



Research Paper

Minimal invasive MPFL reconstruction using quadriceps tendon graft with lateral release: 2 years follow up

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ABSTRACT

Background: Medial Patellofemoral Ligament (MPFL) reconstruction is a popular procedure to repair recurrent patellar dislocation. Many methods of reconstruction describe the use of hamstring tendons as the graft of choice. This study aimed to compare the functional outcome of MPFL reconstruction using quadriceps tendon graft with arthroscopic lateral release and to identify possible risks.

Methods: This is a retrospective cohort study in patients with a history of recurrent dislocation trauma from 2014 to 2016 that already done MPFL reconstruction using quadriceps tendon grafts with arthroscopic lateral release. Patient reported outcomes were evaluated pre-operative and 2 years post-operatively using IKDC score, Lysholm knee score, Kujala score, KSS Score, thigh circumference size, and kneel down ability. Patellar fracture, redislocation, and other complications were also assessed 2 years post-operative.

Results: Eight patients included in this study and showed significant improvement in clinical outcomes. The Lysholm score increased from 64.37 ± 8.23 to 90.87 ± 3.23 ($p = 0.011$), IKDC score increased from 62.93 ± 7.52 to 88.36 ± 3.64 ($p < 0.001$). Kujala score increased from 60.87 ± 7.94 to 88.37 ± 4.34 ($p < 0.001$), KSS knee score increased from 83.25 ± 11 to 93.87 ± 1.73 ($p = 0.012$). KSS function also increased from 57.50 ± 11.65 to 88.13 ± 3.72 ($p = 0.011$) with decreased in thigh circumference (1–3 cm). Five patients have full ROM, able to kneeling, while 3 patients were able to kneeling with adjustments. There were no postoperative infection, patellar fractures nor redislocations.

Conclusion: MPFL reconstruction using quadriceps tendon grafts with arthroscopic lateral release can provide improved clinical results without complications of patellar fracture or stiffness of the knee, infection, and redislocation.

Level of evidence: Level 3, Retrospective Cohort Study.

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1. Introduction

The medial patellofemoral ligament (MPFL) is a structure that connects the patella and femoral medial epicondyle and acts primarily as a checkrein to avoid lateral dislocation of the patella. Research shows the MPFL serves the purpose to support the tissues' ability to withstand impact and prevent damage to the tendons and ligaments. The MPFL structure holds an important role which

prevents the patella from lateral dislocation [1,2]. Anatomical structure of MPFL was known in 1957 as transversal structure which strengthens the patella and medial part of gastrocnemius [3]. When the knee is flexed to 20°, MPFL holds 50–60% of the pressure from lateral pulling force, while other ligaments such as the patellomeniscal, medial retinaculum, medial patellotibial provide 13%, 3%, and 3% contribution, respectively [3]. MPFL receives the highest force during maximum knee extension or at the beginning of knee flexion which is the time when quadriceps muscles contract to pull the patella [3,4]. When there is a patellar dislocation due to injury, the chance of MPFL rupture is high. As the consequences, the incidence of MPFL rupture will also be higher (18 from 19 cases) [5].

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Injury of this ligament commonly due to sports, especially football players, and runners, and vehicular accidents, especially motocross riders [6].

Recurrent patellar dislocation could happen to any patient with history of acute patellar dislocation. The incidence reached 30–60% after conservative treatment of acute patellar dislocation. Another study reported 44% redislocation happened after surgical intervention. Up to 19% of patients experienced patellofemoral pain, and 63% patients reported dissatisfaction during follow up [2]. While many surgical procedures are available to do MPFL reconstruction, no gold standard in repair methods and graft of choice is established [7,8]. MPFL reconstruction is commonly recommended for patients with patellar instability.

Various methods of MPFL reconstruction in the literature considering graft of choice, patellar fixation, femoral fixation, and graft tensioning [7]. Hamstring tendon usually used as graft choice [9,10]. Eventhough, MPFL reconstruction has some risks by drilling bone tunnels and/or creating anchors for graft attachment to the patella, concerns also exist regarding the potential complications such as implant breakage or patellar fractures from the patellar tunneling as well as considerable implant costs [9]. MPFL reconstruction usually done in combination with lateral release because lateral release alone did not show good result [11]. In the past, the lateral release technique is performed to reduce excessive pull from the retinaculum and restore the patella to its normal position.

