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Comparison of Femoral and Tibial Tunnel Widening after Anterior Cruciate Ligament Reconstruction with Biostable and Bioabsorbable Interference Screws: A Radiographic Evaluation

Randy Presly Octavianus [a*], Muh.Sakti [b] and Supriyadi [b]

[a] Faculty of Medicine, Dian Nuswantoro University, Semarang, Indonesia.
[b] Faculty of Medicine, Hasanuddin University, Makassar, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objective and Background: Tunnel widening is a common occurrence following ACL reconstruction, with the exact cause still not fully understood. One factor that may contribute is the choice of graft fixation device. This study aims to compare tibial and femoral tunnel widening after arthroscopic ACL reconstruction, using biostable versus bioabsorbable interference screws, as seen on radiographs.

**Corresponding author: Email: randy.presly@dsn.dinus.ac.id, fk.rendy.presly@dsn.dinus.ac.id;*

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Methods: This randomized prospective study involved ACL reconstruction with a single-bundle hamstring graft and femoral fixation using an endobutton. Tibial fixation was performed using either a biostable screw (Group 1) or a bioabsorbable screw (Group 2). Tunnel widening was measured on AP and lateral radiographs at postoperative, six months, and one year intervals. Statistical analysis was performed using the Chi-square test and the Mann-Whitney test to compare tunnel widening between groups.
Results: There were no statistically significant differences in tunnel widening at the postoperative period, six months, or one year within each group. However, a significant difference was found between the biostable and bioabsorbable screw groups, particularly at the one-year follow-up. This difference was evident in both the femoral and tibial tunnels on AP and lateral radiographs, with all comparisons showing a p-value < 0.05.
Conclusion: The study found significant differences in tunnel widening between the two screw types, especially at the one-year follow-up. These results suggest that the choice of fixation device may influence tunnel widening over the long term, though no differences were observed in the short-term (postoperative and six months).

Keywords: Tunnel widening; ACL reconstruction; biostable fixation; bioabsorbable fixation; radiographic analysis.

1. INTRODUCTION

Perhaps the most pervasive is tunnel widening that follows ACL reconstruction. Until now, the main trigger for tunnel widening has been unclear; but scientists think that it might be due to factors such as a mix of biomechanical influences and innate biological mechanisms [1,2]. Micromotion of graft with tunnel is presumed to cause inflammation reaction or stress shielding, which cause the tunnel widening it self [3,4].

A good fixation mechanism is required. Thus, restoration of knee function stage should be done as soon as possible [5,6]. Interference screw are one of the widely used type of fixation implant in acl reconstruction presently specifically biostable and bioabsorbable. Biomechanics test, especially selection of graft fixation material is important for good results and improve or avoid complication after ACL reconstruction [7,8].

2. METHODOLOGY

2.1 Sample

The research is conducted at Orthopaedic and Traumatology Faculty Medicine of Hasanuddin University – Teaching Hospital of Hasanuddin University Makassar, Awal Bros Hospital Makassar, Siloam Hospital Makassar. This research was conducted from January 2017 to January 2019. Samples were retrieved from patients with ruptured ACL who underwent reconstruction procedure with Bioabsorbable interference screw dan biostable interference for the period January 2017 to January 2019, and had met inclusion and exclusion criteria [9,10].

2.2 Methods

1. Patient who met the research criteria underwent Xray data collection procedure as the primary data.
2. Assessment was done in three stages which are post-operation, 6 months post-operation, and last at 1 year post-operation.
3. Assessment was done directly based on Xray measurement by the Fauno and Kaalund study.
4. Data gathered at post-operation and during continuous follow-up throughout the year were analyzed. Usage of bioabsorbable interference screw and biostable interference screw were compared using statistical analysis.
5. Upon analysis, interpretation of the data result is done, elaborated in discussion, and concluded.

