Peer Review File

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Review Comments

Comment 1: In the manuscript: "Biomechanics of Different Anterior Cruciate Ligament Reconstruction Fixation Methods" by McDermott et al, an overview of the different fixation techniques for anterior cruciate reconstruction is provided. The review is clearly written and has logic flow and addresses an important topic. In the manuscript, it is stated that: "The purpose of this review was to highlight the unique advantages and disadvantages of each type of graft fixation method and provide perspective on the role that the biomechanical properties play in optimizing fixation strategies based on clinical outcomes." I agree that the first part of this purpose has been achieved, in particular in relation to clinical outcomes, but the second is only scarcely addressed. Consequently, it remains unclear what the authors would like to achieve with the paper, other than providing a summary of what is known about ACLR fixation techniques.

My major concern with the manuscript is that it lacks a clear problem statement. As it is not explained in large detail what the issues are with current fixation techniques and which issues still must be overcome, the reader is left with the question of relevance and impact.

My second major concern is that often essential details are left out. It remains unclear whether information provided applies to soft-to-bone or bone-to-bone fixations or both? For healing mechanics, it makes a large difference when a tendon to bone versus bone-to-bone graft is being used. Please clarify if differences have been found, depending on the graft and whether the statements made can be applied to all graft types. Second, often, mechanical properties are mentioned but it remains unclear if that accounts for the fixation or the graft, and for the latter whether this applies to the properties during the operation or during in vivo remodeling after the operation. Also, these details should be provided. Specific instances of this can be found in the list below.

Reply 1: Thank you for your thorough review. It seems there is appreciation for the vast amount of information available and such a broad topic with multiple intricacies that can affect the biomechanics of ACLR fixation. While this review is not able to nor intends to completely include all details of ACLR biomechanics and the supported literature, a more specific problem statement has been provided. Additionally, through the comments below, we feel that we have made the appropriate changes as suggested above to improve the clarity of our narrative review.

Changes in the text:

Lines 79 to 81: "The overall reported ACL graft rupture rate at longer than 10 year follow up was 6.2%, with 10.3% clinical failure. While many different factors can lead to ACLR failure, graft fixation is one important factor."

Lines 124-126: "Other biomechanical studies comparing metal and bioabsorbable IFS fixation of a soft tissue graft found no differences in ultimate load to failure or construct stiffness."

Lines 132-135: "Brand et al (26) found that bioabsorbable screws were comparable or superior to titanium screws for IFS fixation with respect to

load-to-failure for soft tissue grafts and that the bioabsorbable implant produced less screw thread-induced laceration of the soft tissue graft during testing."
Lines 171-174: "Other biomechanical studies comparing ALDs and FLDs demonstrated no differences in device elongation when cycled on an Instron machine. This is clinically relevant as graft/construct elongation will produce laxity and resultant clinical failure."
Additional changes outlined below in specific comments.

Comment 2: I strongly encourage the authors to add a table/overview with the advantages and disadvantages of each fixation method.

Reply 2: We have added a table describing advantages and disadvantages of each fixation method as well as tables for each category of fixation. Please see tables below for your reference.

Changes in the text: Table 1 - Line 100; Table 2 - Line 146; Table 3 – line 151; table 4 – line 193; table 5 – line 210; table 6 – line 243

Table 1. The advantages and disadvantages of the different types of interference screws used for anterior cruciate ligament reconstruction.

Interference Screw Type	Advantages	Disadvantages
Metal	• No breakdown • Rigid fixation	• MRI artifact • Irrigation/need for removal
Biocomposite	• MRI compatible • ↓ Removal • ↓ Graft injury	• Tissue reaction • Breakage • Osteolysis
PEEK	• Biocompatible • Non-resorbable • MRI compatible	• Breakage
Legend: ↓ = decreased		

Table 2. Studies on Compression Fixation in Anterior Cruciate Ligament Reconstruction.

