

Interference Screws Are Biomechanically Superior to Suture Anchors for Medial Patellofemoral Ligament Reconstruction: A Systematic Review and Meta-Analysis



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Purpose: To systematically review the literature to evaluate the biomechanical properties of the interference screw (IS) versus suture anchor (SA) techniques for patellar and femoral fixation of medial patellofemoral ligament (MPFL) reconstruction. **Methods:** A systematic review was performed by searching PubMed, the Cochrane library, and Embase using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to identify studies that analyzed the biomechanical properties of IS and SA techniques for MPFL reconstruction. The search phrase implemented was “medial patellofemoral ligament reconstruction biomechanics.” Evaluated outcomes included ultimate load to failure (N), stiffness (N/mm), and mode of failure. Forest plots were created for statistical analysis and heterogeneity was assessed via I^2 statistic. **Results:** Six studies met inclusion criteria, including a total of 108 cadaveric specimens, for MPFL patellar fixation, and 3 studies met inclusion criteria, including a total of 50 cadaveric specimens, for MPFL femoral fixation. Pooled analysis from 5 studies reporting on stiffness for MPFL patellar fixation revealed a statistically significant difference in favor of IS compared with SA ($P = .007$). Pooled analysis from 3 studies reporting on ultimate load to failure of femoral fixation revealed a statistically significant difference in favor of IS compared with SA ($P = .043$). **Conclusions:** The use of IS was associated with a greater stiffness compared with the use of SA in MPFL patellar fixation, but there was no difference in load to failure between IS and SA. The use of IS was associated with a greater load to failure compared with the use of SA in MPFL femoral fixation, but there was no difference in stiffness between IS and SA. **Clinical Relevance:** There have been multiple individual biomechanical studies conducted comparing IS and SA fixation for MPFL patellar and femoral fixation; however, they have yielded conflicting results, with small sample sizes. Pooling the data from these studies in a meta-analysis may allow for more meaningful biomechanical data to coincide with the existing, albeit scarce, clinical data, this may help to inform clinical decision making for surgeons managing these injuries.

Patellar dislocations and instability account for a substantial source of pain and discomfort in young athletes.¹ Although there are several nonoperative and operative treatments for patellar instability, reconstruction of the MPFL has become an appealing surgical

option for patients who qualify, especially as the techniques and constructs for MPFL reconstruction evolve.² The medial patellofemoral ligament (MPFL) is responsible for patellar tracking within the trochlear groove throughout the initial stages of knee flexion and is commonly implicated in the pathogenesis of patellar instability.² Reconstruction of the MPFL typically involves the use of either an allograft or autograft and a construct to aid in the fixation of the graft to the native origin and insertion of the pathologic MPFL.³ A commonly used construct for MPFL fixation is the interference screw (IS), although the IS has come under scrutiny due to the large socket required for fixation and trochlear and notch geometries that limit safe placement.⁴

Suture anchors (SAs) have demonstrated efficacy in other tendinous and ligamentous repairs within the musculoskeletal system and may represent a viable

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alternative to IS for fixation in MPFL reconstruction.^{5,6} Rather than drilling sockets for IS placement, multiple SAs can be used to fix the graft to the femoral and/or patella, reducing the footprint and avoiding physeal involvement and possible arrest. Furthermore, the use of SA may allow the surgeon to better control the tension of the anticipated graft and avoids the reliance on drilling sockets for screw placement.^{7,8} However, SA are not devoid of limitations—they are typically more expensive than suture alone, physeal violation is still possible, and the integrity of fixation is focused on the anchors.⁹

Several studies have examined the biomechanical effects of IS and SAs for patellar and/or femoral fixation in MPFL reconstruction; however, the biomechanical superiority of IS versus SAs is not well understood. The purpose of this study was to systematically review the literature so as to evaluate the biomechanical properties of the IS versus SA techniques for patellar and femoral fixation of MPFL reconstruction. We hypothesized that IS would exhibit superior biomechanical properties compared with the SA technique in both patellar and femoral fixation.

Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines using a Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist. Two independent reviewers searched the PubMed, Embase, and Cochrane Library databases up to March 2022. The electronic search string used was “medial patellofemoral ligament reconstruction.” The inclusion criteria were human and animal cadaveric studies that assessed the biomechanics of patellar and femoral fixation during MPFL reconstruction with an IS and/or SA. Exclusion criteria included cadaveric studies performed *in vivo*, studies that focused on repair of ligaments other than the MPFL, nonbiomechanical studies, and studies without full text available. Data extraction from each study was performed independently by 2 reviewers and reconciled by a third author. There was no need for funding or a third party to obtain any collected data.

The Quality Appraisal for Cadaveric Studies (QUACS) scale was used to evaluate the quality of cadaver study methodology.¹⁰ The scale consists of a checklist encompassing 13 items. Each is to be scored with either 0 (no/not stated) or 1 (yes/present) point. Points are only assigned if a criterion is met without any doubt, and a final percentage is given as the total score. Scores greater than 75% are considered satisfactory.

All outcomes evaluated were biomechanical in nature and included: ultimate load to failure (N) and stiffness (N/mm). Mode of failure also was assessed. Of the 6 studies that evaluated patellar fixation, all 6 reported on

ultimate load to failure and 5 commented on stiffness.^{4,11-15} Of the 3 studies that evaluated femoral fixation, all 3 studies commented on ultimate load to failure and 2 commented on stiffness.¹⁶⁻¹⁸

Due to the high quality of included studies as assessed by the QUACS scale and similar study designs, pooling of data was performed. When standard deviations were absent and only standard errors were reported, standard deviations were computed using the methodology described in the Cochrane Handbook for Systematic Reviews of Interventions (version 6.2.0). Weighted averages were calculated for all quantitative outcomes. The outcomes were summarized in a forest plot when data from 2 or more studies were available. Using a random-effects model, standardized mean differences with 95% confidence intervals were calculated and embedded within the forest plot. A random-effects model was used to incorporate the heterogeneity between each included study into the final statistical analysis. To quantify the degree of heterogeneity due to between-study characteristics, I^2 statistics were used to calculate heterogeneity. Meta-analyses statistics and generation of forest plots figures were performed using OpenMetaAnalyst, which implements metafor R console code.

Results

A total of 473 studies were reviewed by title and/or abstract to determine study eligibility based on aforementioned inclusion criteria (Fig 1). Six studies, including a total of 108 cadaveric specimens, met inclusion criteria for MPFL patellar fixation and 3 studies, including a total of 50 cadaveric specimens, met inclusion criteria for MPFL femoral fixation. These studies are summarized in Table 1.^{4,11-18}

