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Comparison of the effects of endobutton continuous loop and adjustable zip loop devices on bone tunnel enlargement and clinical results in arthroscopic anterior cruciate ligament reconstruction

A retrospective observational study

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Abstract

It was aimed to reveal the effects of 2 different techniques [Endobutton Continuous Loop (CL), ZipLoop technique] used for graft fixation in anterior cruciate ligament (ACL) reconstruction on bone tunnel enlargement and clinical results. Patients who underwent arthroscopic ACL reconstruction using hamstring tendon graft due to ACL rupture between January 2016 and December 2020 were retrospectively analyzed. The study included 80 patients who were operated on by the same surgical team in the same clinic. Forty patients who underwent repair using the suspension system ZipLoop technique were classified as Group 1, and 40 patients who underwent repair using the Endobutton CL technique were classified as Group 2. Plain radiography and MRI were used to evaluate bone tunnel widening. Visual analog scale (VAS), International Knee Documentation Committee (IKDC) knee assessment score, and Lysholm scores were evaluated at the last follow-up to evaluate clinical outcomes. When bone tunnel enlargement was evaluated between the groups, femoral and tibial tunnel enlargement was found to be greater and statistically significant in Group 2 patients in direct radiography measurements. No statistically significant difference was found in tunnel enlargement in MRI measurements ($P > .05$). However, in MRI measurements, the graft apex–tunnel apex distance was found to be greater and statistically significant in Group 2 patients ($P < .05$). When the clinical results of both groups were compared, no statistically significant difference was found in VAS, IKDC and Lsyholm scores ($P > .05$). The graft fixation method affects bone tunnel enlargement. However, it was observed that this had no effect on clinical results.

Abbreviations: ACL = anterior cruciate ligament, AP = anterior–posterior, CL = continuous loop, CT = computed tomography, IKDC = International Knee Documentation Committee, MRI = magnetic resonance imaging, VAS = visual analog scale.

Keywords: anterior cruciate ligament, tunnel enlargement

1. Introduction

Anterior cruciate ligament (ACL) injuries are a significant sports injury that is frequently seen in young and physically active individuals.[1,2] Successful ACL reconstruction depends on many factors, but complications such as complete or partial graft rupture, loosening, and widening of the bone tunnel may occur after ACL reconstruction.[1–3] Bone tunnel widening is 1 of these important complications. However, although the cause is not yet

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

The research protocol was approved by the Kahramanmaraş Sütçü İmam University Clinical Research Ethics Committee. Written informed consent was obtained from all participants before inclusion in the study (Date: June 10, 2020, Session No: 2020/11 Decision No: 06)

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clear, it is believed to be multifactorial, involving both mechanical and biological factors.[4–6] Potential factors contributing to bone tunnel widening include graft type, movement of the graft within the tunnel, type of fixation and fixation devices, improper tunnel placement, aggressive rehabilitation, and synovial fluid leakage within the bone tunnel.[7–9] The method of graft fixation is 1 of these factors and is also important when using purely soft tissue grafts such as the hamstring tendon.[7–9] Although many techniques for graft fixation have been described, there is no consensus on the optimum fixation method.[7–9] In recent years, there has been an increasing trend in the use of cortical suspensory fixation techniques that include a fixed and adjustable ring.[1,7,10–15] While bone tunnel widening has been observed more frequently in studies using hamstring tendon grafts, there is ongoing debate as to whether it is associated with poor clinical outcomes.

This study aimed to investigate the effectiveness of different fixation methods in the femoral and tibial tunnels using a 4-strand hamstring tendon graft in ACL reconstruction on bone tunnel enlargement and clinical outcomes. The hypothesis is that the graft fixation method plays an important role in bone tunnel enlargement, but this does not directly affect the clinical results.