Reference	Year	Study Type	Study Purpose	Conclusion
Compression Fixation				
Scheffler[11]	2002	Biomechanical study	Evaluate tensile properties with incremental cyclic loading based on level and method of graft fixation	- Fixation with interference screws allows graft slippage - Can be limited by bone block or application of hybrid fixation, especially on tibial side
Shumborski[15]	2019	Randomized control trial	Compare the clinical performance of ACL reconstruction with PEEK and titanium interference screws at 2 years	- No significant differences in graft rerupture rate, contralateral ACL rupture rate, subjective outcomes, or objective outcomes.

Kramer[16]	2020	Retrospective review	Retrospectively analyze the complications associated with tibial bioabsorbable interference screw use in adolescents after ACLR	- Screw-site pain most common complication - Reoperation for screw-related symptoms was 5%
Laxdal[17]	2006	Randomized control trial	Compare the clinical/radiographic results in metal versus bioscrew IFS for ACLR	- No biomechanical significant differences on arthrometer - No differences in functional outcome
Kaeding[18]	2005	Prospective study	Compare bioscrew and metal IFS	- No functional/biomechanical differences between groups
Shen[19]	2010	Meta-analysis	Investigate the outcomes between bioabsorbable and metallic screw fixation in anterior cruciate ligament (ACL) reconstruction.	- No significant difference in knee joint stability or knee joint function outcome between bioabsorbable and metallic interference screws
Myers[20]	2008	Randomized control trial	Prospectively assess the outcome of ACLR by use of bioscrew and titanium IFS	- No differences in functional/radiographic outcomes
Drogset[21]	2011	Prospective study	Compare long-term clinical outcome after ACL-reconstructions with BPTB-grafts fixed with metal interference screws or bioabsorbable screws	- No significant differences between the groups in any parameter measured - Better Pivot shift results in the bioscrew group
Kousa[22]	2003	Biomechanical study	Evaluate initial fixation strength among hamstring tendon graft tibial fixation devices	- PEEK screw was the strongest in the single-cycle load-to-failure test
Xu[23]	2021	Meta-analysis	Compare metal and bioscrew IFS	- No difference between two in knee function or laxity - Metallic screws had fewer complications
Benedetto[24]	2000	Randomized control trial	Compare a bioabsorbable to a metal screw in anterior	- No significant functional or patient reported differences were found between the

			cruciate ligament reconstruction	groups at 1 year
Arama[25]	2015	Randomized control trial	Compare clinical/radiologic outcomes of the PLLA-HA screw versus titanium screw for hamstring tendon ACLR	- No difference in any clinical outcome measure at 2- or 5-year follow-up between the 2 groups
Brand[26]	2005	Biomechanical study	Compare the biomechanical properties of eccentrically positioned bioabsorbable and titanium interference screws for hamstring tendon graft	- Bioscrew was similar in load-to-failure with metallic screw - Less graft thread-induced laceration in bioscrew
Kruppa[27]	2020	Biomechanical study	Investigate the force in soft tissue grafts secured with a tibial interference screw	- Graft force in soft tissue grafts secured with a tibial interference screw decreased substantially - Screw length/diameter had no affect
Sawyer[28]	2013	Biomechanical study	Investigate the biomechanics in soft tissue grafts secured with a tibial interference screw	- Single insertion of interference screws for soft tissue graft fixation weakens the biomechanical properties of the graft itself
Micucci[29]	2010	Biomechanical study	Evaluate the effect that interference screw diameter has on fixation strength of a soft-tissue anterior cruciate ligament (ACL) graft	- No statistically significant differences in ultimate strength and graft slippage between screws
Legend: ACLR = anterior cruciate ligament reconstruction; IFS = interference screw; bioscrew = bioabsorbable screw				

Table 3. Studies on Suspensory Fixation in Anterior Cruciate Ligament Reconstruction.