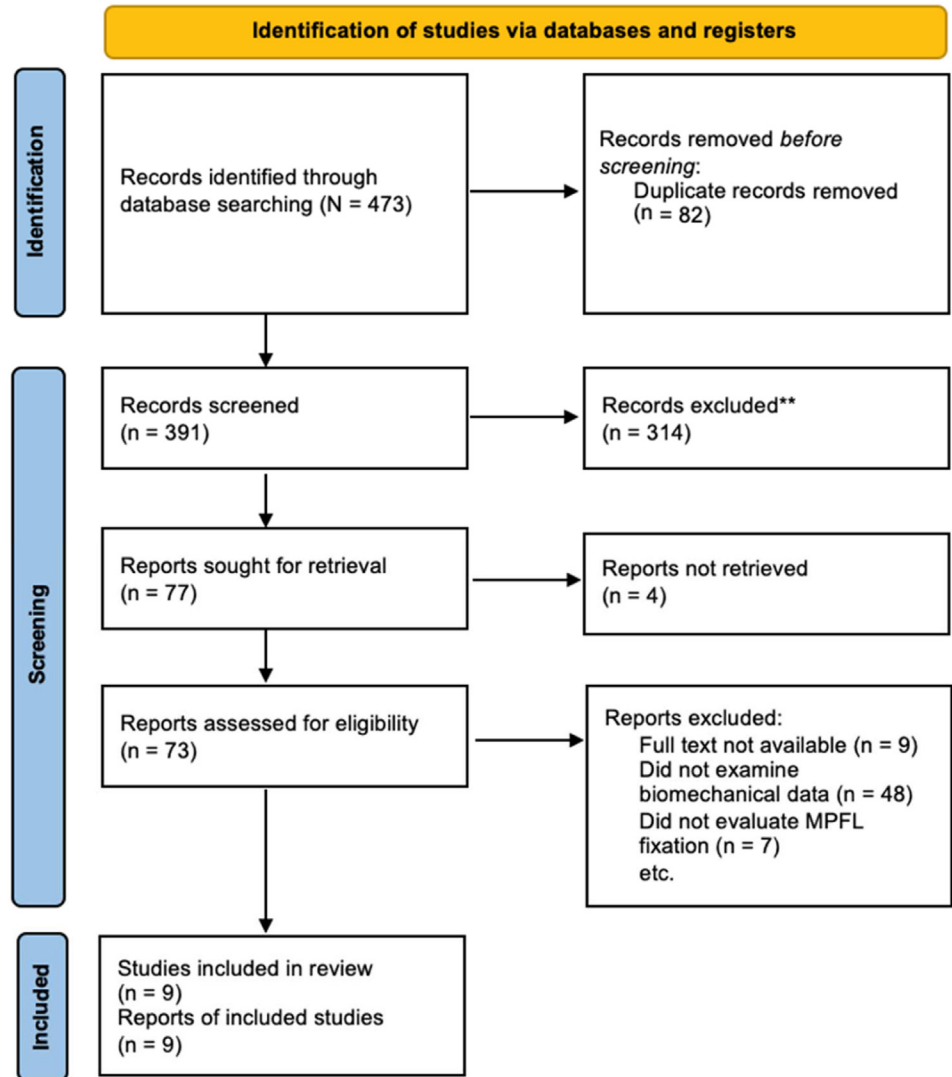
Graft Preparation

Two of the 6 studies reporting on patellar fixation used bovine extensors of the foot.^{12,13} One of the 6 studies on patellar fixation used bovine flexor tendons of the foot.¹⁹ Two of the 6 studies on patellar fixation used a human gracilis autograft.^{4,15} One of the 6 studies on patellar fixation utilized a semitendinosus graft.¹⁴ Two of the 3 studies reporting on femoral fixation used bovine extensor tendons of the foot^{16,18}; the remaining study used a semitendinosus graft.¹⁷

IS Surgical Technique

All 6 studies reporting on patellar fixation included cadaveric specimens undergoing MPFL reconstruction with an IS. All studies describe the debridement of the patella of skin, subcutaneous tissue, and transection of the native MPFL. All 6 studies described placing 2 transverse guide pins in the proximal one third of the patella and over-reaming to a depth of 20 mm. The tails of the suture, which had already been secured to the

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart detailing the database search and inclusion/exclusion process. (MPFL, medial patellofemoral ligament.)



graft, were threaded through 2 IS and the graft was subsequently reduced into the tunnel. The distance between the 2 screws was 15 mm.

All 3 studies reporting on femoral fixation included cadaveric specimens undergoing MPFL reconstruction with an IS. All studies described skin and subcutaneous tissue removal to expose the femoral attachment of the native MPFL and subsequent sharp transection of the native MPFL. In 2 studies, the free ends of the suture attached to the graft were threaded through the Beath pin.^{16,17} A Beath pin was introduced to the femur and a reamer was used to create a socket that extended to the lateral cortex. The end of the tendon graft was passed through the femoral tunnel and, after applying traction to the stem, a 6-, 7-, or 8-mm × 25-mm IS was used to secure the graft within the tunnel. In the remaining study, the whipstitched end of the graft was loaded into the tenodesis driver via a loop-in technique, fixating the graft into the femoral socket.¹⁸

SA Surgical Technique

All 6 studies reporting on patellar fixation included cadaveric specimens undergoing MPFL reconstruction with a SA. All studies described debridement of the patella of any skin and subcutaneous soft tissue, as well as transection of the native MPFL. In 4 studies, 2 drill guides were used to create 2 pilot holes on the medial facet of the patella to aid in the insertion of the SA.^{4,13-15} Tension was applied to further affix the SA to the medial patella. In 2 studies, 2 pilot holes were created on the superomedial facet of the patella to aid in the insertion of the 2 SAs.^{11,12} The free ends of the graft were secured to the patella via several locking sutures in 4 studies.^{4,11,14,15} In one of the remaining studies, a nonabsorbable suture was passed around the graft and secured with a series of 4 surgeon's knots.¹² In the final study, a free limb of the graft was captured with a suture threaded back through the pilot hole and then passed back through the graft limb and tied.¹³

