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Bone tunnel enlargement after the reconstruction of anterior cruciate ligament using bone-tendon-bone graft

Uvećanje koštanog kanala nakon rekonstrukcije prednje ukrštene veze kolena upotrebom kost-tetiva-kost grafta

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Abstract

Background/Aim. Bone-tendon-bone (BTB) graft is one of the strongest biological grafts and it provides a strong initial fixation with the application of interference screws making possible the primary bone healing and bone integration of the graft on the place of fixation during arthroscopic reconstruction of the arterior cruciate ligament of the knee. The aim of our research was to determine if BTB graft from which, throughout the surgical treatment, soft tissue and periosteum are removed, leads to the reduction of the enlargement in the femoral and tibial bone after the arthroscopic reconstruction of the anterior cruciate ligament. **Methods.** The first phase consisted of bio-mechanical study on 12 pairs of cadaveric BTB grafts. The testing was performed on the mechanical testing machine. The second phase involved clinical testing. The first group consisted of 40 patients treated with the classical BTB autograft. The second group consisted of 56 patients who had two thirds of the bony parts of the bone-tendon-bone autografts of the soft tissue and periosteum removed. We measured the distance between the edge of the sclerotic tunnel on the tibial and femoral bone in three different points: proximal (F1;T1), middle (F2;T2) and the lower part (F3;T3). **Results.** The experimental part of the study showed no statistically significant difference in graft breakout force expressed in N/mm2 between classically treated BTB graft and graft with a partially removed soft tissue and periosteum. By comparing the expansion of tunnels in all segments in both bone tunnels between study groups, statistically significantly lower enlargement was measured in the group with BTB grafts with partially removed soft tissues and periosteum ($p < 0.05$). **Conclusion.** The use of BTB grafts with partially removed soft tissues and periosteum provides less bone tunnel expansion as compared to classically treated grafts of the anterior cruciate tendon.

Key words:
arthroscopy; knee; anterior cruciate ligament; transplants; rehabilitation.

Apstrakt

Uvod/Cilj. Kost-tetiva-kost (KTK) graft jedan je od najčvršćih bioloških graftova i obezbeđuje jaku inicijalnu fiksaciju i primenu interferencijalnih zavrtanja, čime se postiže primarno zaceljenje kosti i integracija grafta za kost na mestu fiksacije tokom artroskopske rekonstrukcije prednje ukršene veze kolena. Cilj našeg istraživanja bio je da utvrdi da li KTK autokalem kod koga se tokom hirurške obrade uklanjaju meka tkiva i periost dovodi do smanjenja uvećanja kanala u butnoj kosti i golenjači nakon artroskopske rekonstrukcije prednje ukrštene veze kolena. **Metode.** Prva faza sastojala se od biomehaničkog ispitivanja na 12 parova kadaveričnih KTK kalemova. Testiranje smo vršili na mehaničkoj kidalici. Druga faza je podrazumevala kliničko ispitivanje. Prvu grupu činilo je 40 ispitanika sa klasično obrađenim KTK autokalemom. Drugu grupu činilo je 56 ispitanika kod kojih su sa dve trećine koštanih delova KTK autokalema odstranjena meka tkiva i periost. Merili smo rastojanje između sklerotičnih ivica tunela na golenjači i butnoj kosti u tri različite tačke: proksimalno (F1;T1), u sredini (F2;T2) i u donjem delu (F3;T3). **Rezultati.** Eksperimentalni deo studije pokazao je da ne postoji statistički značajna razlika u sili kidanja kalema izražene u N/mm^2 između klasično obrađenog KTK kalema i KTK grafta sa delimično uklonjenim mekim tkivima i periostom. Upoređivanjem proširenja kanala u svim segmentima u oba koštana tunela između ispitivanih grupa, statistički značajno manje uvećanje kanala izmereno je u

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grupi sa KTK kalemom sa delimično uklonjenim mekim tkivima i periostom ($p < 0.05$). **Zaključak.** Upotreba KTK autokalema sa delimično uklonjenim mekim tkivima i periostom daje manje proširenje koštanih kanala u odnosu na klasično obrađivane kaleme prednje ukrštene veze.