2.3 Data Analysis

Data analysis was done by using SPSS for Windows version 22 computer program. The statistical analysis that was done are [11]:

1. Mann-Whitney test, to measure the tunnel size on tibia and femur after ACL reconstruction was done on every tibia fixation group, both with Bioabsorbable and Biostable Interference screw. The comparison result is significant if the value of p is less than 0,05 ($p<0,05$).
2. T-Test Identity, to compare the measurement result of tibia and femur on both groups. The extent of the relation is assessed based on the coefficient correlation value ($R > 0,500$: strong correlation).

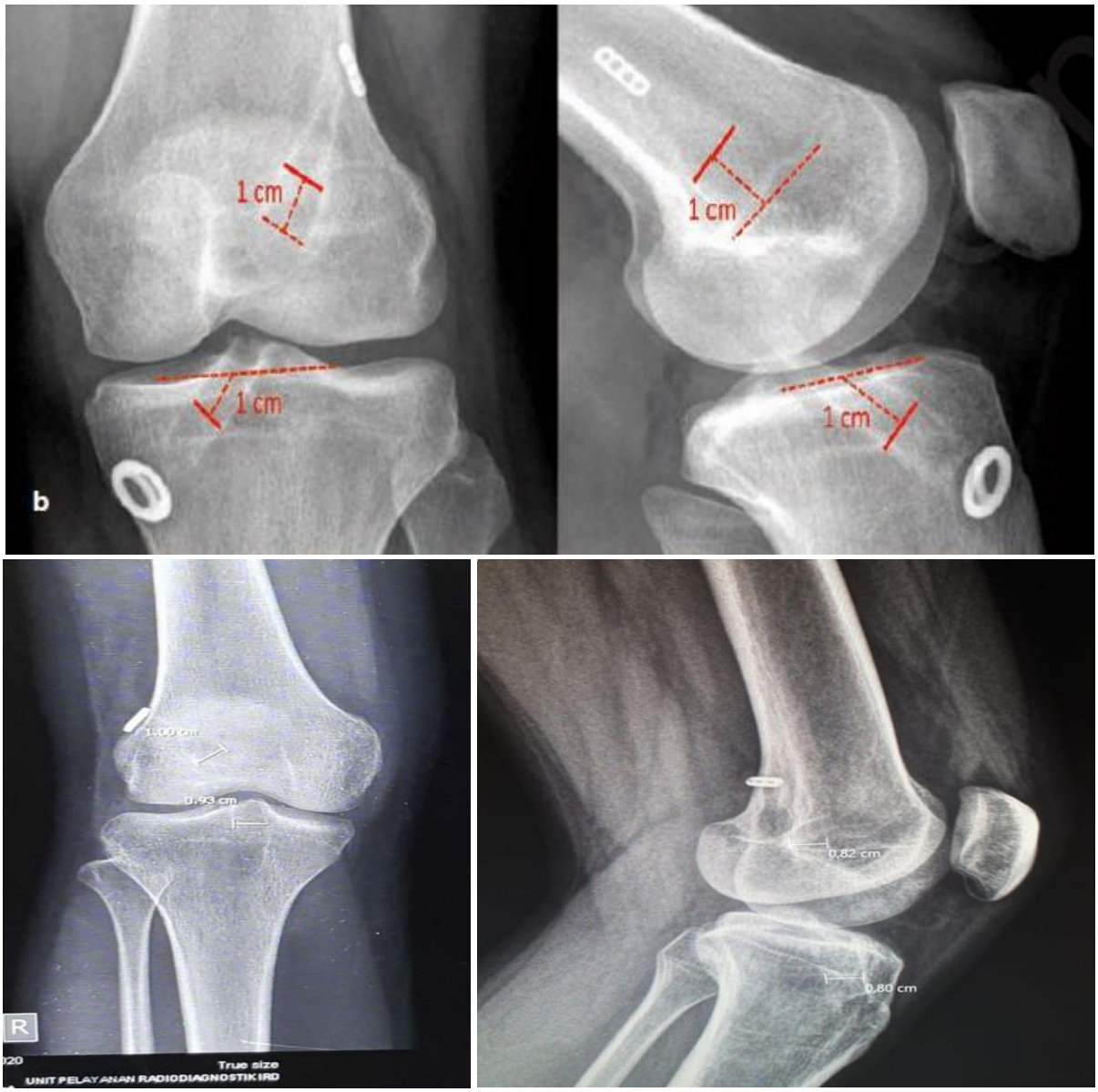

Fig. 1. Illustration of Fauno Kaalund study measurement

3. RESULTS AND DISCUSSION

3.1 Results

The research was done at 23 patients, 9 patients using Biostable Screw and 14 patients using Bioabsorbable Screw. Subjects' ages ranged between 19-32 years with the mean 25,0±3,6 years.