2. Materials and methods

The medical records of patients who underwent arthroscopic ACL reconstruction with a double-bundle (4-strand) hamstring tendon graft for ACL rupture between January 2016 and December 2020 were retrospectively examined following approval from the local ethics committee (Date: June 10, 2020, Session No: 2020/11 Decision No: 06).

The study included patients with complete medical records, complete data, at least 1 year of follow-up, and postoperative rehabilitation at the same center. All patients were operated on at the same center and by the same surgeon. Patients with missing postoperative data and rehabilitation at different hospitals were excluded from the study.

The patients were categorized into 2 groups based on different graft fixation methods employed in the femoral and tibial tunnels. Forty patients undergoing repair using the ZipLoop technique with suspension system were classified as Group 1, and 40 patients undergoing repair using the Endobutton continuous loop (CL) technique were classified as Group 2. The tibial tunnel was fixed with bioscrew + dowel and U staple in Group 1, and it was fixed with bioscrew and U staple in Group 2.

Direct radiography and MRI at the last follow-up were used to evaluate the bone tunnel enlargement of the patients. In addition, the relationship between bone tunnel enlargement and graft size was studied statistically to investigate whether graft size has an effect on bone tunnel enlargement.

Demographic characteristics, etiology, operation time, and length of hospital stay were evaluated. Statistical analysis was performed to compare the postoperative time required to return to sports, daily sports activity levels, jumping percentage, and thigh diameter between the 2 groups. During the final follow-up visit, visual analog scale (VAS) scores, International Knee Documentation Committee (IKDC) knee evaluation scores, and Lysholm scores were determined. 80 patients with complete medical records, complete data, postoperative rehabilitation in the same center, and sufficient follow-up period were included in the study.

2.1. Radiological assessment

In direct radiography, the anterior–posterior (AP) radiograph of the knee was used to measure the diameters of both the tibial and femoral tunnels, whereas the lateral radiograph was used for measuring only tibial tunnel diameters. Tibial tunnel diameter was measured at 3 different levels, namely, distal, middle, and proximal, and the average of these measurements was calculated. The femoral tunnel measurement was conducted at 2 different points by determining both the start and end points of the tunnel, and the average of these measurements was calculated (Fig. 1A and B). The degree of bone tunnel enlargement was determined by subtracting the intraoperative tunnel diameters from the measurements obtained via direct radiography. Percentages of tibial and femoral bone tunnel enlargement were calculated