Ključne reči:
artroskopija; koleno; ligament, prednji ukršteni; graftovi; rehabilitacija.

Introduction

Nowadays, the primary arthroscopic reconstruction of the anterior cruciate ligament (*ligamentum cruciatum anterius* – LCA) has reached a significant level of precision and is routinely performed. In the last two decades, in literature, one can find the problem of enlargement of bone tunnel in the femoral and tibial bone after the primary reconstruction of the anterior cruciate knee ligament [1–3]. In 1994 Fahey and Indelicato [4] were the first who published the study pointing out the significance of this problem. The widening of the tunnel has no effect on the clinical results of the reconstruction of the cruciate ligament [5, 6]. However, this phenomenon can significantly complicate the revision surgery of the LCA.

All the agents responsible for the development of bone tunnel enlargement in the femoral and tibial bones are divided into two large groups. The first group consists of biological factors such as: the immune response of the body when using allografts [7], toxic effect (sterilization with ethylene oxide) [8], non-specific inflammatory response (the effect of cytokines on synovial fluid) [9], bone-cell necrosis caused by high temperature during the drilling of the bone tunnel [10] and avascular necrosis of bone cells of the graft itself [3, 9]. The second group consists of the so called mechanical reasons and these are : the movement of graft in the bone tunnel [9, 11] and its effect on the walls of the tunnel, aggressive rehabilitation [12, 13], and the effect of strong forces on the badly positioned graft [14, 15]. The extension of the tunnel is larger and it occurs more often when using hamstring tendon and allografts than in the application of bone-tendon-bone (BTB) autograft [16].

BTB autograft is used daily by orthopedic surgeons in the reconstruction of the anterior cruciate ligament because it gives good clinical results. Franke [17] says that BTB autograft is one of the most popular grafts equally represented both in the USA and in Europe thanks to the studies of Eriksson [18] and Clancy [19].

The application of BTB autograft in 80–90% of the cases has excellent clinical results and some of the most common complications are related to the lesion of extensor appliance of the given region [20, 21]. BTB graft is one of the strongest biological grafts and it provides a strong initial fixation with the application of interference screws making possible the primary bone healing and bone integration of the graft on the place of fixation during arthroscopic reconstruction [20, 21].

Over the years of using this graft the manner of its treatment has not significantly been changed. Pujol et al. [22] describe the arthroscopic double bundle LCA reconstructive technique making two BTB grafts from one donor place. Imitating the anatomical LCA reconstruction Shino et al. [23] and Herbort et al. [24] tried to improve the BTB technique, creating a rectangular tunnel and bony part of the graft, neglecting the importance of the cross-sectional area of the classic BTB graft, with a width of 10 mm and a thickness of 3–5 mm which ultimately depends on the individual patient's characteristics [25–28].

The aim of this study was to reduce the level of the enlargement of bone tunnel in the femoral and tibial bones by using different BTB grafts.

Methods

The experimental part of the research

Biomechanical testing was performed on 12 pairs of cadaveric BTB grafts. The age of cadaveric donors ranged from 19–38 years (average age was 25), 10 men and 2 women. The average time from taking the graft to testing on mechanical test machine was 6 weeks (3–12 weeks).The pairs consisted of BTB grafts of the same size (25 mm long and 10 mm thick) taken from the same cadaver where soft tissues and periosteum (up to bone part cortex of BTB graft) were partially removed. We wrapped thus obtained pairs into aluminum foils after washing them in the physiological solution and placed them into plastic bags which were kept at the temperature of -20 ºC. After that, before testing, we kept them at the temperature of 4 ºC for 12 hours and then at room temperature on the test day.