Tibia Comparison in F & K Study (Table 1): provides a comparison of tibia tunnel widening using biostable screws and bioabsorbable screws at three time points: post-operative, 6 months, and 1 year. The variables compared are tibia AP (anteroposterior) and lateral tibia. The p-values indicate the statistical significance of the differences between the two groups. Below is a detailed discussion of the findings.

a) Post Operative: Tibia AP: Biostable Screw: Mean = 0.88 (SD = 0.05), Bioabsorbable Screw: Mean = 0.79 (SD = 0.06), p = 0.002: This difference is highly significant ($p < 0.05$), indicating that the use of biostable screws leads to greater tibia tunnel widening in the anteroposterior direction immediately after surgery compared to bioabsorbable screws.

Table 1. F & K study tibia comparison

Variable	Group	n	Mean	SD	p
Post Op Tibia AP	Biostable Screw	9	0,88	0,05	0,002
	Bioabsorbable Screw	14	0,79	0,06	
Post Op Tibia Lat	Biostable Screw	9	0,80	0,04	0,001
	Bioabsorbable Screw	14	0,71	0,05	
6 months Tibia AP	Biostable Screw	9	0,95	0,07	0,949
	Bioabsorbable Screw	14	0,95	0,05	
6 months Tibia Lat	Biostable Screw	9	0,85	0,06	0,501
	Bioabsorbable Screw	14	0,83	0,04	
1 year Tibia AP	Biostable Screw	9	1,03	0,08	0,044
	Bioabsorbable Screw	14	1,12	0,09	
1 year Tibia Lat	Biostable Screw	9	0,92	0,08	0,051
	Bioabsorbable Screw	14	1,00	0,09	

Tibia Lat: Biostable Screw: Mean = 0.80 (SD = 0.04), Bioabsorbable Screw: Mean = 0.71 (SD = 0.05), p = 0.001: The difference is also highly significant ($p < 0.05$), showing that biostable screws result in greater lateral tibia tunnel widening compared to bioabsorbable screws in the immediate post-operative period.

b) 6 Months Post Operative. Tibia AP: Biostable Screw: Mean = 0.95 (SD = 0.07), Bioabsorbable Screw: Mean = 0.95 (SD = 0.05), p = 0.949: There is no significant difference between the two groups at this time point, with $p > 0.05$, suggesting that after 6 months, tibia tunnel widening is similar in both groups.

Tibia Lat: Biostable Screw: Mean = 0.85 (SD = 0.06), Bioabsorbable Screw: Mean = 0.83 (SD = 0.04), p = 0.501: Again, no significant difference between the groups at 6 months post-operation ($p > 0.05$).

c) 1 Year Post Operative. Tibia AP: Biostable Screw: Mean = 1.03 (SD = 0.08), Bioabsorbable Screw: Mean = 1.12 (SD = 0.09). p = 0.044: At 1 year post-operation, the difference becomes statistically significant ($p < 0.05$), indicating that bioabsorbable screws tend to cause greater tibia tunnel widening in the anteroposterior direction compared to biostable screws after 1 year.

Tibia Lat: Biostable Screw: Mean = 0.92 (SD = 0.08, Bioabsorbable Screw: Mean = 1.00 (SD = 0.09), p = 0.051: The difference is close to being significant ($p \approx 0.05$), suggesting a trend toward bioabsorbable screws causing slightly more lateral tibia tunnel widening after one year, although this difference is not statistically significant.