Reference	**Year**	**Study Type**	**Study Purpose**	**Conclusion**
Suspensory Fixation				
Houck[30]	2018	Meta-analysis	Compare the biomechanical results of fixed- versus	- Adjustable loop device had strongest “time zero” ultimate load to failure

			adjustable-loop femoral cortical suspension devices in studies simulating ACLR	when compared to fixed loop device
Onggo[31]	2019	Systematic review	Compare biomechanical and clinical outcomes between ALD and FLD in the femoral fixation	- Superior biomechanical properties of FLDs - ALDs and FLDs yielded similar clinical outcome scores and graft rerupture rates
Eguchi[32]	2014	Biomechanical study	Evaluate the mechanical strength of two cortical suspension devices	- FLD greater mechanical strength than ALD - Increased cyclic displacement in ALD
Singh[33]	2020	Biomechanical study	Compare loop elongation and load at failure of ALDs/FLDs	- FLD had highest failure load - No differences in elongation between devices
Smith[34]	2018	Biomechanical study	Compare elongation of ALD/FLD	- No statistically significant differences among the devices for total or dynamic elongation
Johnson[35]	2015	Biomechanical study	Compare five femoral suspensory fixation devices	- Significant differences were observed between current fixed-loop and adjustable-loop cortical suspension devices for soft tissue femoral fixation when subjected to high loads experienced during rehabilitation
Petre[36]	2013	Biomechanical study	Compare four femoral suspensory fixation devices	- Each ALD/FLD had the necessary biomechanical properties with regard to ultimate failure strength, displacement, and stiffness for initial fixation of soft tissue grafts in the femoral tunnel
Barrow[37]	2014	Biomechanical study	Compare ALD/FLD to native knee physiologic loads	- The ultimate load of all graft-fixation devices exceeded the forces likely to be experienced in a patient's knee during the

				early postoperative rehabilitation period
Legend: ALD = adjustable loop device, FLD = fixed loop device				

Table 4. Studies on Post Fixation in Anterior Cruciate Ligament Reconstruction.

Reference	Year	Study Type	Study Purpose	Conclusion
Post Fixation				
Weiss[12]	2019	Biomechanical study	Comparative biomechanical analysis of tibial fixation strength for ACLR with interference screw compared with screw post and washer, and compared with the associated fixation of both methods (hybrid fixation)	- Hybrid fixation group presented a significantly higher final stiffness in comparison - Higher yield load compared to the interference screw group
Zainal Abidin[38]	2021	Biomechanical study	Analyze the biomechanical effects of different types of fixators (cross-pin, interference screw, and cortical button) towards stability after ACLR	- Cross-pin was found to have optimum stability in terms of stress and strain at the femoral fixation site
Speziali[39]	2014	Systematic review	Systematically review the fixation techniques for the ACL reconstruction and associated clinical outcomes at the early follow-up	- Femoral side cross-pin, metallic interference screw, bioabsorbable interference screw, and suspensory device were used in 32.3, 27.3, 24.8, 15.5% of patients, respectively - Tibial side fixation was achieved with metallic interference screw, bioabsorbable interference screw, screw and plastic sheath, screw post and cross-pin in 38.7, 31, 15.7, 12.8, and 1.7% of patients, respectively
Muench[40]	2022	Biomechanical	Compare knee	- No significant differences

		study	kinematics in a cadaveric model of ACL repair using an ALD or suture anchor fixation with suture tape augmentation	between the three techniques
Legend: ACL = anterior cruciate ligament; ACLR = anterior cruciate ligament reconstruction; ALD = adjustable loop device, FLD = fixed loop device				

Table 5. Studies on Hybrid Fixation in Anterior Cruciate Ligament Reconstruction.