There are many MPFL reconstruction techniques which vary in terms of grafts and fixation methods. Up to now, there is no consensus as to which method is the best. There is no clinical evidence which confirms one technique is superior than the other techniques [12,13]. The aim of this study was to evaluate functional outcomes in minimal invasive MPFL reconstruction using quadriceps with lateral release and identified the possible risks.

2. Methods

This is a retrospective study done with consecutive sampling in patients diagnosed with recurrent patellar dislocation from 2014 until 2016. All patients completed informed consent forms prior to participate in this study. This study approved by The Medical and Health Research Ethics Committee of University of Gadjah Mada (IRB number KE/FK/1158/EC/2018).

The inclusion criteria were patient with recurrent patellar dislocation age 16–45 years old. Exclusion criteria were as follows: associated ligament injury, chondral damage, meniscal injury, fracture around the knee, laxity and presence of pathologic condition in the lower extremity or an abnormal contralateral knee joint. The diagnosis of recurrent patellar dislocation was previously established and the patients completed with total 8 patients were included in this study. All patients received MPFL reconstruction using quadriceps with lateral release. Patient reported outcomes were evaluated pre-operative and 2 years post-operatively using IKDC score, Lysholm knee score, Kujala score, KSS Score, thigh circumference size, and kneel down ability. Patellar fracture, redislocation, and other complications were also assessed 2 years post-operative.

2.1. Surgical technique

A single senior knee surgeon performed all procedures. Patients in supine position under regional anesthesia, while tourniquet was applied in the thigh and inflated without elevation and exsanguination. Standard anterolateral and anteromedial portals were used. Diagnostic arthroscopy of the knee joint was performed, followed by arthroscopic lateral patellar release. Arthroscopic release

performed using radiofrequency to release lateral retinaculum from the inferior third of the tendon of vastus lateralis down to the anterolateral arthroscopic portal extended to the inferior third of the tendon of vastus lateralis. See Fig. 1.

2.2. Graft harvesting

A 1.5- to 2-cm transverse mark is made at the proximal pole of the patella. The transverse incision is used to insert device for harvesting the graft. The skin and subcutaneous tissue is injected with local anesthetic (or saline) to distend the tissue off the tendon. A longitudinal incision is made with a No. 15 blade, and the subcutaneous tissue is excised. It is critical to ellipse out the underlying subcutaneous tissue for adequate visualization through the small incision. A sponge over a key elevator is used to sweep tissue off of the anterior quadriceps tendon and anterior patella. A retractor is placed into the proximal apex of the incision.

The ConMed quadriceps harvest knife is used for graft harvest (no reference 8750) The design of the blade limits the depth of the cut to 8 mm, then introduced, starting at the middle of the superior patellar border, and pushed up to a minimum of 10 cm (as marked on the instrument). The thickness of the graft is determined a 5-mm tendon separator (ConMed). The tendon strip is cut subcutaneously by a special tendon cutter (ConMed). See Fig. 2. The graft is left attached distally, and the free proximal end is armed with resorbable sutures by use of web-stitch technique. The QT strip is then subperiosteally elevated from the surface of the patella. The proximal third of the medial patellar border is exposed. From the medial patellar border, the prepatellar tissue is elevated, creating a tunnel that reaches the medial edge of the graft using a periosteal elevator. A surgical clamp is introduced into the tunnel from medial to lateral, and the graft is passed through the tunnel. The graft is then secured to the retinaculum tissue on the medial patellar edge by resorbable No. 2-0 sutures Ethibond. See Fig. 3.

A 1.5-cm skin incision is made over the adductor tubercle. Starting at the patella, a curved clamp is used to create a tunnel in the space between the vastus medialis and the capsule. A suture loop is then pulled through the tunnel. This loop is used later to pull the graft toward the femoral insertion. Under fluoroscopic guidance, a 2.4-mm guide pin is drilled into the insertion of the MPFL. It is directed anterolaterally to exit the femur on the lateral cortex well proximal to the lateral epicondyle. If found accurate by fluoroscopy, the guide pin is over-reamed with a 6-mm (or 7-mm) cannulated reamer to a depth of 30 mm. Graft diameter is 5–6 mm. The graft is inserted into the tunnel. The knee is cycled 10 times with moderate tension on the graft. Fixation is performed with a resorbable interference screw (ConMed) with a similar diameter to the tunnel at 30° of knee flexion. See Fig. 4.