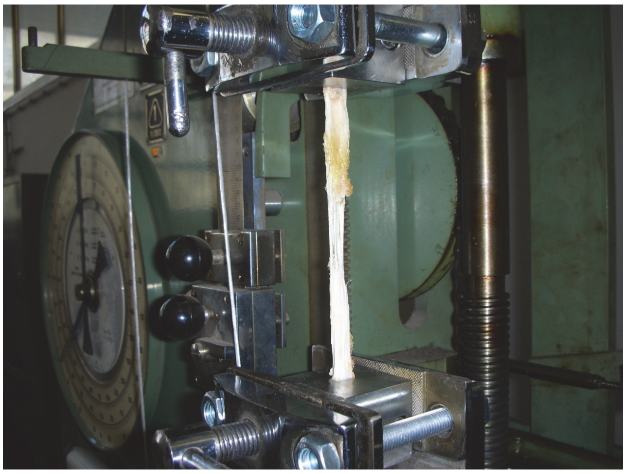

Fig. 1 – Mechanical testing machine (model WPM-Rauenstein, Universal Testing Machine, Leipzig, Germany).

The testing was performed on the mechanical testing machine (Figure 1) (»WPM- Rauenstein, Universal Testing Machine, Leipzig, Germany) with the maximum load of 5 kN to check whether the treated BTB grafts (with no periosteum and soft tissue) would retain the same force expressed in N/mm^2 in comparison to classically treated and prepared BTB grafts. The force expressed in N/mm^2 at which the graft cracks was recorded for each sample. During the testing, we always used the same graft holder. Each cadaver BTB graft was placed in the same way – so that the bone part is in the graft holder precisely to the joint of BTB [29]. Having realized that there was no statistically significant difference in the force required for tearing the graft (expressed in N/mm^2, between the classically treated graft and BTB graft with partially removed soft tissue and periosteum, we could start the clinical trial.

Clinical part of the research

The study was randomized and prospective. The tested group consisted of 96 patients of both sexes, aged from 18 to 48 years with unilateral complete rupture of the anterior cruciate ligament. The patients involved in the study were not previously treated surgically for these injuries and were divided into 2 groups. The groups were comparable according to all demographic characteristics and there was no statistically significant difference when it comes to gender, laterality, age, level of sports activity, the time passed from injury to surgery, combined lesions of meniscus and lesions of cartilage. The only difference between the groups was in the way the BTB graft was treated. With all the patients the uniform program of rehabilitation was carried out according to Shelborn's modified protocol [12]. The study did not include patients with multiligament injuries, degenerative changes and deformities of the knee joint.

There were 40 patients in the first group with the classically treated BTB autograft, the average age being 27 ± 5.514 years and the average body mass index (BMI) 21.94 kg/m^2. In the second group, there were 56 patients who had BTB autografts the soft tissue and periosteum partially removed and their average age was 26 ± 4.982 years and the average BMI 21.37. In the first group, the average duration of the injury was 8.2 ± 5.036 months and in the second 9.4 ± 4.131 months. There was no statistically significant difference in the duration of injury between the groups ($t = -1.242$; $p > 0.05$) nor when it comes to the age of the patients and BMI.

From the patients in the first group, during the surgery with the normal vertical incision above the patella ligament, a BTB graft was taken, on which, after the treatment, bone blocks were cylindrical with the diameter of 10 mm and length 25 mm. During the preparation of the graft itself soft tissue and periosteum were not removed from the bone parts of the future ligament. In the second group, very same technique of taking the graft was applied as in the first group, but the processing method was different. During the preparation of bone blocks, from two thirds of the bone part of the graft soft tissue and periosteum were completely removed (to the cortex of bone part of the BTB graft) with a scalpel. During the processing the cylinders obtained also had the diameter of 10 mm.

After a detailed introduction to the planned procedure, the voluntarily registered candidates who agreed to participate in the study were selected. On those patients the parameters obtained with the analysis of radiographic images seven days after the surgery in the period from 3 to 12 months after the surgery was analyzed and compared. We determined preoperatively and postoperatively the Lachman test [30] (positive and negative), Pivot shift test [31] (subluxation of the tibia relative to the femur), Lysholm [32], Tegner [33] and International Knee Documentation Committee (IKDC) score [34] for the knee. Arthrometric measurements implied the determination of front motion of the tibia relative to the femur (Lachman test) in mm using the arthrometer. The front mobility was measured by the arthrometer on both the operated and the opposite knee and the differences were registered.