Reference	**Year**	**Study Type**	**Study Purpose**	**Conclusion**
Hybrid/Adjunct Fixation				
Pereira[2]	2021	Systematic review	Review the current evidence on tibial-graft fixation	- No consensus on the best method for tibial fixation of the grafts in ACL reconstructions regarding tension
Brand[7]	2000	Review	Review of literature on graft fixation devices	- Fixation should be done at normal anatomic attachment - No consensus on best device
Weiss[12]	2019	Biomechanical study	Comparative biomechanical analysis of tibial fixation strength for ACLR with interference screw compared with screw post and washer, and compared with the associated fixation of both methods (hybrid fixation)	- Hybrid fixation group presented a significantly higher final stiffness - Also had a higher yield load compared to the interference screw group
Oh[41]	2006	Biomechanical study	Evaluate the effect of hybrid femoral fixation with bioabsorbable interference screws	- Hybrid femoral fixation with suspensory fixation and a bioabsorbable interference screw is stronger than interference or suspensory fixation alone with respect to ultimate tensile strength, stiffness, and slippage

Walsh[42]	2009	Biomechanical study	Compare biomechanical screw/suspensory fixation versus either alone	- Combined screw/suspensory had higher load-to-failure - Combined yield stiffer construct
Verioti[43]	2015	Biomechanical study	Compare three methods of tibial-sided fixation	- No significant difference between IFS, IFS + post, or IFS + suture anchor
Athiviraham[44]	2021	Biomechanical study	Determine whether initial tensioning of suture tape before fixation with a knotless suture anchor significantly affects final tension of the suture tape	- Final tension of the suture tape construct appears to be reproducible and consistent, independent of the initial tension introduced with suture anchor placement
Eisen[45]	2008	Technique article	Describes transosseous backup suture fixation for ACLR	- Technique for backup tibial fixation precludes the need for external hardware
Carulli[46]	2017	Randomized control trial	Compare the clinical/radiological outcomes of patients with tibial fixation by a centrally placed resorbable screw/sheath to a resorbable interference screw/staple fixation	- No significant differences between groups
Teo[47]	2017	Retrospective review	Determine whether supplementary tibial graft fixation with a staple is routinely necessary for ACLR	- No significant difference in the objective and subjective outcome assessments between staple/no staple
Diego[48]	2017	Technique article	Describe femoral fixation with a combined metal IFS and staple	- Technique for combined IFS/staple femoral fixation
Gerich[49]	1997	Biomechanical study	Evaluate the primary biomechanical parameters of this technique compared with a standard IFS fixation	- Staple fixation resulted in comparable max load to failure, graft slippage, and stiffness to IFS
Legend: ACLR = anterior cruciate ligament reconstruction; IFS = interference screw				

Table 6. The advantages and disadvantages of various anterior cruciate ligament reconstruction graft fixation methods.

Fixation Method	Advantages	Disadvantages
Compression	• ↓ Graft-tunnel micromotion • ↓ Tunnel widening • ↓ Graft creep	• Risk of screw-tunnel divergence • Graft damage • Cancellous fixation • Graft slippage
Suspensory	• Minimally invasive • ↑ Tension between graft/bone interface • Cortical fixation • Similar biomechanics to compression	• ↑ Graft-tunnel motion • "Windshield wiper phenomenon" • Tunnel widening
Suture Anchor	• Maintenance of tension	• Anchor pull-out
Post/Staple	• Useful in open physes • Useful in graft-tunnel mismatch • Stable, inflexible fixation	• Hardware irritation • More invasive
Legend: ↓ = decreased, ↑ = increased		

Other specific concerns/points that can help the authors further improving the quality. Please make sure to address these in the manuscript:

Comment 3: The title suggests that the primary goal of the manuscript is to provide a thorough biomechanical analysis of the different fixation techniques. Also, in lines 54-56 of the introduction, it is suggested that biomechanical properties of the fixation methods will be discussed. However, the paper focusses more on the clinical outcome of the different techniques. Please consider changing the title.

Reply 3: We have revised the title to reflect the focus on clinical outcomes.

Changes in the text: The title now reads: "Biomechanics of Different Anterior Cruciate Ligament Reconstruction Fixation Methods & Implications on Clinical Outcomes"

Comment 4: Line 56-61: "Currently there is no consensus on the optimal graft fixation technique." Is that because they work equally well? Is it important to reach consensus? What are the requirements for a "successful clinical outcome"? Please specify what the scientific or clinical problem is.