2.3. Rehabilitation Program

A knee brace with range of motion of 0° to 90° was used for 4 weeks during postoperative rehabilitation. The patients were mobilized with partial weight bearing for 3 weeks and full weight bearing was started thereafter. Passive range-of-motion exercise to a maximum of 90° was started immediately postoperative until the 3rd week, and followed with full flexion exercise. Stationary cycling is started 6 weeks postoperative. Return to pivoting sports was allowed 3 months after the operation.

2.4. Patient reported outcomes

Functional outcomes preoperative and 2 years postoperative were assessed with direct patient examination and interview. Donor site morbidity were also recorded two years after surgery.

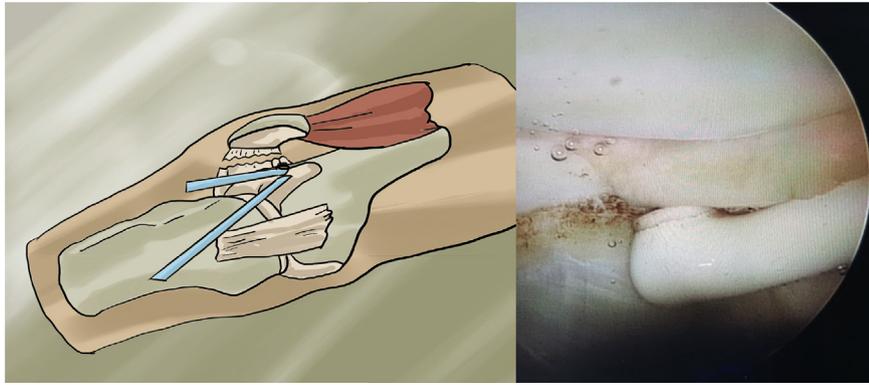


Fig. 1. Lateral retinacular release. This procedure was done arthroscopically.

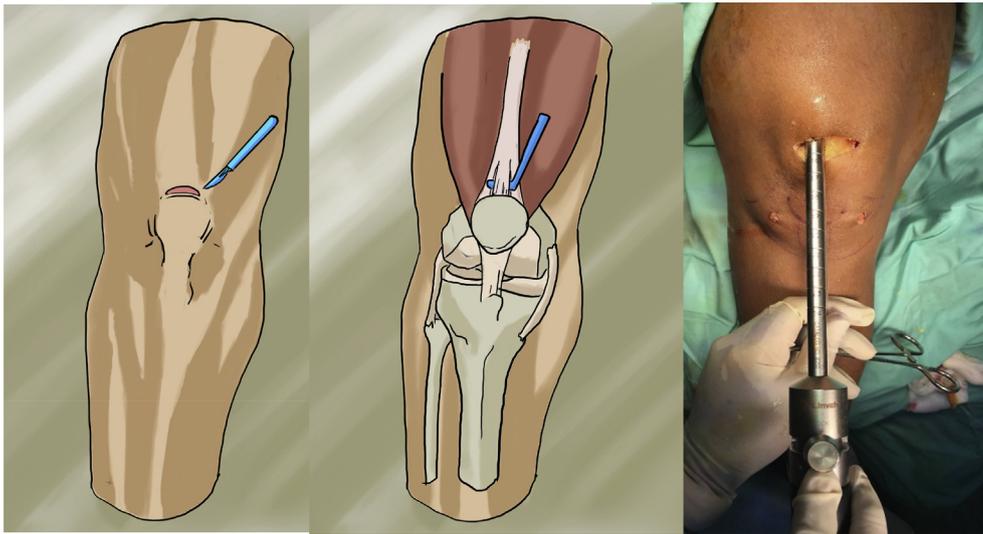


Fig. 2. Graft harvesting. The transverse incision was made above patellar pole. The graft was isolated and then harvested using coned device.



Fig. 3. Graft preparation. The graft was then measured minimum 10 cm. After making the stitch, the graft was inserted subvastus

The thigh circumferences were measured 15 cm proximal to superior pole of patella, the surgical side was then compared to non operative side. A single orthopaedic surgeon outside the surgical team examined and interviewed all the patients. Functional

outcome (IKDC, Lysholm score) and thigh circumference of donor site were compared pre and postoperative. Complications were assessed. Patellar tracking and stability (no redislocation) was assessed using J sign.