Interpretation and Discussion of Results:

a) Post Operative Period: There are significant differences between biostable and bioabsorbable screws in both AP and lateral tibia tunnel widening immediately after surgery. The biostable screw tends to result in more tunnel widening, which could indicate that biostable screws may have more durable mechanical properties or provide better fixation, thus allowing for greater tunnel expansion initially compared to bioabsorbable screws.
b) 6 Months Post Operative: There is no significant difference between the groups at the 6-month mark, both in AP and lateral measurements. This suggests that despite initial differences, the effects of screw type may start to converge over time, possibly due to the biological healing process and tissue adaptation.
c) 1 Year Post Operative: At 1 year, a significant difference appears in AP tibia tunnel widening, with bioabsorbable screws showing slightly greater tunnel widening. This could be due to the absorption process of the screw, which might alter the mechanical support over time, potentially leading to more tunnel expansion. For lateral tibia, the difference is nearly significant ($p \approx 0.05$), indicating a potential trend where bioabsorbable screws could cause slightly more lateral expansion over the long term, although this is not statistically conclusive.

This study suggests that biostable screws lead to greater tibia tunnel widening immediately after surgery, both in AP and lateral directions. However, by 6 months, the differences become less pronounced, indicating that the type of

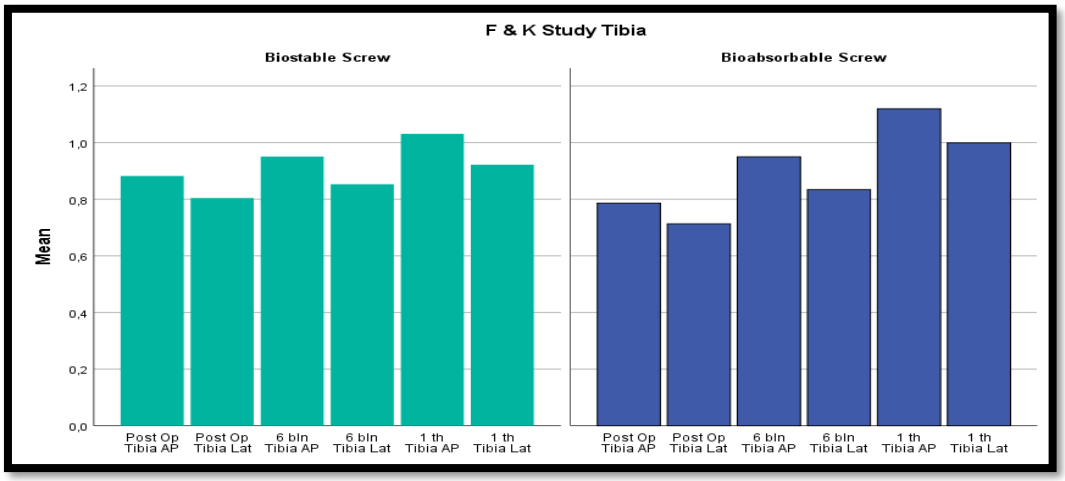

Fig. 2. F & K study tibia comparison

Notes: In the comparison of both group, there is no significant difference on the size of tibial tunnel on Tibia AP and Lateral on 6 months and on Tibia Lateral 1 year post-op (all the result denote the value of p>0,05)

