, and that lateral one is designated as positive. The greater the LPD value, the greater the degree of patella lateral displacement. (V) TT-TG (*Figure 3*): in general, TT-TG >20 mm is believed to be nearly always associated with patellar instability (3,14). (VI) Insall-Salvati Index (ISI) (*Figure 4*): the normal range is 0.8–1.2. An ISI >1.2 indicates patella alta (15). (VII) Trochlear dysplasia: Dejour classification was used to assess the severity of trochlear dysplasia (17). (VIII) Knee joint function: subjective outcomes were assessed postoperatively by the Kujala knee scoring scale and Lysholm knee scoring scale (range, 0–100), with high scores indicating a good

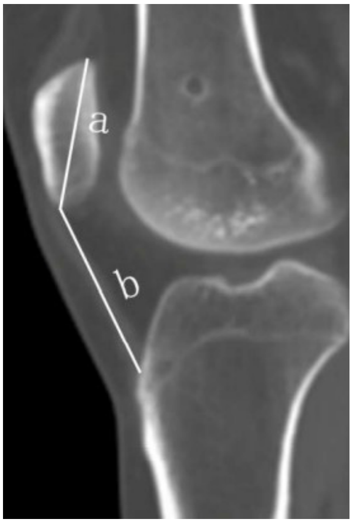

Figure 4 Method of measuring the Insall-Salvati index. The knee joint was reconstructed in the sagittal direction according to the direction of patellar tilting. The length of patellar (a) and patella ligament (b) were measured. Insall-Salvati index was the ratio of b to a.

outcome.

Statistical analysis

All calculations were performed with IBM SPSS 23.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used for the normality tests. Normal distribution was depicted as mean ± standard deviation with 95% confidence intervals (CIs), whereas skewed distributions were depicted as medians with 25th and 75th percentile. The Wilcoxon test (paired samples) was used to compare the skewed distribution within the group, and the paired-sample *t*-test was used to compare the normal distribution. The comparison of the data between groups was performed with Student's *t*-test (normal distribution) or Mann-Whitney U test (skewed distribution). The normal distribution of CT data and knee function scores were analyzed using the Pearson correlation coefficient. The association study of CT measures in skew distribution and knee function scores employed Spearman's correlation coefficient. The Spearman or Pearson correlation analysis (bilateral sides) was performed with $|r| <0.3$ as weak association, $0.3\leq |r| <0.5$ as mild association, $0.5\leq |r| <0.8$ as moderate association, $|r| \geq 0.8$ as marked association, and $|r| >0.95$ as highly marked association. The significant P value was set at <0.05.

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine [No. 2021-KY-127(K)], and informed consent was provided by all the patients.

Results

Patients

A total of 62 patients (67 knees) were admitted in this study: 36 patients (40 knees, 25 left, 15 right) were enrolled in group A, including 6 males and 30 females, with an average age of 22.68±7.83 years at the time of surgery. The follow-up time was 12–38 months, with an average time of 1.43 years; 26 patients (27 knees, 19 left, 8 right) were enrolled in group B, including 5 males and 21 females, with an average age of 24.30±7.85 years. The short-term follow-up time was 12 to 51 months, with an average time of 1.77±1.06 years. The mid-term follow-up time was 5 years to 10 years 7 months, with an average time of 6.51±1.57 years. 26 knees (24 patients) were allocated to subgroup A*. There was no significant difference between groups in terms of gender, age, dislocation or subluxation as the primary complaint, and length of short-term follow-up.

Radiographic parameters and clinical scores

In group A, there were 8, 16, 9, and 7 cases of type A, B, C, and D, respectively; 40% of patients had obvious trochlear dysplasia. In group B, there were 4, 9, 8, and 6 cases of Dejour type A, B, C, and D, respectively; 52% of patients had obvious trochlear dysplasia (type C-D).

None of the patients experienced re-dislocation during the follow-up. The preoperative average TT-TG distance of group B was 21.02±1.59 (95% CI: 20.393–21.655) mm, which was significantly larger than the 17.37±4.28 (95% CI: 16.003–18.739) mm of group A. The average ISI was 1.19±0.17 (95% CI: 1.141–1.248) in group A and 1.23±0.20 (95% CI: 1.150–1.310) in group B, respectively, with no significant difference. There were no significant differences in the comparison of preoperative PTA, LPA, CA, and LPD between groups (*Table 1*).