Reply 4: There are multiple reasons as to why there is no optimal graft fixation technique which includes different types of ACLR grafts used, surgeon preference, industry influence/competition, lack of evidence-based recommendations from clinical outcomes studies, and variations in the reported biomechanical effectiveness for different fixation types.

Changes in the text: Line 81-87: "Currently, there is no consensus on the optimal graft fixation technique. The reasons for lack of consensus may be attributed to several

factors including but not limited to different types of ACLR grafts used, surgeon preference, industry influence/competition, lack of evidence-based recommendations from clinical outcomes studies, and variations in the reported biomechanical effectiveness for different fixation types. Therefore, it is important for surgeons to understand the reported advantages and disadvantages of using different ACLR fixation types based on biomechanics and clinical outcomes."

Comment 5: Line 73-74: "… and less likelihood of graft injury during time of insertion." This is a bit unclear, can you explain where this is based on?
Reply 5: There is evidence to suggest that metal interference screws can damage soft tissue grafts during the insertion of the screw as it compresses the graft against the bone tunnel. Shumborski et al discuss that biocomposite screws decrease this risk of graft damage as they are not metal.
Changes in the text: No changes made.

Comment 6: Line 86: What is meant by "mechanical characteristics"?
Reply 6: This refers to the properties of the PEEK anchor itself to include its modulus of elasticity and that it is insoluble and chemically inert (Shumborski 2019).
Changes in the text: Lines 116-118: "The absence of metal artifact on MRI, modulus of elasticity similar to human bone, biological compatibility, and equivalent clinical outcomes suggest that PEEK implants may be an excellent choice of ACLR graft fixation."

Comment 7: Line 89-91: "When tested biomechanically, there were no statistically significant differences between bioabsorbable and metallic screw fixation (P>0.05)." Please indicate what type of mechanical test was performed, was this a bone-pull-out test?
Reply 7: A KT-1000/-2000 knee arthrometer was used to measure the anterior tibial motion relative to the femur to simulate the function of an intact anterior cruciate ligament.
Changes in the text: Line 121: "When tested biomechanically with a KT-1000/-2000 arthrometer, there were no statistically significant…"

Comment 8: Line 95-110: "The utilization of compression fixation specifically in the setting of all-soft tissue grafts has become a point of concern as surgeons questioned whether IFSs would provide adequate fixation without risking injury to the graft at time of insertion". From the text, I get the impression that for soft tissues, screw fixations are indeed risking graft integrity, but it remains unclear if this also poses a risk for bone-to-bone grafts, as is suggested in line 95-97 ('specifically' to me means that it primarily applied to soft tissue grafts but also for other grafts). Please clarify.
Reply 8: Correct, there appears to be increased risk of compromising graft integrity with screw fixation at time of insertion for all-soft tissue grafts compared to screw fixation for bone-to-bone grafts. Therefore, it does seem appropriate to keep the word "specifically" in this sentence.
Changes in the text: None.

Comment 9: Line 116-117: “In the realm of suspensory fixation, fixed-loop devices (FLDs) and adjustable-loop devices (ALDs) are both commercially available.” Please elaborate a bit more on their functioning.

Reply 9: Successful ACLR is dependent on appropriate tension of the ACL. Suspensory fixation through fixed and adjustable loop devices allow for tension across the construct. Fixed loops are one continuous suture that connects the graft to the button such that it cannot be adjusted once in place. Adjustable loops allow for implantation and then subsequent tensioning thereafter.

Changes in the text: Lines 154-157: “In FLDs, the graft is attached to a suture loop that is connected to a button that is flipped against cortical bone. In ALDs, the graft is secured to an adjustable loop of suture and a button such that the tension in the construct can be set after flipping the button against the cortex.”

Comment 10: Line 118-119: “FLDs keep the graft on tension to maintain the interface between the graft and the bone for healing.” Please explain how graft tension is maintained.

Reply 10: As previously described.

Changes in the text: Lines 157-159: “FLDs keep the graft on tension by connecting it at a constant length to the cortical button to maintain the interface between the graft and the bone for healing.”