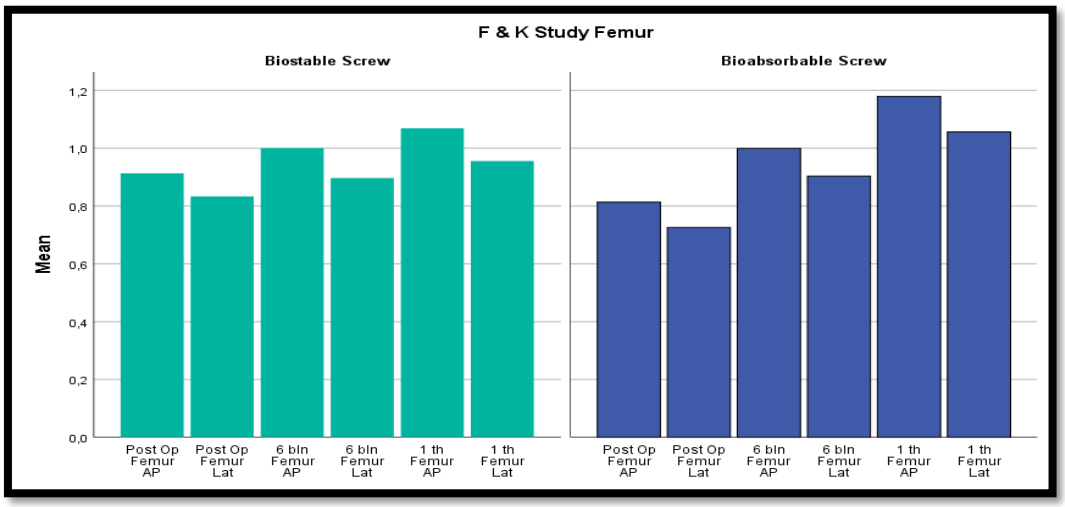

Fig. 3. F & K study femur comparison

Notes: *In the comparison of both group, there is significant difference on the size of Femur AP and Lateral on 1 year post-op. (all result denote the value of p<0,05)*

screw might have a more transient effect in the early post-operative period. At 1 year, although bioabsorbable screws show slightly greater tunnel widening, the differences are not large enough to draw definitive conclusions. These results indicate that the long-term effects of screw type on tibia tunnel widening may require further investigation with a larger sample size and longer follow-up periods to confirm these trends.

Comparison of Femur in F & K Study (Table 2): a comparison of femoral tunnel widening using biostable screws and bioabsorbable screws at three time points: post-operative, 6 months, and 1 year. The variables compared are femoral AP (anteroposterior) and lateral femur. The p-value indicates the statistical significance of the differences between the two groups. Below is an analysis of the results.

1. Post-Operative Period. Femoral AP: Biostable Screw: Mean = 0.91 (SD = 0.05), Bioabsorbable Screw: Mean = 0.81 (SD = 0.08), p = 0.007: This difference is statistically significant (p < 0.05), indicating that biostable screws cause greater femoral tunnel widening in the anteroposterior direction immediately after surgery compared to bioabsorbable screws. Femoral Lat: Biostable Screw:

Mean = 0.83 (SD = 0.05), Bioabsorbable Screw: Mean = 0.73 (SD = 0.08), p = 0.003: This difference is also statistically significant ($p < 0.05$), showing that biostable screws result in greater femoral tunnel widening in the lateral direction after surgery compared to bioabsorbable screws.

2. 6 Months Post-Operative. Femoral AP: Biostable Screw: Mean = 1.00 (SD = 0.08), Bioabsorbable Screw: Mean = 1.00 (SD = 0.07), p = 0.924: There is no significant difference between the two groups at this time point ($p > 0.05$), indicating that at 6 months post-surgery, the femoral tunnel widening in the anteroposterior direction is nearly the same between the two groups.

Femoral Lat: Biostable Screw: Mean = 0.90 (SD = 0.07), Bioabsorbable Screw: Mean = 0.90 (SD = 0.06), p = 0.800: There is no significant difference between the two groups at this time point ($p > 0.05$), indicating that at 6 months post-surgery, the lateral femoral tunnel widening is nearly identical between the two groups.

c) 1 Year Post-Operative 1) Femoral AP: Biostable Screw: Mean = 1.07 (SD = 0.09), Bioabsorbable Screw: Mean = 1.18 (SD = 0.07), p = 0.008: This difference is statistically significant ($p < 0.05$), with bioabsorbable screws causing greater femoral tunnel widening in the anteroposterior direction after 1 year post-surgery. 2) Femoral Lat: Biostable Screw: Mean = 0.96 (SD = 0.10), Bioabsorbable Screw: Mean = 1.06 (SD = 0.07), p = 0.014: This difference is also statistically significant ($p < 0.05$), with bioabsorbable screws causing slightly more femoral tunnel widening in the lateral direction after 1 year compared to biostable screws.