Postoperative clinical scores and radiological measurements are shown in *Tables 2-5*. There were significant changes in the CA, PTA, LPD, and LPA between 3 days

Table 1 Preoperative CT measurements in group A and group B

Preoperative CT measurements	Group A (n=40)	Group B (n=27)	P value
PTA (°)	26.20±9.42 (22.553, 29.855)	25.50±6.17 (22.089, 28.917)	0.796
LPA (°)	–5.47±12.06 (–10.144, –0.792)	–0.38±9.10 (–5.376, 4.702)	0.158
CA (°)	28.71±25.28 (18.909, 38.516)	40.30±20.60 (28.896, 51.707)	0.136
LPD (mm)	9.62±4.01 (8.067, 11.179)	11.09±2.50 (9.704, 12.474)	0.207
ISI	1.19±0.17 (1.141,1.248)	1.23±0.20 (1.150, 1.310)	0.406
TT-TG (mm)	17.37±4.28 (16.003, 18.739)	21.02±1.59 (20.393, 21.655)	<0.001

Data are shown as mean ± SD (95% CI). CT, computed tomography; PTA, patellar tilt angle; LPA, lateral patellofemoral angle; CA, congruence angle; LPD, lateral patellar displacement; ISI, Insall-Salvati index; TT-TG, tibial tubercle-trochlear groove distance; SD, standard deviation; CI, confidence interval.

Table 2 Comparison of postoperative CT measurements in group A (n=40)

Postoperative CT measurements	3 days (n=40)	Short-term (n=40)	P value
PTA (°)	7.16 (4.615, 12.9475)	12.69 (6.67, 20.12)	0.003
LPA (°)	13.73 (8.2775, 20.11)	7.83 (2.01, 12.88)	0.001
CA (°)	–23.65±29.06 (–32.949, –14.358)	3.75±30.45 (–5.987, 13.487)	<0.001
LPD (mm)	0.42±5.14 (–1.225, 2.061)	5.37±5.06 (3.754, 6.991)	<0.001
ISI	1.21 (1.0325, 1.2875)	1.25 (1.1075, 1.300)	0.230
TT-TG (mm)	16.53±3.06 (15.551, 17.506)	17.32±4.28 (15.954, 18.689)	0.081

Data are shown as mean ± SD (95% CI) or M (P25, P75). CT, computed tomography; PTA, patellar tilt angle; LPA, lateral patellofemoral angle; CA, congruence angle; LPD, lateral patellar displacement; ISI, Insall-Salvati index; TT-TG, tibial tubercle-trochlear groove distance; SD, standard deviation; CI, confidence interval.

Table 3 Comparison of postoperative CT measurements and clinical scores in group B (n=27)

Postoperative CT measurements/ clinical scores	3 days (n=27)	Short-term (n=27)	Mid-term (n=27)	P^a	P^b	P^c
PTA (°)	3.75±7.64 (0,725, 6.774)	12.54±6.88 (9.820, 15.262)	15.23±6.10 (12.816, 17.645)	<0.001	<0.001	0.002
LPA (°)	16.62±6.93 (13.878, 19.363)	7.08±6.48 (4.511, 9.642)	4.69±6.28 (2.206, 7.173)	<0.001	<0.001	0.049
CA (°)	–22.70±27.93 (–33.750, –11.652)	–2.48±21.55 (–11.010, 6.041)	3.99±18.85 (–3.465, 11.452)	0.001	<0.001	0.083
LPD (mm)	0 (–3.93, 3.8)	5.90 (2.84, 8.05)	4.55 (2.40, 6.64)	<0.001	<0.001	0.106
ISI	1.18±0.14 (1.126, 1.238)	1.09±0.13 (1.034, 1.138)	1.08±0.10 (1.036, 1.117)	0.074	0.001	0.655
TT-TG (mm)	12.23±4.02 (10.642, 13,823)	12.84±3.75 (11.352, 14.322)	12.79±3.81 (11.281, 14.295)	0.178	0.157	0.869
Kujala score		86 (80, 92)	95 (89, 98)			0.001
Lysholm score		90 (80, 99)	95 (85, 99)			0.254