Comment 11: “The disadvantage of FLDs include the potential for inaccurate graft and tunnel measurements leading to graft laxity and poor osseointegration.” Please explain.

Reply 11: Because this graft-suture-button is a set length, there is little room for error in the distance between the femur cortex where the button sits, and where the graft is pulled into the femoral tunnel from inside the notch. Too long a distance, and the graft will be lax and the bone will not form around the graft in the tunnel due to increased motion.

Changes in the text: Lines 160-162: “The disadvantage of FLDs include the potential for inaccurate graft and tunnel measurements leading to graft laxity and poor osseointegration as FLDs are a set length and cannot be adjusted once implanted.”

Comment 12: Line 123-125: “In a systematic review comparing FLDs and ALDs, Onggo et al29 reported superior biomechanical properties in FLDs including higher graft stiffness and higher ultimate load-to-failure.” Please specify if this only concerned graft mechanical properties. Additionally, how this relates to the healthy ACL, as a higher stiffness of an ACL graft is not beneficial for knee kinematics per se.

Reply 12: This only concerned graft mechanical properties. The historical concern with ALDs is that they need to be re-tensioned and can result in graft laxity over time. Advances in this technology advise that the knee be flexed/extended (cycled) intra-operatively and re-tensioned to avoid this phenomenon. This systematic review showed that while FLDs demonstrated superior graft stiffness and ultimate load to failure, that re-tensioning of the ALDs per the manufacturer guidelines resulted in no

clinical differences. They did not comment on graft over-tensioning as you allude to, but they mention that both are sufficient for the normal forces an ACL withstands.
Changes in the text: Lines 165-169: "In a systematic review comparing FLDs and ALDs, Onggo et al31 reported superior biomechanical graft properties in FLDs including higher graft stiffness and higher ultimate load-to-failure. It is important to note that the authors found biomechanical improvement with re-tensioning of ALDs after tibial fixation as per manufacturer instructions and that both constructs possessed the necessary biomechanical strength of a native ACL."

Comment 13: Line 125-127: "It is important to note that the authors found biomechanical improvement with re-tensioning of ALDs after tibial fixation as per manufacturer instructions." Please elaborate.
Reply 13: See the aforementioned comment/reply and corresponding change in text.
Changes in the text: Lines 165-169: "In a systematic review comparing FLDs and ALDs, Onggo et al31 reported superior biomechanical graft properties in FLDs including higher graft stiffness and higher ultimate load-to-failure. It is important to note that the authors found biomechanical improvement with re-tensioning of ALDs after tibial fixation as per manufacturer instructions and that both constructs possessed the necessary biomechanical strength of a native ACL."

Comment 14: Line 133-136: "Petre et al35 also biomechanically compared suspension devices in soft tissue grafts and found that all devices tested had the necessary physiologic biomechanical properties with regard to displacement, failure strength, and stiffness for initial fixation in ACLR." Please define how it was assessed that all devices had the necessary properties, and explain what that means.
Reply 14: Their biomechanical testing included: ultimate load to failure, stiffness, and displacement. The measurements for each of these constructs/products exceeded that of a native ACL, meaning that each of those products can withstand the normal physiologic load the knee undergoes.
Changes in the text: Lines 178-182: "Petre et al36 also biomechanically compared suspension devices in soft tissue grafts in a porcine model looking at ultimate load to failure, stiffness, and displacement. They found that all devices tested had the necessary physiologic biomechanical properties with regard to displacement, failure strength, and stiffness for initial fixation in ACLR when compared to the native ACL."

Comment 15: Line 138-139: "ALDs have been shown to possess the physiologic strength necessary to be used in ACLR when cyclically tested." This description is also to vague, please clarify what the requirements are to be able to use the technique for ACLR.
Reply 15: When compared to normal knee kinematics and physiologic loads, the ALDs were strong enough to withstand normal and beyond.
Changes in the text: Lines 184-186: "ALDs have been shown to possess the physiologic strength necessary to be used in ACLR when cyclically tested in vitro and compared to the native knee.36,37

Comment 16: Paragraph line 141: “Post Fixation”. I was not aware of this term or technique, and from reading the text, it remains unclear. In particular, the part where post, IFS, cross-pin, screw-post, suture anchors and washer fixations are described, merged in a hybrid technique or compared is not clear (let alone if they are all part of the ‘post fixations’ group). Please clarify and add illustrations.