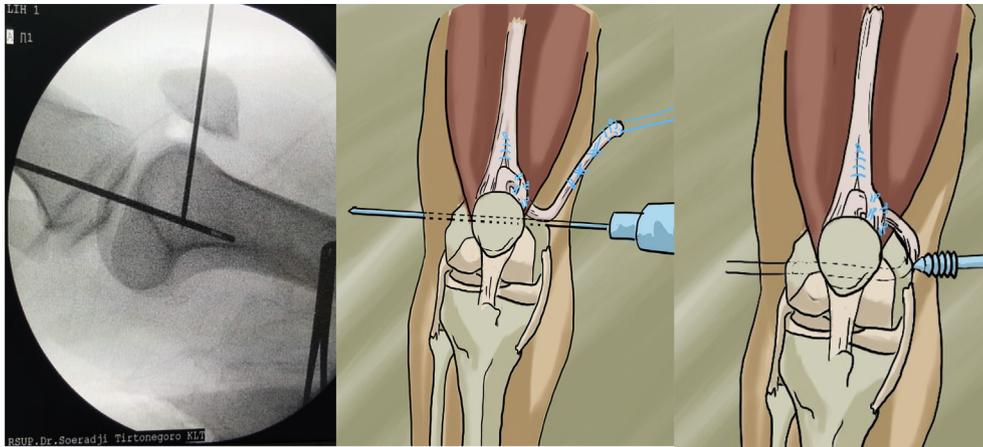


Fig. 4. Graft Placement. The image intensifier was used to determine the schottle point. After the drilling, the graft was inserted in and fixed with screw.

2.5. Statistical analysis

A binominal proportions formula was used to calculate sample size in this study. The sample size calculation was intended for hypothesis test for a population proportion (two-sided test), in a descriptive paper where no outcome parameter was analysed for its association. The formula was written as follows

$$n = \frac{Z\alpha^2 \cdot P(1 - P)}{d^2}$$

Explanation:

n = sample size

$Z\alpha^2$ = standard normal value, based on α

If $\alpha = 0.05$ then $Z = 1.67$

If $\alpha = 0.01$ then $Z = 1.96$

P = Estimated Population Proportion

Q = 1-P

D = Tolerated Deviation = 10%

Patellar dislocation is a rare condition with incidence 5.8 to 77.8 per 100,000 populations. Researchers obtained sample size, p-value, and 77.8/100,000 using sample size calculator provided by WHO [14]. Total sampling was conducted to obtain samples then was followed by sample selection based on inclusion and exclusion criteria.

Initial calculation:

$$n = \frac{3.8416 \cdot (0.05 - 0.05 \cdot (1 - 0))}{0.1^2} = 0.297109699$$

Due to the fact that previous number was less than 10%, then the number was multiplied by design effect and number of age sex estimates.

$$n = 0.29711 \cdot 1.5 \cdot 8 = 3.565316388$$

Adjustment was done due to compensation without response and sample size was obtained.

$$n = 3.565316 / 0.8 = 4.45664548$$

Minimum sample size for this study was 4. Total sampling was conducted to obtain samples, then was followed by sample

selection based on inclusion and exclusion criteria. The total subject was 8, none of the subject drop out from the study.

The outcomes of continuous variables (IKDC, Kujala and Lysholm scores) were compared before and after surgery using the Wilcoxon test, a nonparametric test applied to data with abnormal distribution. Statistical significance was assessed at $p < 0.05$. Data was then analysed using SPSS 21 using paired student *t*-test.

3. Results

During the period of study, 8 patients fulfilled inclusion criteria. The demographic data of the study population are shown in Table 1.

Average age of the subjects was 20 ± 3 years. Female subjects were 87.5% and male subjects were 12.5% with mostly due to sports activity (62.5%).

High circumference diameter between surgical side and contralateral side was shown in Table 2. Surgical side thigh circumference mean was 47.5 ± 3.1 cm and contralateral thigh circumference was 45.5 ± 3.2 cm with no significant was found between those two groups ($p > 0.05$). Functional outcome showed improvement as seen in Table 3.