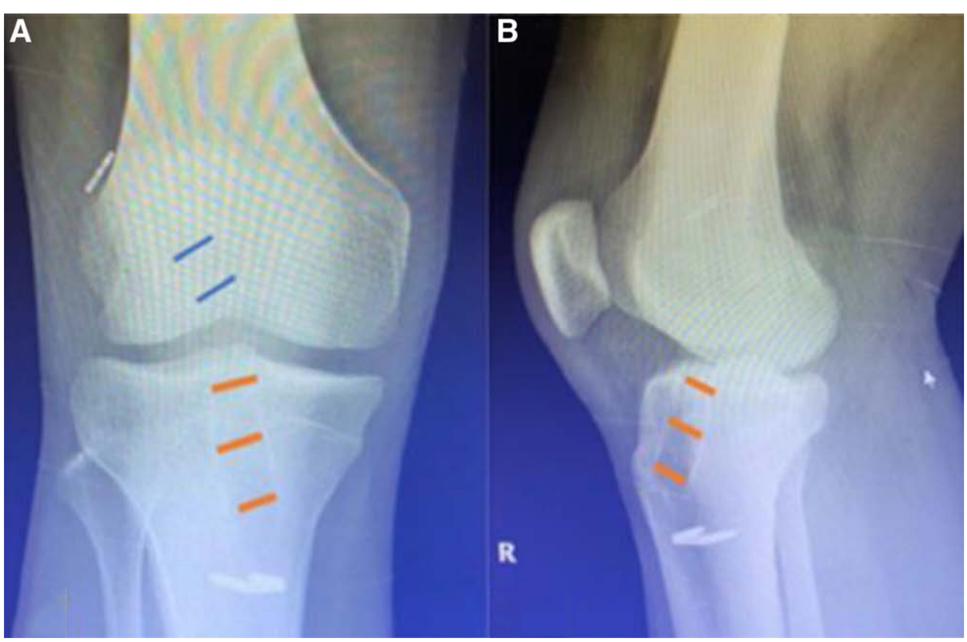

Figure 1. Radiological measurements. (A) Measurement of tibial and femoral tunnel enlargement in AP radiography. Measurement locations are marked in red in the tibal tunnel and blue in the femoral tunnel. (B) Measurement of tibial tunnel enlargement in lateral radiography. Measurement locations are marked in red in the tibal tunnel. AP = anterior–posterior.

For MRI, 10 patients were selected from each group using the systematic sampling method. In these patients, measurements of femoral and tibial tunnel diameters, as well as the graft apex–tunnel apex distance, were performed in both coronal and sagittal sections (Fig. 2). The tibial tunnel was measured 1 cm distal to the ACL insertion site, whereas the femoral tunnel was measured at its widest point.

2.2. Statistical analysis

After transferring the data into the computer environment, statistical analysis was conducted using the SPSS (IBM Corp. Released 2013. IBM SPSS Statistic for Windows, Version 22.0, Armonk) program. Categorical data were expressed as percentage, and continuous variables were expressed as mean values with standard deviations. For intergroup comparisons involving categorical data, Pearson chi-square, Spearman chi-square, and Fisher exact test were employed. The conformity of the data to normal distribution was evaluated using the Shapiro–Wilk test, analysis of Skewness and Kurtosis, and examination of histogram values. For continuous variables without normal distribution, the relationship between groups was evaluated using the Mann–Whitney *U* test. Continuous variables that demonstrated a normal distribution were assessed using the *t*-test. The dependent nonparametric Wilcoxon test was used to analyze repeated measurements within groups. In these analyses, a *P*-value of <.05 was considered statistically significant.

Figure 2. Measurement of graft apex–tunnel apex distance in MRI. The graft apex is shown with the yellow line. The tunnel apex distance measurement from the graft apex to the red arrow is shown. MRI = magnetic resonance imaging.

3. Results

All patients included in the study were men. There was no significant difference between the 2 groups in terms of age, operated side, etiology, operation time, or follow-up period ($P > .05$) (Table 1). The length of hospital stay was significantly shorter in Group 1 than in Group 2 ($P = .001$).

At the end of a mean follow-up period of 36.9 ± 18.1 months, all patients exhibited statistically significant improvements in daily sports hours, jump percentage, and thigh diameter difference compared with their preoperative condition ($P < .05$) (Table 2).

In Group 1, the mean VAS score was 2.33 ± 1.7, the mean IKDC knee score was 81.45 ± 14.13, and the mean Lsyholm score was 90.18 ± 8.44, whereas in Group 2, the mean VAS score was 2.4 ± 1.28, the mean IKDC knee score was 77.82 ± 12.68, and the mean Lsyholm score was 91.20 ± 6.35 (Table 3). There was no statistically significant difference in VAS, IKDC, or Lsyholm score between the 2 groups ($P > .05$). Postoperative VAS score improved significantly in all patients ($P < .05$). The mean time to return to sports was 7.7 ± 1.59 months in Group 1 and 7.09 ± 1.65 months in Group 2. No statistically significant difference was found between the 2 groups ($P > .05$).

The mean intraoperative tunnel diameter was 7.77 ± 0.73 in Group 1 and 7.90 ± 0.79 in Group 2. There was no statistically significant difference between the 2 groups.