Table 1. Fixation Details of Included Studies

Study	Anatomic Fixation	Techniques Compared	Anchors Used	Number of Screws	Number of Anchors	Screws Used	N	Age, y	Ultimate Load to Failure (N)	Stiffness (N/m)
Raoulis et al., 2021 ⁴	Patella	IS, SA	Stryker 3 mm	2	2	Stryker 6 mm	16 – 8;8	63.66 ± 9.0 y	+	+
Joyner et al., 2017 ¹¹	Patella	IS, SA, suspensory cortical	Bioabsorbable SA, not otherwise specified	2	2	6.25 mm × 15 mm or 5.5 mm × 15 mm PEEK	18 – 9;9	NR	+	–
Mehtha et al., 2017 ¹²	Patella	Bone tunnels, IS, SA	2.9-mm PushLock	2	2	Arthrex 4.75 mm × 15 mm	30 – 15;15	NR	+	+
Russ et al., 2015 ¹⁴	Patella	IS, SA	3.0-mm Biocomposite SutureTak SAs, Arthrex	2	2	4.75-mm Biocomposite SwiveLock, Arthrex	16 – 8;8	55.8 ± 7.7 y	+	+
Lenschow et al., 2013 ¹⁵	Patella	SA, transosseous suture, IS, bone bridge, transpatellar tunnel	4.75- × 15- mm SwiveLock, Arthrex	2	2	6- × 19-mm MegaFix IS	20 – 10;10	28 ± 2 wk	+	+
Russo et al., 2016 ¹³	Patella	IS, SA, converging tunnel, bone tunnel	3.5- × 12- mm titanium	2	2	4- × 15-mm polyetheretherketone (PEEK) IS	14 – 7;7	NR	+	+
Johnston et al., 2020 ¹⁸	Femoral	IS, SA	4.5-mm biocomposite SA, Arthrex	1	1	7- × 23-mm biocomposite IS, Arthrex	18 – 9;9	NR	+	+
Gould et al., 2021 ¹⁷	Femoral	IS, SA	5.5-mm biocomposite, Arthrex Inc	1	1	6-mm biocomposite IS, Arthrex Inc	12 – 6;6	52.8 y	+	+
Dobke et al., 2020 ¹⁶	Femoral	IS, SA, adductor tenodesis	5-mm titanium SA	1	1	7 × 25 mm IS	20 – 10;10	8-9 mo	+	–

IS, interference screw; NR, not reported; PEEK, polyether ether ketone; SA, suture anchor.

Table 2. Summary of the Methodologic Quality Assessment of Included Studies

Study	MQAT (%)
Raoulis et al., 2021 ⁴	84.6
Joyner et al., 2017 ¹¹	84.6
Mehta et al., 2017 ¹²	76.9
Russ et al., 2015 ¹⁴	84.6
Lenschow et al., 2013 ¹⁵	84.6
Russo et al., 2016 ¹³	76.9
Johnston et al., 2020 ¹⁸	84.6
Gould et al., 2021 ¹⁷	92.3
Dobke et al., 2020 ¹⁶	76.9

MQAT, Methodologic Quality Assessment Tool.

All 3 studies reporting on femoral fixation included cadaveric specimens undergoing MPFL reconstruction with a SA. All studies described skin and subcutaneous soft-tissue removal to expose the femoral attachment of the native MPFL with subsequent sharp transection of the native MPFL. In 2 studies, the graft of choice was secured to the SA via 3 running locked suture throws medial to lateral in a Krackow configuration.^{16,17} In the remaining study, the locked suture throws were passed over each other and tied to the midway point of the tendon graft, resulting in 5 alternating half hitches.¹⁸ The marked femoral site was predrilled and tapped to create a pilot hole to secure the SA and the SA was promptly inserted. One study described the use of an additional figure-of-8 suture posteriorly to the graft for additional fixation to the exposed periosteum.¹⁷

Study characteristics, including number of screws, anchors, and companies used, are documented in Table 1. The sex and age for cadaveric specimens were recorded in 3 studies (Table 1).^{4,14,17}

Methodologic Quality Assessment

The risk of bias and methodologic quality of the included studies were assessed using the QUACS scale, which has been previously validated. The mean QUACS score was 82.89 ± 5.13 (range 76.9-92.3), found in Table 2.^{4,11-18} All 9 studies satisfied the threshold for a satisfactory methodologic quality (>75%). The lack of demographics, including age and sex, when describing the cadavers used in each study was the main limitation

that detracted from the quality assessment of the included studies.