Reply 16: A post is any sort of implant, typically a screw, that is placed into bone and the graft is secured to it. In a typical scenario, a screw is placed unicortically or bicortically anterior to posterior in the tibia, and suture that has been looped through the graft is then tied around this screw before the screw is fully inserted. This is a common historical method of graft fixation that can still be seen in current practice. A cross pin utilizes a similar technique, but is a pin instead of a screw.

Changes in the text: Line 189-191: “Post fixation is another method of ACLR, which is usually a metal screw, with or without a washer, or a cross pin that acts as a stable, inflexible point of fixation in the bone separate from the tunnel aperture that acts as a point of fixation for the graft.”

Comment 17: Line 153-154: How does this failure rate of 17.3% relate to the failure rate of other fixation mechanisms? Is this very poor or similar to other fixation mechanisms?

Reply 17: This is higher than typically seen. The same review found a 5.8% failure with suspensory fixation.

Changes in the text: Lines 201-202: “Speziali et al39 reported a failure rate of 17.3% when a cross-pin was used on the femoral side, which is in contrast to 5.8% with suspensory fixation.”

Comment 18: Line 162-163: “As such, hybrid fixation methods have been explored to determine if adjunct fixation improves stiffness.” Of what exactly? The graft or the fixation? Same for line 166.

Reply 18: Hybrid fixation is implemented either as a backup to the intended fixation or as an adjunct to theoretically increase the strength of the graft and avoid failure of fixation. Lines 194-196 detail the primary concern: that tibial bone is softer and that surgeons were concerned that the IFS against the graft and metaphyseal bone of the tibia was not strong enough to hold graft tension while osseous integration occurred.

Changes in the text: Lines 212-214: “As such, hybrid fixation methods have been explored to determine if adjunct fixation improves graft stiffness and increase the fixation strength of the construct.”

Comment 19: Paragraph starting at line 159: “Hybrid/Adjunct Fixation”. It remains unclear how these are a different class compared to the explanation of different techniques in the previous paragraph, where also techniques were merged. Please clarify.

Reply 19: This category of fixation implies the combination of multiple techniques. Most commonly, IFS is combined with some sort of backup or adjunct like a post or a suture anchor. The theory is that while IFS fixation is considered strong, it is parallel to the tunnel and so the graft has the chance to slip and become lax, resulting in failure. By

adding additional fixation in a different plane (ie: anterior to posterior fixation with a suture anchor) the graft is secured by two methods in case one fails.
Changes in the text: Lines 210-212: "Throughout the evolution of ACLR, hybrid fixation techniques have gained popularity, specifically when considering IFS fixation in isolation with concern of graft slippage with parallel fixation in a different plane."

Comment 20: Line 189: Is "biomechanical properties" referring to the biomechanical properties of the fixation method, the materials used in the fixation method, or the graft itself?
Reply 20: Fixation method.
Changes in the text: Lines 239-241: "Due to the high technical demands of ACLR with significant clinical implications for graft failure, the biomechanical properties of overall graft fixation by compression, suspensory, post and hybrid fixation techniques have been compared throughout the literature."

Comment 21: Line 190-192: "While each method of graft fixation possesses its own advantages and disadvantages, there is no clear superior fixation technique from a biomechanical perspective when performed technically correct." It remains unclear what this 'biomechanical' perspective is, please clarify.
Reply 21: 'Biomechanical' perspective relates to the mechanical properties of the reconstructed ACL based on different fixation types. This includes cyclic loading, load to failure, graft stiffness, and knee kinematics.
Changes in the text: None.