Data are shown as mean ± SD (95% CI) or M (P25, P75). [a], comparison of 3 days postoperatively and short-term follow-up; [b], comparison of 3 days postoperatively and mid-term follow-up; [c], comparison of short-term and mid-term follow-up. CT, computed tomography; PTA, patellar tilt angle; LPA, lateral patellofemoral angle; CA, congruence angle; LPD, lateral patellar displacement; ISI, Insall-Salvati index; TT-TG, tibial tubercle-trochlear groove distance; SD, standard deviation; CI, confidence interval.

Table 4 Comparison of CT measurements and clinical scores at the short-term follow-up between group A and group B

CT measurements/clinical scores	Group A (n=40)	Group B (n=27)	P value
PTA (°)	13.88±9.08	12.54±6.88	0.519
LPA (°)	6.92±8.73	7.08±6.48	0.938
CA (°)	3.75±30.45	–2.48±21.55	0.927
LPD (mm)	5.37±5.06	4.20±3.00	0.073
ISI	1.25 (1.1075, 1.300)	1.06 (1.00, 1.16)	<0.001
TT-TG (mm)	17.32±4.28	12.84±3.75	<0.001
Kujala score	95 (92, 99)	86 (80, 92)	<0.001
Lysholm score	94.5 (87, 99)	90 (80, 99)	0.180

Data are shown as mean ± SD (95% CI) or M (P25, P75). CT, computed tomography; PTA, patellar tilt angle; LPA, lateral patellofemoral angle; CA, congruence angle; LPD, lateral patellar displacement; ISI, Insall-Salvati index; TT-TG, tibial tubercle-trochlear groove distance; SD, standard deviation; CI, confidence interval.

Table 5 Comparison of CT measurements and clinical scores at short-term follow-up between subgroup A* and group B

CT measurements/clinical scores	Subgroup A* (n=26)	Group B (n=27)	P value
PTA (°)	15.36±8.94 (11.753, 18.974)	12.54±6.88 (9.820, 15.262)	0.202
LPA (°)	6.03±9.05 (2.373, 9.687)	7.08±6.48 (4.511, 9.642)	0.630
CA (°)	13.14±30.87 (0.673, 25.611)	–2.48±21.55 (–11.010, 6.041)	0.039
LPD (mm)	6.82±5.13 (4.745, 8.887)	4.20±3.00 (3.075, 5.205)	0.029
ISI	1.265 (1.193, 1.300)	1.065 (0.995, 1.1625)	<0.001
TT-TG (mm)	19.76±2.87 (18.594, 20.917)	12.84±3.75 (11.352, 14.322)	<0.001
Kujala score	95.5 (93.75, 99)	86 (80, 92)	<0.001
Lysholm score	92.5 (86.5, 96.75)	90(80, 99)	0.503

Data are shown as mean ± SD (95% CI) or M (P25, P75). Subgroup A*, patients with TT-TG >15 mm in group A. CT, computed tomography; PTA, patellar tilt angle; LPA, lateral patellofemoral angle; CA, congruence angle; LPD, lateral patellar displacement; ISI, Insall-Salvati index; TT-TG, tibial tubercle-trochlear groove distance; SD, standard deviation; CI, confidence interval.

postoperatively and short-term follow-up in both group A and B. The CA, PTA, and LPD increased at short-term follow-up, and the LPA decreased compared to 3 days after the operation in both groups (*Tables 2,3*). In group B, in addition to the same changes mentioned above, the ISI (1.08±0.10; 95% CI: 1.036–1.117) at the mid-term examinations was lower compared to the ISI (1.18±0.14, 95% CI: 1.126–1.238) at 3 days postoperatively (P=0.001; *Table 3*). The PTA increased (12.54±6.88, 95% CI: 9.820–15.262 *vs.* 15.23±6.10; 95% CI: 12.816–17.645; P=0.002) yet the LPA decreased (7.08±6.48; 95% CI: 4.511–9.642 *vs.* 4.69±6.28; 95% CI: 2.206–7.173; P=0.049) between short-term and mid-term outcomes (*Table 3*). There was no statistical difference in the comparison of TT-TG between different postoperative periods intergroup of groups A and B.