Mean value of pre-operative Lysholm score was 64.37 ± 8.23 , while mean value of post-operative Lysholm score was 90.87 ± 3.23 with significant improvement ($p = 0.011$). Mean value of pre-operative IKDC was 62.93 ± 7.52 , while mean value of post-operative IKDC 88.36 ± 3.64 and showed significant improvement ($p < 0.001$). Mean value of pre-operative Kujala score was 60.87 ± 7.94 and significant improved to 88.37 ± 4.34 post operative ($p < 0.001$). Mean value of KSS Knee Score pre-operative and postoperative were 83.25 ± 11.00 and 93.87 ± 1.73 respectively with significant improvement ($p = 0.012$). Mean value of KSS Functional Score pre-operative and postoperative were 57.50 ± 11.65 and 88.13 ± 3.72 respectively and showed significant ($p = 0.011$).

Table 1
Subjects characteristics.

Characteristics	mean	median (percentile 25 - percentile 75)	n (%)
Age	20 (3)	19.0 (17.2–22.2)	
Sex			
Female			7 (87.5)
Male			1 (12.5)
Mechanism of Injury			
Accident			3 (37.5)
Sports Activity			5 (62.5)

Table 2
Thigh circumference.

Variables	mean	median (percentile 25 – percentile 75)	P value
Surgical side thigh circumference	47.5 ± 3.1	47.5 (44.5–50.0)	0.230
Contralateral thigh circumference	45.5 ± 3.2	46.0 (42.7–47.7)	

Table 3
Pre-operative and Post-operative analysis.

Variables	Pre-operative		Post-operative		p value
	mean	median (percentile 25 – percentile 75)	mean	median (percentile 25 – percentile 75)	
Lysholm score	64.37 ± 8.23	65.50 (63.25–69.25)	90.87 ± 3.23	90.00 (89.25–94.00)	0.011
IKDC	62.93 ± 7.52	63.80 (59.18–67.53)	88.36 ± 3.64	87.40 (85.23–91.70)	0.000
Kujala score	60.87 ± 7.94	61.50 (57.00–67.00)	88.37 ± 4.34	87.00 (85.00–91.75)	0.000
KSS Knee Score	83.25 ± 11.00	88.00 (70.00–92.25)	93.87 ± 1.73	94.50 (93.25–95.00)	0.012
KSS Function	57.50 ± 11.65	57.5 (51.25–68.75)	88.13 ± 3.72	90.00 (86.25–90.00)	0.011

Seven from eight patients had unable to kneeling pre-operative and all patients were able to kneeling post-operative as seen in Table 4. In assessing redislocation, all patients had negative results for J sign post-operative, which were seen previously in all patients pre-operative. No patients had infection after the surgery. No quadriceps avulsion and patellar fracture were found.

4. Discussion

There are many MPFL reconstruction techniques which vary in terms of grafts and fixation methods. Up to now, there is no consensus as to which method is the best. There is no clinical evidence which confirms one technique is superior than the other techniques [12,13]. From several case series studies of MPFL reconstruction, the Kujala score from 12 case series showed the average of 87.7 (95% CI: 85.15–90.39) post-surgical intervention. In several studies which compared graft fixation methods reported Kujala score as 95.2 (82–100) [15]. Another study by Nomura et al. which used synthetic grafts reported a rise in Kujala score from 63.2 to 94.2 (12). Our study showed significant improvement in Kujala score. Compared to other study, significant improvement was seen. All patient was able to do more activity before surgery, has full range of motions. Most of the patient was able enjoying recreational sports but none participate in competitive sports. Other studies which evaluated reconstruction using quadriceps tendon also showed a significant increase of Kujala score of 35.8 + 5.5 ($p < 0.001$), and Lysholm score from 43 + 6.4 to 89.3 + 3.1 ($p < 0.001$) [16].

Reconstruction of MPFL aims to restore anisometrical positions, which allow mobility. MPFL is located in the anterior part of the epicondyle. MPFL is non-isometric which can be tense during knee extension and lax during knee flexion. Changes in location of MPFL insertion to the proximal part cause lax MPFL during knee extension and tense MPFL during knee flexion and can cause knee to lose its ability to flex. On the contrary, when the reconstruction was made in the distal part, MPFL would be tense during extension and lax during flexion [7]. Malposition also can cause pain, discomfort and degeneration of patellar cartilage.