In our study, the mean femoral tunnel enlargement was determined to be 2.19 ± 0.87 mm in Group 1 on the AP radiographs. In Group 2, the mean femoral tunnel enlargement was determined to be 2.65 ± 0.78 mm on the AP radiographs of the knee. When comparing with the intraoperative tunnel diameter, the percentage of femoral tunnel enlargement was 28.1% in Group 1 and 33.4% in Group 2. The mean tibial tunnel enlargement was 2.86 ± 0.79 mm on the AP radiographs and 2.76 ± 0.78 mm on lateral radiographs of the knee in Group 1, whereas in Group 2, it was 3.6 ± 0.81 mm on the AP radiographs and 3.37 ± 0.74 mm on the lateral radiographs of the knee.

When the bone tunnel enlargement was compared between the 2 groups, both femoral and tibial tunnel enlargements were significantly higher in Group 2 than in Group 1 ($P < .05$) (Table 4).

Additionally, to investigate whether graft size had an effect on bone tunnel enlargement, bone tunnel enlargement was calculated according to graft size. Bone tunnel enlargement increased numerically with increasing graft size in both groups. However, bone tunnel enlargement was calculated as a similar percentage and no statistically significant difference was detected ($P > .05$) (Table 5).

While MRI measurements indicated greater femoral and tibial tunnel enlargements in Group 2, there was no statistically significant difference between the 2 groups in terms of tibial tunnel enlargement ($P > .05$). However, femoral tunnel enlargement was significantly higher in Group 2 ($P < .05$). In addition, the graft apex to tunnel apex distance was significantly shorter in Group 1 ($P = .008$) (Table 4).

4. Discussion

The most important finding of our study was that the graft fixation method affected bone tunnel enlargement, which is a significant complication. However, it was observed that bone tunnel enlargement had no effect on clinical outcomes.

The enlargement of femoral and tibial tunnels after ACL reconstruction is a common condition.[5,6,11,16,17] Graft type, graft fixation method, inappropriate tunnel position, and inflammatory and excessive immunologic reactions play a role in tunnel enlargement.[4,11] In addition, many factors such as the size of the graft, the patient's bone quality and postoperative rehabilitation may affect bone tunnel enlargement. One of the most important

Table 1

Distribution of patients' general demographic data by groups.

	Group 1 (n = 40)	Group 2 (n = 40)	P
Age (yr)	34.68 ± 1.13	32.38 ± 1.42	.21*
Gender			
Female	–	–	
Male	40	40	
Side, n (%)			
Right	18 (45)	20 (50)	.654†
Left	22 (55)	20 (50)	
Etiology, n (%)			
To fall	6 (15)	12 (30)	.82‡
Sport injury	24 (60)	25 (62.5)	
Trauma	3 (7.5)	–	
Other	7 (17.5)	3 (7.5)	
Diagnosis in MRI			
Acl injury	31	30	.263‡
Meniscus tear	7	4	
Acl injury + meniscus tear	2	6	
Diagnosis in arthroscopy			
Acl injury	37	36	1‡
Acl injury + meniscus tear	3	4	
Length of hospital stay (d) (Mean ± SD) (Median)	2.55 ± 1.11 (2.00)	3.63 ± 1.67 (3.00)	.001*
Operation time (min) (Mean ± SD) (Median)	136.50 ± 46.55 (120)	114.75 ± 33.2 (120)	.008*

SD = standard deviation.
* Statistical significance between groups according to Mann–Whitney *U* test.
† Statistical significance between groups according to Pearson chi square test.
‡ Fisher exact test.

Table 2

Comparison of patients' daily sports activity, jumping percentage, thigh diameter and VAS before and after surgery.