3.2 Discussions

(1) Post-Operative Period. Femoral Tunnel AP: A significant difference in AP femoral tunnel widening is observed immediately after surgery, where biostable screws cause more widening. This suggests that biostable screws may provide stronger or more durable mechanical support, contributing to greater femoral tunnel widening initially. Femoral Tunnel Lat: Similarly, biostable screws lead to greater lateral femoral tunnel widening during the post-operative period. This could be due to the higher initial strength of the biostable screws in stabilizing the graft, resulting in more lateral femoral tunnel widening. **2)** 6 Months Post-Operative:No significant difference is observed between the two groups in both AP and lateral directions at 6 months post-surgery. This indicates that while differences were observed immediately after surgery, by 6 months, the femoral tunnel widening is similar between both groups, possibly reflecting biological healing or adaptation that occurs over time. 3) 1 Year Post-Operative: Femoral Tunnel AP: At 1 year, bioabsorbable screws lead to more femoral tunnel widening in the AP direction. This may be due to the absorption process of the bioabsorbable screws, which likely results in a decrease in mechanical support over time, causing more femoral tunnel widening after a longer period. Femoral Tunnel Lat: Similarly, in the lateral direction, bioabsorbable screws tend to cause more femoral tunnel widening after 1 year. This may reflect the higher rate of absorption of bioabsorbable screws, which affects femoral tunnel changes in the lateral direction as well.

Table 2. F & K study femur comparison

Variable	Group	n	Mean	SD	p
Post Op Femur AP	Biostable Screw	9	0,91	0,05	0,007
	Bioabsorbable Screw	14	0,81	0,08	
Post Op Femur Lat	Biostable Screw	9	0,83	0,05	0,003
	Bioabsorbable Screw	14	0,73	0,08	
6 months Femur AP	Biostable Screw	9	1,00	0,08	0,924
	Bioabsorbable Screw	14	1,00	0,07	
6 months Femur Lat	Biostable Screw	9	0,90	0,07	0,800
	Bioabsorbable Screw	14	0,90	0,06	
1 year Femur AP	Biostable Screw	9	1,07	0,09	0,008
	Bioabsorbable Screw	14	1,18	0,07	
1 year Femur Lat	Biostable Screw	9	0,96	0,10	0,014
	Bioabsorbable Screw	14	1,06	0,07	

This study demonstrates that biostable screws cause more femoral tunnel widening immediately after surgery, both in the AP and lateral directions, compared to bioabsorbable screws. However, after 6 months, no significant differences are found between the groups, suggesting that both types of screws result in similar outcomes as the healing progresses. After 1 year, bioabsorbable screws cause more femoral tunnel widening, likely due to the absorption process, which reduces mechanical support over time. These findings highlight the differences in the long-term behavior of biostable versus bioabsorbable screws, and further studies with larger sample sizes and longer follow-ups are needed to confirm these results.

The tunnel widening at post-operation, 6 months and 1 year post-operation in each group was not statisticeal significant [10]. In contrast, the difference on femur tunnel and tibia between group were statistically significant [12]. In comparison of femur AP and lateral size at 1 year post-op between groups (Mann Whitney U-test) there was a significant difference in both p<0,05 respectively for the two variables, tibia AP and lateral size at the postoperative period of time likewise found maximum significant difference applying Mann Whitney Utest in group(p<0.05) [13,14]. Tunnel widening at the postoperative period, 6 months, and 1 year postoperative in each group (the group using biostable screws and the group using bioabsorbable screws) did not show any statistically significant differences [12]. This means that during the first 6 months postoperatively, the type of tibial fixation did not significantly affect the development of tunnel widening. However, a significant difference in femoral and tibial tunnel widening between the two groups was observed at 1 year postoperatively. These results suggest that although there were no significant differences in the short term (6 months), the type of fixation used for the tibia influences the development of femoral and tibial tunnels over a longer period (1 year) [15]. This finding suggests that although there were no significant differences in tunnel widening during the early postoperative period (6 months), the type of screw used can affect femoral and tibial tunnel widening one year after surgery. Edoardo Monaco et al. (2019) reported that tibial tunnel widening after ACLR using hamstring tendon autograft was significantly greater with suspensory femoral fixation and bioabsorbable tibial interference screws compared to the all-inside technique, with a median 2-year follow-up. The clinical relevance of this study is to counter concerns raised by biomechanical studies regarding the potential increase in tunnel widening This study also emphasizes the importance of conducting further monitoring of patients who undergo ACL reconstruction to ensure that tunnel development can be tracked and preventive actions can be taken if necessary. Although there were no significant differences in the first 6 months postoperatively, the significant difference in tunnel widening of the femur and tibia between the two groups over time (1 year postoperatively) highlights the importance of fixation factors in the long-term outcomes of ACL reconstruction [13]. Tibial tunnels in ACLR with screw fixation are associated with a larger increase in tunnel volume during the first 2 years and a greater decrease up to 5 years postoperatively, while femoral tunnel volume does not show significant differences. On the tibial side, the need for staged ACLR revision may be higher after biodegradable interference screw fixation in the case of recurrent rupture, especially within the first 2 years following primary ACLR. Concerns may still exist regarding the higher graft failure rates with the all-inside ACLR technique [12].