Surgical treatment and postoperative protocol

The patients were in the dorsal position with a leg on the arthroscopic support in general or epidural anesthesia. The surgeries were carried out in ischemia. All the patients were operated on with the same arthroscopic single-bundle anatomic technique. A 10 mm diameter drill was used for both bone tunnels (on the tibia and the femur). The graft was fixed with cannulated titanium screws (Grujić & Грујић, Novi Sad, Serbia), 8 x 25 mm. After the surgery, all patients had an elastic bandage for 14 days. In the rehabilitation process, we used a modified Shelbourne protocol [12]. From the first day after the surgery, all the patients were subjected to continuous passive motion of the operated knee with the help of kinetec. A partial support was allowed after two weeks and the full support six weeks after the surgery. All the patients followed the same rehabilitation program with the chain of kinetic exercises for the reinforcement and restoring the muscle strength of the anterior and posterior thigh. The patients were checked a week after the completion of hospital treatment, and then 6 weeks after the surgery when they get the full support on the operated leg, and then 3 and 6 months after the surgery when they are practically in the full competitive form. We did the clinical check-ups again in the interval from 1 to 4 years (the average of 2 years). All the patients within our study were operated on by the same orthopedic surgeon, using the same graft fixation method and the uniform program of the rehabilitation was carried out by the same doctor.

The monitoring of radiological parameters

The lateral and anterior-posterior (AP) radiograph of the operated knee was done 7 days after the surgery and 6 and 24 months after the surgery. The AP images were made with the knee in full extension and the lateral images with the knee in a passive extension (with the heel set on the base around 10 cm high. The source of radiographic rays was located 100 cm from the cassette and positioned vertically to it. The diameter of the tunnel on the AP and lateral images were determined according to the modified Peyrache et al. [35] method. We measured the distance between sclerotic edges of the tunnel on the tibia and femur in three different points: proximal (F1; T1), medial (F2; T2) and the lower part

(F3; T3), i.e., at the level of the joint cavity and 1 cm and 2 cm distal to the tibia and proximal to the femur (Figure 2). The results were compared to the width of the drill, with which the tunnel was drilled during the surgery. The obtained results could be viewed as the percentage of the diameter change which was calculated in the following way:

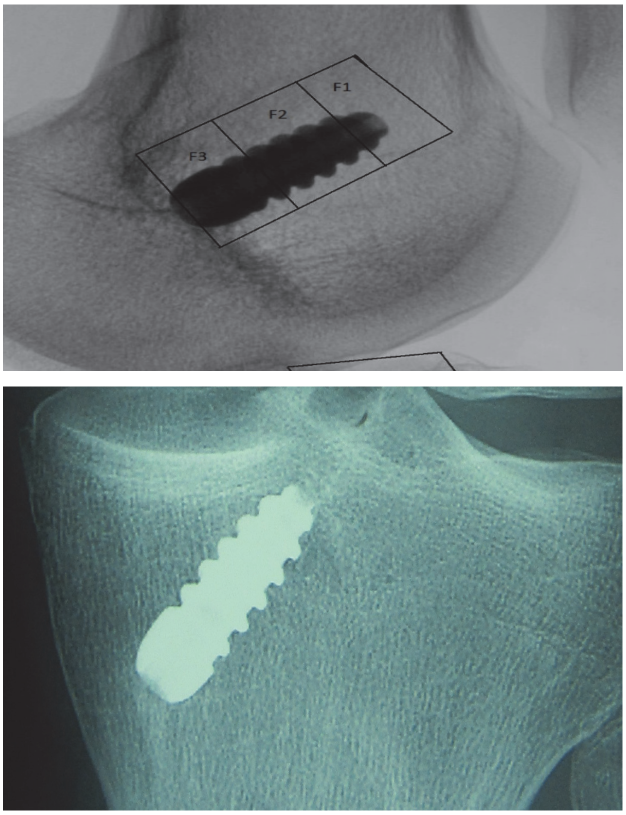

Fig. 2 – Distance between sclerotic edges of the fibia and femur in three different points (F1, F2, F3).