	Group 1	P	Group 2	P
Daily sport activity (min)				
Pre-op (Mean ± SD)	44.63 ± 40.69		57 ± 37.70	.001*
Post-op (Mean ± SD)	92.25 ± 61.66	.001	102.75 ± 55.15	
VAS				
Pre-op (Mean ± SD)	5.63 ± 2.33	.001	7.05 ± 1.47	.001
Post-op (Mean ± SD)	2.33 ± 1.7		2.40 ± 1.28	
Thigh diameter				
Pre-op (Mean ± SD)	49 ± 9.25	.001	48.83 ± 12.23	.001
Post-op (Mean ± SD)	51.20 ± 4.63		52.60 ± 4.46	
Jump percentage				
Pre-op (Mean ± SD)	94.68 ± 2.45	.001	95 ± 2.12	.001
Post-op (Mean ± SD)	96.9 ± 1.78		97.2 ± 1.77	

SD = standard deviation, VAS = visual analog scale.
* Statistical significance between groups according to Wilcoxon test.

causes for bone tunnel enlargement is the micromovement of the graft in tunnel.[16,17] This movement occurs as a result of the bungee effect (up and down) (longitudinal movement of the graft within the tunnel) and windshield wiping movement (side to side) (windshield wiper-like movement).[4,11,16,17]

Various measurement techniques have been described for assessing bone tunnel enlargement, with radiography, CT, and MRI being the primary methods.[5,18,19]

Radiography is a frequently employed method for assessing bone tunnel enlargement because of its easy accessibility. However, radiography may have the disadvantage of low reliability of measurements.[5,6] In our study, to facilitate objective measurements on radiography, the tibial tunnel was measured from its proximal, middle, and distal widest points on both AP and lateral radiographs, and the average of these values was used for analysis. In the case of the femoral tunnel, only the proximal and distal parts of the tunnel were measured on the AP radiographs, and the average of these values was considered. The extent of bone tunnel enlargement was determined by subtracting the measurements obtained during surgery from the drill size. Bone tunnel enlargement was also calculated as a percentage.

Table 3

Statistical evaluation of clinical results according to groups.

	Group 1	Group 2	P
Time to return to sports (mo) (Mean ± SD) (median)	7.7 ± 1.59 (7)	7.09 ± 1.65 (8)	.143*
Lysholm score (Mean ± SD) (median)	90.18 ± 8.44 (92.00)	91.20 ± 6.35 (93.50)	.104*
IKDC score (Mean ± SD) (median)	81.45 ± 14.13 (76)	77.82 ± 12.68 (75)	.054*
VAS (Mean ± SD)	2.33 ± 1.7	2.4 ± 1.28	.162*

SD = standard deviation, VAS = visual analog scale.
* Statistical significance between groups according to Mann–Whitney *U* test.

Table 4

Results of radiological measurements in direct radiography and statistical values between groups.

	Group 1	Group 2	P
İntraoperative tunnel diameter (Mean ± SD) (median)	7.77 ± 0.73 (8)	7.90 ± 0.79 (8)	.380*
Femoral tunnel (mm) (Mean ± SD)	2.19 ± 0.87	2.65 ± 0.78	.019†
Femoral tunnel (%) (Mean ± SD)	28.10 ± 11.36	33.42 ± 8.82	.022†
Tibial tunnel (AP radiography, mm) (Mean ± SD)	2.86 ± 0.79	3.6 ± 0.81	.001†
Tibial tunnel (AP radiography, %) (Mean ± SD)	41.86 ± 35.35	45.36 ± 8.47	.001†
Tibial tunnel (lateral radiography, mm) (Mean ± SD)	2.76 ± 0.78	3.37 ± 0.74	.001†
Tibial tunnel (lateral radiography, %) (Mean ± SD)	35.61 ± 9.85	43.38 ± 8.36	.001†

AP = anterior–posterior, SD = standard deviation.
* Statistical significance between groups according to Mann–Whitney *U* test.
† *t*-Test.

MRI offers a clear evaluation of graft and tunnel morphology following ACL reconstruction.[4,5] In our study, femoral and tibial tunnel diameters were measured in patients selected from both groups using a systematic sampling method. While patients undergoing repair using the Endobutton CL system exhibited greater tibial and femoral tunnel enlargement, only the enlargement in the femoral tunnel was found to be statistically significant.