No significant differences were found in the incidence of cross-pin issues between the two groups (p=0.35-0.83) or in stability assessments using the KT-2000 arthrometer and pivot shift test before surgery (p=0.79 and 0.77, respectively) or after surgery (p=0.89 and 0.75, respectively). Additionally, there were no significant differences between the two groups in Lysholm knee scores, Tegner activity scores, or International Knee Documentation Committee (IKDC) scores before surgery (p=0.07-0.47) or after surgery (p=0.15-0.89). This study suggests that double fixation with different fixation mechanisms does not offer advantages over single fixation mechanisms. The results obtained using the double femoral fixation mechanism were not superior to those achieved with single femoral fixation [14,16]. Chuan Jiang et al (2024) Compared to the PLGA/β-TCP screws commonly used in clinics today, the mPLA/HA screws demonstrate comparable biosafety and mechanical properties, with satisfactory biomechanical characteristics. Additionally, mPLA/HA screws exhibit excellent osteoinductive activity, both in vivo and in vitro, indicating their potential in stimulating bone growth around the fixation area. The use of mPLA/HA screws in anterior cruciate ligament reconstruction (ACLR) in a canine model has been shown to effectively

address tibial tunnel widening (TW) postoperatively, which is a crucial factor in the success of ACLR procedures. These findings suggest that mPLA/HA screws not only possess good mechanical strength but also contribute to improved screw-bone integration, ultimately enhancing the long-term stability of the ACL graft and preventing complications related to tunnel widening [15]. The primary advantage of mPLA/HA screws over PLGA/β-TCP screws is their ability to improve integration between the screw and bone, which plays a critical role in ensuring fixation stability and improving patient clinical outcomes. This provides hope for advancements in fixation techniques for ACL reconstruction in the future, with the potential for using more environmentally friendly materials that are effective in promoting bone healing. Hatipoğlu et al. (2021) demonstrated a significant decrease in the average femoral tunnel width in both groups (BPTB and HT) after two years, with a p-value < 0.001 on radiographic evaluation. However, significant differences in tibial tunnel width were only found in the BPTB group ($p < 0.001$), while no significant difference was observed in the HT group ($p = 0.616$). Anteroposterior and lateral tunnel width changes were more prominent in the BPTB group compared to the HT group ($p < 0.001$). The better tunnel widening observed in the BPTB graft suggests superior ossification, which may be attributed to more effective bone-to-bone healing. Based on these results, we suggest that the BPTB graft may offer better strength and durability in the long term, making it a superior choice in ACL reconstruction [17]. This result was consistent with Janssen et al, hamstring graft healing after 6 until 12 months post-operation is at the ligamentation phase [17]. Stage with the vascularisation degree of graft descent to normal value, similarly to uninjured ACL and distributed in all graft [10]. Collagen fiber can also be seen microscopically at this stage as well as on intact ACL, but further research to compare pore producing process on different fixation graft property is still needed [18].