Comment 22: Line 192-194: "However, studies suggest that achieving graft tension levels close to 90 N and graft fixation at a 30-degree knee-flexion angle are likely more clinically important to achieving superior clinical outcomes.2" More clinically important compared to what? Selecting a certain fixation technique?
Reply 22: This sentence has been revised for clarity.
Changes in the text: Line 245-247: "However, one study suggests that graft tension levels close to 90 N and graft fixation at a 30-degree knee-flexion angle are recommended to achieving overall satisfactory clinical outcomes."

Comment 23: Line 196-199: "Overall, biomechanical implications on clinical decision making for ACLR soft tissue graft fixation has remained a challenge, and biomechanical studies have yet to account for the "windshield-wiper" effect leading to higher risk of tunnel widening observed for suspensory devices." Does that also apply to the bone-to-bone graft?
Reply 23: Prior research has demonstrated that tunnel osteolysis occurs no matter what graft type (bone vs soft tissue) or fixation method is used and is a reported natural phenomenon. However, the windshield-wiper effect applies to soft-tissue grafts and suspensory fixation devices where the graft is not fixed directly in the closed socket tunnel. This has been added to clarify below:
Changes in the text: Lines 249-257: "Overall, biomechanical implications on clinical decision making for ACLR soft tissue graft fixation has remained a challenge, and biomechanical studies have yet to account for the "windshield-wiper" effect leading to

higher risk of tunnel widening observed for suspensory devices. Prior research has demonstrated that tunnel osteolysis or widening occurs no matter what graft type (i.e., bone or soft tissue) or fixation method is used and is a reported natural phenomenon. However, there is higher risk of tunnel osteolysis due to this windshield-wiper effect when using soft-tissue grafts and suspensory fixation devices where the graft is not fixed directly in the closed socket tunnel."

Comment 24: Line 203-206: "In contrast, a recent biomechanical study reported that tibial and femoral fixation with three unique adjustable-loop suspensory devices demonstrated higher ultimate failure loads and lower graft elongation when compared to a construct with femoral fixed-loop suspensory fixation and tibial IFS fixation. Contrary to these findings, other studies have found that the biomechanical properties are similar between groups with no definitive clinical impact" Failure load of what exactly? Biomechanical properties of what, the graft or the fixation?

Reply 24: Fixation Method

Changes in the text: Lines 263-265: "Contrary to these findings, other studies have found that the fixation method biomechanical properties are similar between groups with no definitive clinical impact.53,54"

Comment 25: "This lack of consensus suggests that the ideal fixation method should likely be individualized based on patient-specific biology and demands, patient expectations and desired outcomes, as well as surgeon experience with the goal of restoring anatomic ACL position and function." How can you tune the fixation device to the patient-specific biology and demands, patient expectations and desired outcomes? Can you provide perspective here?

Reply 25: Changed to factors.

Changes in the text: Lines 291-294: "The lack of consensus suggests that the ideal fixation method should likely be individualized based on patient-specific factors and demands, patient expectations and desired outcomes, as well as surgeon experience with the goal of restoring anatomic ACL position and function."

Comment 26: Line 221-223: "The advantages and disadvantages of each fixation method should be considered when determining the optimal ACLR fixation method based on an individualized approach." Sure, but it remains unclear how? Do surgeons choose this patient specific, or do they applied what they can apply best as all fixation techniques result in similar clinical outcomes?

Reply 26: Having a thorough understanding of the fixation methods allows surgeons to apply them to the patient on a case by case and patient-specific basis. The literature currently does not highlight one method as superior. High level comparative studies are needed to make the determination that one method should be used before the others routinely across all patients. In the absence of a gold standard fixation method, it is up to the surgeon to select the technique.

Changes in the text: None

Comment 27: The words “graft” and “implant” are used interchangeably, which is slightly confusing, please consider adjusting this.

Reply 27: We have modified the text to consistently refer to “graft” when referring to the ligament used in the ACL reconstruction and have used the word “implant” when referring to an outside product or surgical device.

Changes in the text: Corresponding changes have been made.