Another important radiological measurement is the graft apex–tunnel apex distance, as defined by Firat et al.[4] Firat et al[4] suggested that the excess of this distance may cause bone tunnel enlargement. In their study, they measured this distance as 4.6 ± 0.3 mm using devices with a suspension system and as 9.5 ± 1.6 mm using the Endobutton CL technique, and they statistically demonstrated that these measurements were correlated with femoral tunnel enlargement.[10] In our study, while the graft apex–tunnel apex distance was 5.7 ± 1.4 mm in patients undergoing repair using the ZipLoop technique with a suspension system, it was measured as 7.5 ± 1.5 mm in those undergoing repair using the Endobutton CL system. Similar results

Table 5

Results of radiological measurements in MRI and statistical values between groups.

	Group 1	Group 2	*P*
Femoral tunnel (coronal plane, mm) (Mean ± SD)	3 ± 1.58	2.93 ± 1.34	.820*
Femoral tunnel (coronal plane, %) (Mean ± SD)	34.98 ± 13,63	39.18 ± 19,93	.406*
Femoral tunnel (sagittal plane, mm) (Mean ± SD)	2.89 ± 0.98	3.15 ± 1,51	.820*
Femoral tunnel (sagittal plane, %) (Mean ± SD)	34.86 ± 13.12	53.3 ± 33.33	.058*
Tibial tunnel (Coronal plane, mm) (Mean ± SD)	2.35 ± 1.37	2.86 ± 1.10	.364*
Tibial tunnel (Coronal plane, %) (Mean ± SD)	30.88 ± 17.77	35.07 ± 14,44	.545*
Tıbial tunnel (Sagittal plane, mm) (Mean ± SD)	2.58 ± 1.82	3,08 ± 1.36	.225*
Tıbial tunnel (Sagittal plane, %) (Mean ± SD)	32.92 ± 24.43	34.25 ± 13.65	.363*
Graft apex–tunnel apex distance (Mean ± SD)	5.7 ± 1.4	7.5 ± 1.5	.008*

SD = standard deviation.

* Statistical significance between groups according to Mann–Whitney *U* test.

have been reported in the literature.[10] Based on these findings, it is observed that the graft apex–tunnel apex distance is greater in patients who undergo repair using the Endobutton CL technique. This increased distance may result in greater graft mobility within the tunnel, potentially because of the graft not fitting completely within the femoral tunnel.[10] When using devices with a suspension system, achieving an exact fit of the graft at the apex of the tunnel shortens the graft apex–tunnel apex distance, subsequently reducing the micromovement of the graft within the tunnel.[4]

In the literature, studies on the relationship of the patient's bone quality, postoperative rehabilitation, graft size and original tunnel diameter on tunnel enlargement are rare.[20–22]In the study conducted by Sauer et al,[20] the original tunnel diameter and the amount of tunnel enlargement were found to be inversely proportional. In our study, as the graft diameter increased, the amount of tunnel enlargement increased in direct proportion. However, tunnel enlargement was similar as a percentage regardless of graft size, and no statistically significant difference was detected. There are studies showing that the patient's bone quality has an effect on tunnel enlargement. In the study conducted by Kobayashi et al,[21] it was emphasized that bone tunnel enlargement is related to bone quality and that bone tunnel enlargement also increases with increasing age. In our study, there is no data on the relationship between the patients' bone quality and bone tunnel enlargement. However, moreover, studies on bone mineral density and tunnel enlargement of patients' bone quality are needed.