Measured diameter of the tunnel-intraoperative diameter of the tunnel

Enlargement of the tunnel was defined as every enlargement of the tunnel compared to intraoperative diameter of the tunnel (which was determined by the size of the drill). The shape of the tunnel was classified as a cone, cavity and a line type of bone tunnel enlargement [36]. The measurements were performed on the scanned radiograms using the high precision calibration. The reproducibility was checked on the measures obtained by 3 different doctors. The precision of the measurement of the angles was 0.5° and linear measurements were 0.5 mm. For each of the parameters that were considered, the average, min. and max. values were calculated as well as standard deviation.

The study was approved by the Ethics Committee of the Medical Faculty of the University of Novi Sad and Ethics Committee of the Clinical Centre of Vojvodina in Novi Sad.

Statistical data analysis

In the statistical analysis the Kolmogrov-Smirnov test was used and depending on the nature of the data parametric tests were used (Student's *t* test, *t*-test for pair samples and ANOVA) or an equivalent non-parametric statistical tests (Mann-Whitney test, Wilcoxon test for pair samples and Kruskal-Wallis test). The values $p < 0.05$ were considered statistically significant. In the data analysis software MS Office Excel 2007 was used, with the statistical software Analyze – lt with the appropriate text comment. The statistical analysis of the results obtained with arthrometric evaluation was performed with the help of the Student's *t*-test. The values $p < 0.05$ were considered statistically significant.

Results

There was no statistically significant difference in the postoperative values of IKDC score between the observed groups ($\chi^2 = 4.265$; $p > 0.05$). With the statistical analysis of the data using the non-parametric Wilcoxon test, it was found that there was a statistically significant difference between the Tegner score of the activities before and after the surgery for each group individually [(I group – Z = -5.561; $p < 0.01$); (II group – Z = -6.534; $p < 0.01$)]. There was also a statistically significant difference between Lysholm score of the activity before and after the surgery for each group individually [(I group – Z = -5.515; $p < 0.01$); (II group Z = -6.511; $p < 0.01$)]. Comparing the difference between the healthy and the diseased knee before and after completing the surgical treatment we did not find a statistical significance between the observed groups (Table 1).

With the statistical data analysis using the Student's *t*-test, we did not determine the existence of statistically significant differences in the tearing force expressed in N/mm^2 between 12 pairs of cadaveric BTB grafts (t = 0.058; $p > 0.05$). The force in N/mm^2 , at which the graft rupture occured, was recorded for each sample. The average value of the tearing force in N/mm^2 of the classically treated BTB graft amounted to 1155.42 ± 157.94 and the average value of tearing force in N/mm^2 of the BTB with partially removed soft tissues and periosteum was 1150.25 ± 157.69 (Figure 3).

Table 1

Functional scores and arthrometric measurements

Type of BTB	Tegner score before / after	Lysholm score before / after	Lachman test (mm) before / after
Classic BTB	1.73 / 8.15	46.73 / 95.93	14.428 / 3.90
BTB without periosteum and soft tissue	1.63 / 8.34	48.43 / 97.14	14.025 / 4.26

BTB – bone-tendon-bone graft.