Table 4
Condition two years post-operative.

Condition 2 Year Post-operative	n (%)
Kneel down:	
• Normal	5 (62.5)
• Require Adjustment	3 (37.5)
Patellar Fractures	0 (0.0)
Quadriceps Avulsion	0 (0.0)

A study by Schottle described the position of MPFL 1.3 mm to the anterior from posterior extension of femoral cortex, and 2.5 mm to the distal perpendicular with posterior origin of femoral condyle, 3 mm to the proximal, perpendicular to the posterior side. Despite newer methods, we followed the method by Fink et al. and well known Schottle point to get close MPFL insertion to its anatomical position [9,17] using an image intensifier in flexion position of 20–30°, which was the best position of MPFL to prevent the movement of patella laterally. This method was also done to prevent over-correction and medial shifting of the patella [11,18].

A study by Evan et al. concluded that non-anatomical location of patella could cause decrease in ROM of the knee and pain which was marked by lower post-surgical intervention KOOS and WOMAC scores [16]. Our study used image intensifier tools during the surgical procedure to ensure the location of tunnels to be as close as possible to the anatomical position.

Decrease in ROM was the second most common complaint after fracture. Sometimes, manipulation under anesthesia was needed because the degree of knee flexion was less than 90° as well as to prevent arthrofibrosis [7]. To prevent those complications, it is recommended for patients to be routinely assessed. The patients also should strictly follow rehabilitation protocols so that they could flex the knee to 0–90° by the end of the third week and 0–120° by the end of the sixth week [19].

Asian people used to kneeling in religion and cultural event there by it's very important in Asian. Kneeling also indicates that the knee has neither limitation nor stiffness and could function optimally. Knee flexion could reach more than 125° [18]. In our study, before the surgery the patient was unable to fully kneel down. It might be due to lack of proper rehabilitation after the first knee dislocation. Most of the patient was neglected case that come only to hospital months after the first injury. No data available regarding recovery after patient first injury. All patients did not lose their ROM by the end of the 2-years postoperative follow-up. Afterwards, 5 patients could kneel normally and 3 patients could kneel with several adjustments in position. Complaints related to wound healing are rare in MPFL reconstructive surgery. If there are complaints related to wound healing, it could be treated with irrigation and debridement method [20,21]. A systematic review reported that there was no soft tissue infection as well as joint infection which correlated with MPFL reconstruction [22]. In our study, there was no history of infection, which needed irrigation and debridement.

According to one study which compared the number of dislocations based on the types of grafts being used, the number of dislocations in autograft was reported low. The number of dislocation in Hamstring tendon was 0–11.1% and in quadriceps tendon

it was 0–6% [23]. Another study stated that the rate of redislocation post reconstructive surgery using either tendon autograft or allograft was less than 2%. This finding was different from ACL reconstruction, in which the autograft was better than allograft [24]. However, the number of redislocations post MPFL reconstruction was reported higher in pediatric and adolescent populations, ranging from 9.8% to 10.3%. These high numbers were not correlated with types of graft being used. Those numbers could have happened because of many factors related to the patients and surgery. For example, young patient who had dislocation could possibly have had secondary congenital abnormality of trochlear dysplasia such as patella alta, abnormality in bone development, and ligamentous laxity [23].

In our study, we used quadriceps tendons in an adult population and there was no re-dislocation as marked by correct patellar tracking indicated by the absence of J sign postoperative. Quadriceps tendons were reported to have similar characteristics to MPFL [13]. Other study used quadriceps tendons also reported no dislocation and subluxation. Patients' satisfaction reached more than 80% [13]. Duration of follow-up in our study was 2 years. It meant that perhaps during the follow-up period of two years, re-dislocation had not happened. In other studies, follow-up was conducted for 38 months to 5 years [9,13,25].