The study results reveal that between 6 to 12 months post-operation, the healing process of the hamstring graft enters the ligamentization phase. During this phase, the vascularization of the graft begins to decrease and reaches levels close to normal, similar to an uninjured ACL. This indicates that the graft is undergoing a healing process approaching that of healthy tissue, with blood vessels starting to develop throughout the graft, supporting optimal tissue recovery. At this stage, collagen fibers can be microscopically detected, which is an important indicator of the healing process, similar to what is found in an intact ACL. The formation of these collagen fibers signifies that the graft is becoming stronger and has the potential to support long-term knee stability. However, while this healing process shows positive development, further research is necessary to compare the pore formation process across different graft fixation types. It is crucial to understand how the fixation method used (bioabsorbable or biostable screws) affects the graft healing quality and speed, and how this relates to fixation stability and the long-term success of ACL reconstruction. The comparison of femoral and tibial tunnel widening in anterior cruciate ligament (ACL) reconstruction using bioabsorbable and biostable interference screws, measured through X-ray radiography, was also analyzed. Tunnel widening is one of the factors that can affect the long-term outcomes of ACL reconstruction as it impacts the stability of the graft and bone fixation. With bioabsorbable screws, which are designed to degrade over time, there is often greater tunnel widening compared to biostable screws, which remain in the body without degradation. This is due to the degradation process of bioabsorbable screws, which can affect their structural integrity over time, leading to slight changes in tunnel size around the fixation. The larger tunnel widening observed in the bioabsorbable screw group indicates the impact of material degradation on tunnel stability. In contrast, biostable screws tend to show less tunnel widening since the material maintains its integrity in the long term. This can influence the strength and stability of the graft fixation, potentially affecting the functional success of ACL reconstruction. However, despite the differences in tunnel widening between the two screw types, it is important to consider that an increase in tunnel size does not necessarily correlate directly with fixation failure or diminished clinical outcomes. Moderate tunnel widening may still be acceptable if graft fixation remains stable and the healing tissue is sufficiently strong to support its function. In conclusion, this comparison highlights the importance of selecting the appropriate screw type in ACL reconstruction, considering its impact on long-term stability and graft fixation success. Further research is needed to determine the safe threshold for tunnel widening that does not compromise clinical outcomes and to evaluate the long-term effects of material degradation on tibial and femoral tunnel fixation [19].

The tunnel widening at post-operation, 6 months and 1 year post-operation in each group was not statisticeal significant [20]. In contrast, the difference on femur tunnel and tibia between group were statistically significant [12]. In comparison of femur AP and lateral size at 1 year post-op between groups (Mann Whitney U-test) there was a significant difference in both p<0,05 respectively for the two variables, tibia AP and lateral size at the postoperative period of time likewise found maximum significant difference applying Mann Whitney Utest in group(p<0.05) [21,22].

This result was consistent with Janssen et al, hamstring graft healing after 6 until 12 months post-operation is at the ligamentation phase [17]. Stage with the vascularisation degree of graft descent to normal value, similarly to uninjured ACL and distributed in all graft [23]. Collagen fiber can also be seen microscopically at this stage as well as on intact ACL, but further research to compare pore producing process on different fixation graft property is still needed [24].

4. CONCLUSION

Tunnel widening difference by Fauno and Kaalund study score on Biostable group with Bioabsorbable is not a statistically signific ant at post-operative or 6 month s post-operative difference [9]. The only significant difference whether in biostable or bioabsorbable screw is the progressive expanding tunnel by the measurement of Fauno and Kaalund study 1 year post-operation [15].

CONSENT

As per international standards or university standards, patient(s) written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

It is not applicable.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors hereby state that NO generative AI tools such as large language models (ChatGPT, COPILOT, etc.) or text-to-image generators were utilized in the creation or editing of this work.

DATA AVAILABILITY

All relevant data are included in the paper and its supporting information files. This study aims to inform researchers identify Comparison Evaluation Radiograph of Femoral & Tibial Tunnel Following ACL Graft Reconstructions Using Biostable & Bioabsorbable Interference Screw.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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