Ultimate Load to Failure

All of the studies on MPFL patellar fixation reported on ultimate load to failure (Fig 2). Three of the 6 studies concluded that the use of IS in MPFL patellar fixation exhibited greater loads to failure,¹²⁻¹⁴ whereas the remaining 3 concluded that there was no difference in ultimate load to failure between IS and SA. The pooled analysis from 6 studies reporting on ultimate load to failure for MPFL patellar fixation failed to reveal a statistically significant difference in favor of IS compared with SA (*P* = .088). Statistical heterogeneity was estimated at 22.06%.

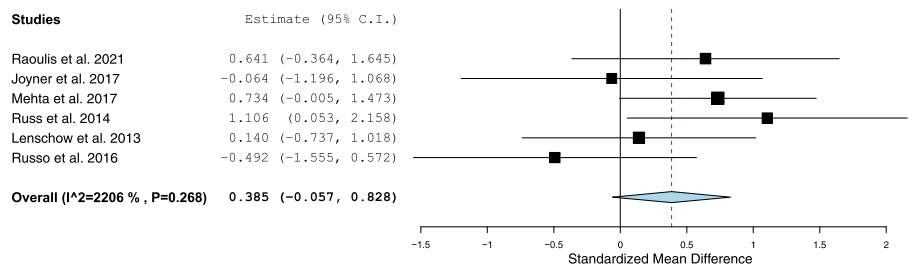
All of the studies on MPFL femoral fixation reported on ultimate load to failure as well (Fig 3). One of the 3 studies concluded that the use of IS in MPFL femoral fixation exhibited higher ultimate load to failure,¹⁶ whereas the remaining 2 studies concluded there was no difference in ultimate load to failure between IS and SA in MPFL femoral fixation.^{17,18} The pooled analysis from 3 studies reporting on ultimate load to failure for MPFL femoral fixation revealed a statistically significant difference in favor of IS compared to SA (*P* = .043). Statistical heterogeneity was estimated at 0%.

Stiffness

Five of the 6 studies on MPFL patellar fixation reported on stiffness (Fig 4). Two of the 5 studies concluded that the use of IS in MPFL patellar fixation exhibited greater stiffness than MPFL patellar fixation with SA,^{4,14} whereas the remaining 3 concluded that there was no difference in stiffness between IS and SA. The pooled analysis from 5 studies reporting on stiffness for MPFL patellar fixation revealed a statistically significant difference in favor of IS compared with SA (*P* = .007). Statistical heterogeneity was estimated at 83.05%.

Two of the 3 studies on MPFL femoral fixation reported on stiffness (Fig 5).^{17,18} One of the 2 studies concluded that the use of IS in MPFL femoral fixation exhibited greater stiffness compared with MPFL femoral fixation with SA,¹⁶ whereas the remaining

Fig 2. Forest plot demonstrating a standardized mean difference of ultimate load to failure in favor of IS MPFL patellar fixation compared with SA. (C.I., confidence interval; IS, interference screw; MPFL, medial patellofemoral ligament; SA, suture anchor.)



Studies	Estimate (95% C.I.)
Raoulis et al. 2021	3.852 (2.196, 5.507)
Mehta et al. 2017	2.080 (1.191, 2.968)
Russ et al. 2014	1.480 (0.374, 2.586)
Lenschow et al. 2013	0.448 (-0.439, 1.336)
Russo et al. 2016	0.148 (-0.901, 1.197)
Overall (I²=8035 %, P< 0.001)	1.490 (0.412, 2.569)

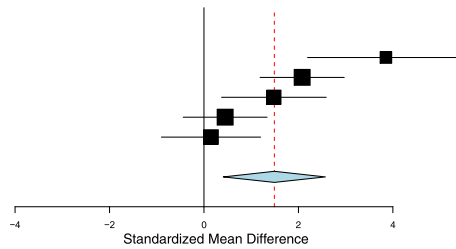


Fig 3. Forest plot demonstrating a standardized mean difference of stiffness in favor of IS MPFL patellar fixation compared with SA. (C.I., confidence interval; IS, interference screw; MPFL, medial patellofemoral ligament; SA, suture anchor.)

study concluded there was no difference in stiffness between IS and SA in MPFL femoral fixation. The pooled analysis from 3 studies reporting on stiffness for MPFL femoral fixation failed to reveal a statistically significant difference in favor of IS compared with SA ($P = .507$). Statistical heterogeneity was estimated at 91.27%.