Clifton et al. mentioned that excessive release in lateral side to the proximal of vastus lateralis obliquus or to the distal in Gerdy's tubercle could cause instability of the patella in medial parts which may create iatrogenic dislocation of patella to the medial [26]. If only the lateral release was done, the degree of satisfaction was 77.3% [27]. In another study, 8 out of 179 patients experienced patellar instability post-surgical intervention and 5 of them needed revision surgery [28]. A study by Bedi and Marzo which was different from other studies added that lateral release of retinaculum reduced the ability of patella to resist movement of patella laterally, suggesting that lateral release should not be done routinely [29]. In our study, we conducted lateral release as an adjunct to MPFL reconstruction. There was neither complaints such as instability in medial parts nor any stiffness post-surgical intervention. Bedi and Marzo reported on the biomechanics of MPFL repair followed by lateral retinacular release. They concluded that after repair of the MPFL, adding a lateral retinacular release (LRR) lowered the ability of the patella to resist lateral displacement, but LRR may not be routinely performed as a part of the stabilizing procedure to address acute patellar dislocation when the MPFL is avulsed from the patella [3].

The MPFL reconstruction mostly done using hamstring ligaments and creates tunnels in the patella. Patella fracture was one of the MPFL complications, which used tunnels to fixate the graft. The numbers of patellar fractures post MPFL reconstruction ranged from 0.45% to 2.25% [15] and in another study which used tunnel modification with 2 oblique patellar tunnels to one 3.5-mm medial tunnel, similar to the tunnel described by Fithian and Gupta [29], reported the numbers of patellar fractures to be 3.35% [28]. Some studies using the same quadriceps tendon techniques reported no complaints of patellar fractures [9,13]. A study by Fink showed the possibility of quadriceps avulsion as a complication. The same result was also confirmed by a biomechanical study in which the weakest part of MPFL reconstruction using quadriceps was the attachment of quadriceps tendon in a patellar pole [9]. In our study, there was no patellar fracture found as the complication of using tunnels in the patella, because in our reconstruction method, no need to create patellar tunnel for quadriceps tendon graft, but it was folded and fixated to the femoral tunnel. In our study, there were no complaints of patellar pole neither pain nor quadriceps tendon avulsion.

However, in one study, reported that stiffness and hypertrophic scars were the most common complications reported in MPFL

reconstruction using quadriceps tendon [22]. This result was different from our study which reported no stiffness after surgery and patients could perform knee movement such as kneel down for praying and other reasons. There was one factor, which differentiated our study from other studies, which was the lateral release, performed as an adjunct. Lateral release could increase the satisfaction degree of patient when it was combined with other procedures. [11].

The main limitation of our study was the duration of follow-up, which was only two years. The period of 2 years could be considered too short to assess moderate- and long-term outcomes. But two years follow up was enough for patients to complete the rehabilitation protocol and return to their sport activity and with that length of follow-up patients were more likely to obtain their peak function after reconstruction. Another limitation was that we did not compare the results to the most common standard, MPFL reconstruction using hamstring grafts. But single senior surgeon did the surgery and an orthopaedic surgeon outside the surgical team did the evaluation. It was done to minimize bias. We also have relatively small sample size due to rare case visit to the hospital.

5. Conclusion

We concluded that MPFL reconstruction using quadriceps tendons and lateral release showed better results both in overall functional aspects and the ability to kneeling in short-term observation with no complication was found. Further study with longer periods of time for follow-up could evaluate outcomes and long-term complications, which would probably have not yet appeared in our evaluation. Another study can also be done to compare the results of this method with hamstring graft. To evaluate patellar tracking objectively, we can conduct study using x ray patella post operatively.

Ethical Approval

We further confirm that any aspect of the work covered in this manuscript has been conducted with the ethical approval from medical and health research committee, faculty of medicine Gadjah Mada University no KE/FK/1158/EC/2018.

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All other authors certify that he or she, or a member of his or her immediate family, has no funding or commercial associations (eg. Consultancies, stock ownership, equity interest, patent/licensing arrangements, etc).

Author contribution

S. Rhatomy : Data collection and analysis, Writing the paper, Manuscript preparation, Performed Surgeries.

N.R. Soekarno: Data analysis, Writing the paper, Manuscript preparation.

R. Setyawan : Data collection and analysis, Manuscript preparation.

S.Primisara: Data collection and analysis.

I.L.Gaol : Manuscript review and editing.

N. C. Budhiparama : Data analysis, Manuscript preparation, reviews and edits.

Conflict of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant

financial support for this work that could have influenced its outcome.

Guarantor

Sholahuddin Rhatomy.

Research Registration Number

None.

Consent

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijso.2019.01.004>.

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