There is no consensus in the literature regarding the postoperative rehabilitation protocol.[22] Patients who underwent a similar postoperative rehabilitation program were included in the study; Full passive range of motion was prescribed to both groups within the first week after surgery. Postoperative bracing protocols, patients were assigned extension-locked brace only. Full weight bearing or partial weight bearing was prescribed depending on the patients' additional meniscus pathologies. In the literature, studies on tunnel widening in postoperative rehabilitation have emphasized that tunnel widening is more common in full and partial active ROM rehabilitation protocols.[22,23] In our study, a similar rehabilitation protocol was applied to both groups. Although tunnel enlargement depends on many factors, there are studies showing that aggressive postoperative rehabilitation causes tunnel enlargement.[22–24]

Studies showing that bone tunnel enlargement has a negative effect on the clinical outcomes are quite rare.[1,4,6,11,16,25–30] In our study, VAS, IKDC, and Lysholm scores were used to evaluate clinical outcomes. In the review performed by Onggo et al,[11] numerous studies utilizing both adjustable and fixed-ring graft fixation devices were examined, and no statistically significant differences were identified in terms of IKDC and Lysholm scores. In the review by Onggo et al,[11] it was observed that the Lysholm score ranged between 85.7 and 94.7 in studies using the ZipLoop technique with a suspension system, whereas the score ranged between 82.3 and 93.9 in those using the Endobutton CL technique.[1,27–30] In the study by Cansever et al,[30] the mean Lysholm score was 94 in patients undergoing repair using the ZipLoop technique with a suspension system, whereas it was 92.5 in those undergoing repair using the Endobutton CL technique. In the study by Lanzetti et al,[1] the mean Lysholm score was found to be 93.2 in patients undergoing repair using the ZipLoop technique with a suspension system and 92.8 in those undergoing repair using the Endobutton CL technique. In our study, the mean Lysholm score was determined to be 90.28 ± 7.44 in patients undergoing repair using the ZipLoop technique with a suspension system and 91.2 ± 6.35 in those undergoing repair using the Endobutton CL technique. In the literature, postoperative IKDC scores after undergoing ACL reconstruction using the ZipLoop technique with a suspension system have been reported to range from 60.9 to 90.4. On the contrary, in patients undergoing repair using the Endobutton CL technique, the scores have been documented to be between 65.43 and 89.5. In the study conducted by Ahn et al,[28] the IKDC score was determined to be 78.6 ± 17.7 in patients who underwent ACL reconstruction using the ZipLoop technique with a suspension system, whereas it was 79.43 ± 12 in those who underwent repair using the Endobutton CL technique. In another study by Pokhorel et al,[27] the mean IKDC score was observed to be 83.98 ± 4.1 in patients undergoing repair using the ZipLoop technique with a suspension system. In the study conducted by Firat et al,[4] the mean IKDC score was 79.43 ± 12 in patients who underwent repair using the Endobutton CL technique. In our study, the mean IKDC knee score was 81.45 ± 14.13 in patients who underwent repair using the ZipLoop technique with a suspension system and 77.82 ± 12.68 in those who underwent repair using the Endobutton CL technique.

5. Conclusions

Our findings suggest that bone tunnel widening is more common in patients undergoing ACL reconstruction using the Endobutton CL technique compared to the ZipLoop technique using a suspension system. However, our study suggests that this bone tunnel widening does not have a negative effect on clinical outcomes, and similar results have been obtained in the literature.[1,11,27–30] However, it should be kept in mind that although bone tunnel widening does not have a direct negative effect on clinical outcomes, it may create technical difficulties in cases requiring revision ACL reconstruction. If revision ACL reconstruction is required in patients with excessive bone tunnel widening, a 2-stage ACL reconstruction with bone graft may be required.[1,6,16,17]

In conclusion, although bone tunnel widening depends on many heterogeneous factors, it is known that bone tunnel widening will be less in graft fixation methods where the graft is completely placed in the bone tunnels.

6. Limitations

The limitation of our study is that the causes that may cause tunnel enlargement, such as comorbid diseases and factors affecting bone quality, were not excluded. Additionally, it is difficult to determine to what extent the patients' sports activity levels and postoperative rehabilitation program affect knee stability and tunnel enlargement.

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