Mode of Failure

Seven of the 9 included studies reported on mode/mechanism of failure, including 2 studies on femoral fixation and 5 studies on patellar fixation. For the IS fixation femoral group, 75% (12/16) of cadavers failed via graft pullout and the remaining cadavers failed via graft rupture (25%). For the SA femoral fixation group, 56.3% (9/16) failed via anchor rupture, 31.3% (5/16) failed via anchor pullout, and the remaining (2/16) failed via graft rupture. For the SA patellar fixation group, 51.6% (16/31) of specimens failed via anchor rupture, 41.9% (13/31) failed via anchor pullout, and 3.2% (1/31) failed via rupture of tendon. For the IS patellar fixation group, 74.4% (29/39) of specimens failed via graft pullout and 12.8% (5/39) failed via rupture of tendon.

Discussion

Our findings suggest that IS exhibit greater levels of stiffness in patellar fixation and greater ultimate loads to failure in femoral fixation. There were no differences in ultimate load to failure in patellar fixation and no difference in stiffness in femoral fixation between cadaveric constructs fixated with IS versus SA.

Overall, the clinical results of MPFL reconstruction, regardless of fixation technique or construct, have historically been strong. A systematic review that evaluated the clinical outcomes of IS versus SA concluded

that femoral autograft fixation with IS versus SA resulted in comparable Kujala, Lysholm, and Tegner scores compared with preoperative baseline scores.¹⁹ Many clinical studies have reported strong early-to-intermediate results following MPFL reconstruction with the use of IS for femoral and/or patellar fixation.²⁰⁻²² Nevertheless, the use of IS in MPFL reconstruction have been associated with increased risk of complications including patellar fracture and graft tensioning,¹ prompting the use of alternative methods of fixation in MPFL reconstruction. Mikashima et al.,²³ in a study of 12 reconstructions, found that 2 patients sustained a patellar fracture from the use of IS for double-bundle reconstruction.

Although a newer fixation construct in MPFL reconstruction, the use of SA has been associated with strong outcomes following MPFL reconstruction in femoral and/or patellar fixation.⁷ SAs were initially introduced as an alternative to IS fixation due to the incidence of fracture associated with tunnel drilling and screw placement. A study, performed by Basso et al.,³ demonstrated that the use of an autologous gracilis graft with SAs achieved strong midterm clinical results at an average of 72.3 months. Another systematic review determined that the use of SA for transpatellar fixation was associated with greater improvement in Kujala scores compared with double transpatellar tunnel fixation methods, though there was no difference in patellar redislocation rate.²⁴

Despite strong clinical results, the widespread implementation of SA has been tempered by poor failure load—Mountney et al.²⁵ demonstrated that the failure load of SA was 142 N, substantially lower than a non-pathologic MPFL (200 N). The results of this biomechanical systematic review suggest that SA graft fixation to the patella is not inferior to IS fixation with

Fig 4. Forest plot demonstrating a standardized mean difference of ultimate load to failure in favor of IS MPFL femoral fixation compared with SA. (C.I., confidence interval; IS, interference screw; MPFL, medial patellofemoral ligament; SA, suture anchor.)