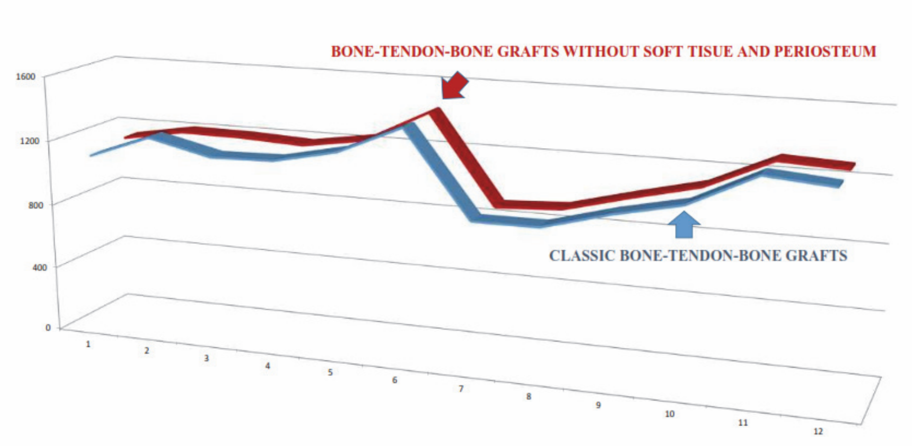

Fig. 3 – Measurement of the tearing force in N/mm^2.

Comparing the radiographic results according to segments (T1, T2, T3 segment in AP projection and profile and F1, F2 and F3 segment in AP and profile) between the examined groups, we found out that the best results were achieved by using the BTB graft with partially removed soft tissues and periosteum. In this group, the level of bone tunnel enlargement in the femoral and tibia bones was significantly lower compared to the classically treated BTB grafts (Figures 4–6) and (Tables 2 and 3)

Table 2

Results of the measurements of bone tunnel percentage of enlargement in tibia by segments among the observed groups

Tibial segment	BTB without periosteum and soft tissue	Classic BTB	*p*
	mean	mean	
Antero-posterior			
T1 proximal third	0.0214	0.5100	< 0.01
T2 middle third	0.0179	0.7175	< 0.01
T3 distal third	0.0179	0.5300	< 0.01
Lateral			
T1 proximal third	0.0161	0.5375	< 0.01
T2 middle third	0.0125	0.7175	< 0.01
T3 distal third	0.0125	0.5300	< 0.01

BTB – bone-tendon-bone graft.

In our sample of 96 patients the conical shape of the bone tunnel enlargement was determined in 28 (29.1%) patients, cavity shapes in 14 (14.58%) patients, and line shapes in 7 (7.29%) patients. Bone tunnel enlargement was not found in 47 (48.95%) patients.

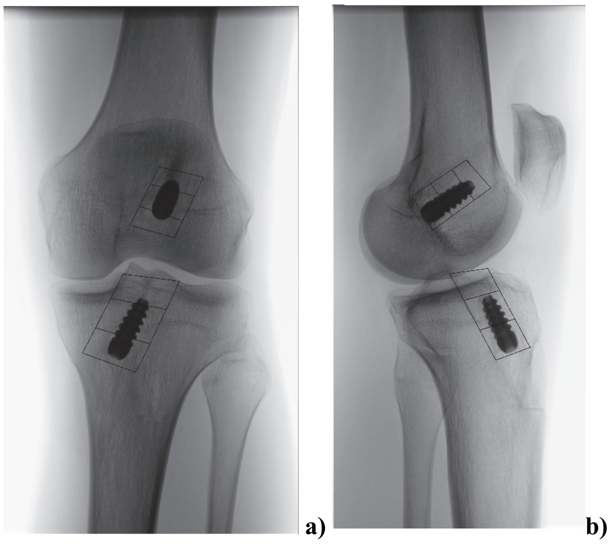

Fig. 4 – Radiographs of the knee.
a) Anteroposterior (AP) position; b) Profile.

Table 3

Results of the measurements of bone tunnel percentage of enlargement in femur by segments among the observed groups

Femoral segment	BTB without periosteum and soft tissue	Classic BTB	*p*
	mean	mean	
Antero-posterior			
F1 proximal third	0.0161	0.3675	< 0.01
F2 middle third	0.0089	0.3675	< 0.01
F3 distal third	0.0018	0.3775	< 0.01
Lateral			
F1 proximal third	0.0125	0.4325	< 0.01
F2 middle third	0.0107	0.4325	< 0.01
F3 distal third	0.0018	0.3350	< 0.01

BTB – bone-tendon-bone graft.