The TT-TG distance (12.84±3.75; 95% CI: 11.352–14.322) and ISI [1.06 (1.00, 1.16)] in group B during short-term follow-up were smaller than those in group A [TT-TG 17.32±4.28; 95% CI: 15.954–18.689; ISI 1.25 (1.1075, 1.300); P<0.001]. There was no statistical difference in the other measured values (*Table 4*). The short-term Kujala score and Lysholm score in group A were 95 [92, 99] and 94.5 [87, 99], respectively, which were higher than those of group B. The difference in the Kujala score was statistically significant (P<0.001; *Table 4*). Some 8 knees with postoperative TT-TG >15 mm in group B at the mid-term follow up had good Kujala scores and Lysholm scores (≥85), except 1 knee's Lysholm score, which was 79. The CA,

Table 6 Spearman association analysis of the CT parameters and clinical scores at mid-term follow-up in group B

CT parameter	r	P value
Dejour classification-Kujala	–0.509	0.007**

**, significantly correlated at the level of confidence (2 sides) 0.01. CT, computed tomography.

LPD, ISI, TT-TG, and the Kujala score were significantly higher in subgroup A* than those of group B in the short-term results (P<0.05; *Table 5*).

The Dejour type of trochlear dysplasia was in a significantly moderate negative (P<0.01; r=–0.509) association with the mid-term Kujala score in group B (*Table 6*).

Discussion

Data in this retrospective study showed that, postoperatively, both groups displayed predominately improved knee function, despite a higher Kujala knee scoring scale in the proximal realignment group. An additional TTT might not be necessary for patients with TT-TG >15 mm.

MPFL serves a critical function in maintaining the stability of the medial patella and preventing lateral dislocation of the patella (6-8). Various studies have clarified the beneficial role of MPFL reconstruction in treating RPD. Han *et al.* (18) performed MPFL reconstruction routinely with LRR based on the hypothesis that the range of motion might be improved and the tensile strength of the lateral retinaculum might be reduced postoperatively. As Migliorini (11) noted, several systematic reviews have documented many more favorable clinical outcomes of the combination of MPFL reconstruction with LRR than the standalone treatment. According to Du *et al.* (19) and Wang *et al.* (20), this combined procedure is the optimum option for patients with RPD to regain knee joint function. The results demonstrated in this trial were similar to those above (19,20), with superior function recovery and no re-dislocation reported in the proximal realignment group.

Several studies have shown that distal realignment offers promising benefits. Enderlein (21) showed that patients with extra distal knee rearrangement had similar results to those with isolated MPFL reconstruction. Su *et al.* (22) verified that the combination of MPFL reconstruction, LRR, and TTT was a reliable choice for patients with RPD with a low failure rate of 5.6% based on data from 108 knees with more than 3 years of follow-up. Many available data suggest that over-medialization of the tibial tuberosity might increase the patellofemoral contact pressure, resulting in degenerative arthritis of the medial compartment (23). In this study, the combination of MPFL reconstruction, LRR, and TTT brought satisfactory clinical outcomes without re-dislocation during follow-up for patients with large TT-TG and ISI. TTT was found to be effective in reducing TT-TG distance and addressing the patella alta. However, the results indicated that the indication of TTT in this study might be excessive. The clinical outcome of knees with preoperative TT-TG >15 mm was higher in the proximal realignment group than in the other groups, even though lower postoperative ISI and TT-TG were observed in the proximal and distal realignment group. This result suggested that the technique of TTT might not be necessary for patients with TT-TG >15 mm. Clinicians should thoroughly assess the patient's condition and surgical indications before surgery. However, it might also be related to larger trauma of the TTT, longer clinical recovery time, or a higher proportion of patients with severe trochlear dysplasia. To verify the necessity of TTT, long-term findings are required.