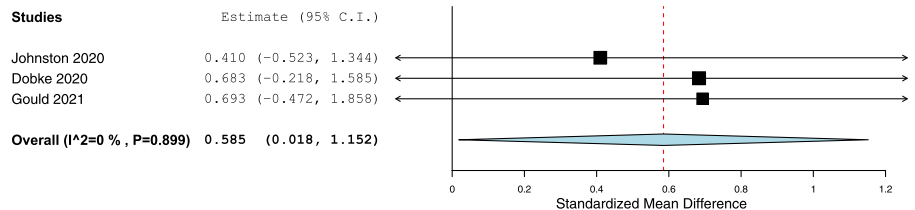
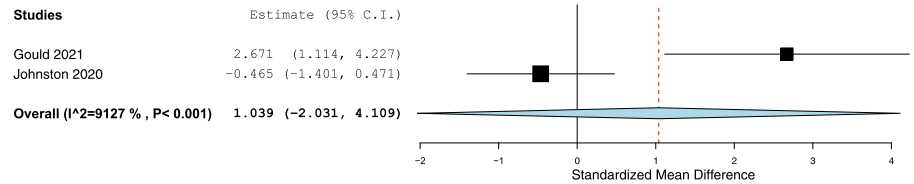


Fig 5. Forest plot demonstrating a standardized mean difference of stiffness in favor of IS MPFL femoral fixation compared with SA. (C.I., confidence interval; IS, interference screw; MPFL, medial patellofemoral ligament; SA, suture anchor.)



regard to failure load. Thus, SA fixation may represent a viable surgical option on the patellar side, particularly given the previous reports that MPFL failure is less likely to occur as a patellar avulsion compared to femoral avulsion or midsubstance rupture.²⁵ On the femoral side, the pooled analyses in the present study suggest that IS fixation has a greater load to failure than SA fixation. Therefore, the use of an IS for femoral fixation may be preferable to minimize the risk of construct failure in skeletally mature individuals, whereas SA femoral fixation may be considered in pediatric patients as a means of avoiding the curvilinear distal femoral physis.

Interestingly, the use of IS in patellar fixation during MPFL reconstruction was associated with greater ultimate load to failure compared with SA. This biomechanical finding is particularly interesting in the setting of clinical results, which suggest there is no difference in clinical or functional outcome between IS and SA, which may suggest that although IS can withstand greater loads, this biomechanical difference may not be clinically relevant. Indeed, Mountney et al.²⁵ evaluated the tensile strength of the intact MPFL and found that it could withstand a load of 208 ± 90 N. This load was surpassed by MPFL reconstructions with both SA and IS in all studies.

Similarly, the use of IS in femoral fixation during MPFL reconstruction was associated with a higher stiffness compared with SA. The clinical implications of a greater stiffness associated with a MPFL reconstruction is not known, though, previous literature suggests that a reconstructed graft that is too stiff can exhibit resistance to elongation and lead to excessive tensioning of the graft.²⁶ Clinically, this can lead to medial patellar overload with concomitant cartilage tears and degeneration. Moreover, although there is scarce literature surrounding the optimal stiffness of a reconstructed MPFL, the stiffness of medial soft-tissue restraints to lateral translation decreased from 22.5 N/mm to 10.5 N/mm after compromising the native MPFL—all reconstructed grafts, whether fixed with IS or SA, exhibited stiffness greater the native MPFL.¹⁵

Mode of failure is important component of the biomechanical analysis within this study that warrants attention. It is not surprising that the most common mechanism of failure for IS is graft slippage and/or

pullout for both femoral and patellar fixation during MPFL reconstruction. In IS fixation, the graft is not directly fixated to the screw; rather, static friction holds the graft in position between the screw and surrounding bone.¹⁷ However, in SA fixation, fixation is achieved at the bone—anchor and anchor—suture interface, thereby explaining anchor rupture and anchor pullout (bone—anchor interface) as the 2 most common mechanisms of failure in specimens treated with SA for fixation.

Limitations

This study has limitations. Only 5 studies were included in this review for patellar fixation and, notably, only 3 studies were included for femoral fixation in MPFL reconstruction, which may suggest that some of the conclusions drawn herein are not adequately powered. Furthermore, the techniques by which ultimate load to failure and stiffness were evaluated exhibited a degree of heterogeneity between studies and, therefore, the results and our concomitant conclusions should be interpreted with caution. Similarly, the quantitative heterogeneity, as represented by I^2 statistic, revealed that both ultimate load to failure and stiffness demonstrated considerable heterogeneity, all of which should be considered when interpreting our findings.

Conclusions

The use of IS was associated with a higher stiffness compared with the use of SA in MPFL patellar fixation, but there was no difference in load to failure between IS and SA. The use of IS was associated with a greater load to failure compared to the use of SA in MPFL femoral fixation, but there was no difference in stiffness between IS and SA.

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