For patients with patella alta, a lack of bony constraints between the patella and trochlea at an early degree of flexion results in patellar instability. Patella alta appears to have a significant impact on patellofemoral instability (14). Yet, it was not a failure risk factor for poorer postoperative results in research by Su *et al.* (22) in a combined treatment of proximal and distal realignment. According to Feller *et al.* (12), there did not appear to be a significant influence on ISI results between solitary MPFL reconstruction and combined procedures, compounded by satisfactory results in both groups. Similar to Su *et al.*'s (22) findings, the clinical results in both groups in this study were not significantly impacted by the postoperative ISI. During short-term follow-up, the height of the patella remained steady following proximal alignment. Besides, the ISI and the Kujala score were both higher after proximal alignment, suggesting that the patella in a high position after surgery did not necessarily affect the functional recovery. In contrast, following proximal and distal alignment, the patella position gradually dropped, which was rather significant in the short-term follow-up despite no statistically significant difference. Patellar alta was no longer a failure risk factor in this study due to the distalization of the tibial tubercle.

Femoral trochlear dysplasia, characterized by a shallow trochlear angle and depth, is a congenital morphological abnormality (24). Severe femoral trochlear dysplasia could significantly affect the stability of the patellofemoral joint and has been reported as the most important anatomic predisposing factor in patellar instability and patellofemoral maltracking (25,26). Nelitz *et al.* (27) analyzed the factors affecting the failure in the surgery for patellar instability in children and adolescents, finding that the failure group had a substantially greater proportion of femoral trochlear dysplasia (grades B–D) than the success group. Similar results could be observed in that more severe trochlear dysplasia (grades B–D) appear to have the most consistent influence on higher rates of recurrent dislocation as well as lower clinical scores, according to a recent meta-analysis (28). In a systematic review, Balcarek *et al.* (29) revealed that the failure rate of MPFL reconstruction in patients with severe trochlear dysplasia (grades B–D) was 7%, compared to 2.1% in the trochleoplasty group. Wagner *et al.* (14) discovered that poor clinical outcomes were correlated with higher degrees of trochlear dysplasia, which might be caused by excessive tension on the stabilizing ligaments; in this case, trochleaplasty should be explored. Similar findings were revealed in this study that a higher degree of femoral trochlear dysplasia was linked to lower clinical scores in the final follow-up, which was not found in the short-term follow-up. It was considered that the patellofemoral joint might be more stable initially after surgery, but as time went on, the stability of the knee joint deteriorated due to high-grade femoral trochlear dysplasia, which hampered functional rehabilitation. Until then, trochleoplasty should be considered as an extra therapeutic option.

The majority of current research assesses changes in patella tracking before and after RPD surgery, but patella maltracking following combination surgery has rarely been reported in the literature. According to Escala *et al.* (26), lateral patellar tilt is a sensitive sign of patellar instability. According to this study, the patella showed a trend of lateral tilt and lateralization following surgery. Mid-term postoperatively, there was a propensity to tilt laterally following proximal and distal alignment, which might be due to uncorrected femoral trochlear dysplasia or the graft failing to prevent the patella from migrating as well as the original ligament did. Regardless of whether treatment was combined with TTT, proximal alignment could realign the extensor device of the knee joint. Even though no re-dislocation or patella subluxation was found in this investigation, a longer follow-up study is required to determine the impact of patella maltracking on knee joint function after surgery.

Due to the limitations associated with research conditions, this study contains a number of flaws. First, as a retrospective study, the sample number was restricted, long-term outcomes were lacking, and the proximal realignment group lacked mid-term data, resulting in failure to compare with the proximal and distal realignment group. Second, some potential for bias in patient selection may be present because not all patients who underwent combined surgery were examined in this series. Third, there might be fundamental differences between the 2 groups due to different surgical indications, and a control group was lacking in this study. However, it is difficult to define an appropriate control group since there is no current gold standard for the treatment of RPD.

Conclusions

CT is a valid objective measurement tool for the follow-up of MPFL reconstruction of RPD. Good postoperative function can be achieved with proximal realignment either with or without the distal realignment. TTT might not be necessary for patients with TT-TG >15 mm.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-71/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine [No. 2021-KY-127(K)], and informed consent was provided by all the patients. Any extra clinical interference (e.g., surgical, pharmaceutical, physical) was not included throughout the duration of the retrospective study.

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