Discussion

The reason why bone tunnel enlargement occurs after the anterior cruciate ligament reconstruction is still unexplained, but it is certainly multifactorial and conditioned by biological and mechanical reasons [37, 38]. Although, any correlation between clinical results and bone tunnel enlargement has not been found in the published studies until now, this phenomenon plays an important role in revision surgery of LCA which is required in 8% of the patients after the primary reconstruction [1–3].

The experimental part of our study which related to biomechanical research showed that there was no statistically significant difference regarding the tearing force of the graft expressed in N⁄mm^2 between the classically treated BTB graft (with soft tissue and periosteum) and BTB graft with partially removed soft tissue and periosteum (soft tissue and periosteum were completely removed from the two thirds of the bone part of the graft). In an experimental study Handl et al. [29] showed on 21 pairs of cadaveric BTB grafts that the tearing force expressed in N/mm^2 is 1482 ± 211. As their sample showed, the force required to tear the natural anterior cruciate ligament ranged from 1246 ± 243 N⁄mm^2. The results of the experimental part of our study showed that the average value of the tearing force in N⁄mm^2 of the classically treated BTB grafts was 1155.42 ± 157.94 and the average value of the tearing force in N⁄mm^2 of the BTB graft with partially removed soft tissues and periosteum was 1150.25 ± 157.69. The results of the experimental part of our study were similar to the results of numerous experimental studies [39–41] which investigated the tearing force of the BTB graft in N⁄mm^2 regardless of the new way of treating the graft and the partial removal of soft tissues and periosteum from bone parts.

Peyrache et al. [35] and Jaureguito and Taulos [39] thought that bone tunnel enlargement in the femoral and tibia was an important complication and that it may be the first, early sign of graft failure. This phenomenon did not affect the clinical stability of the knee but it significantly complicated revision surgeries [1, 40]. One of the few exceptions was the perspective randomized study published in 2008 by Järvelä et al. [41], which showed that with the application of the so-called anatomical "double bundle" technique for a lower level of a bone tunnel enlargement on the tibial insertion (for both tunnels) was obtained comparing to the "single bundle" enlargement technique with a better postoperative knee stability. The author himself admitted that the study was limited by a small number of respondents and mixed measurement methodology. According to literature data [5, 6], despite the significant differences in the size of bone tunnel in the femur and tibia, there was no statistically significant difference among the observed groups regarding the obtained postoperative knee stability.

Comparing the obtained radiographic results between the groups of classically treated BTB graft and BTB graft with partially removed soft tissue and periosteum, in both radiographic projections (AP and profile) we found a statistically significant reduction of bone tunnels enlargement in the femoral and tibial bones in the group with the grafts with partially removed soft tissue and periosteum. Measuring precisely and comparing the changes in the diameter of bone tunnels in this group of respondents, we determined that the best results were obtained in F3 segment (which was one third of the tunnel in the femoral which was closest to the joint cavity), because, it was the part of the tunnel where the bone part of the graft is usually positioned. The graft treated this way without soft tissue and periosteum has a full biological potential of healing.

Although there was a statistically significant reduction in the bone tunnel enlargement on the tibia compared to the classically treated BTB graft, the percentage of the reduction was lower than in the femur. Published data [42–44] confirm that the enlargement is bigger on the tibia than on the femur due to the fact that it is more difficult to position the graft on the tibia in the vicinity of joint cavity so that the movements of both bone and ligament part of the neoligaments are still higher than on the femur. Drogset et al. [45] and Cameron et al. [9] believed that such a radiological result was also a consequence of the fact that the entire femoral tunnel was in cancellous bone unlike the tibial that was localized in the cancellous bone only juxta-articularly. Radiographic measurements showed that the bone tunnel enlargement both in the group with classical BTB graft and in the group with BTB graft without the soft tissue and periosteum was the biggest in T1 and T2 segments (medial and proximal third of the tibial tunnel), i.e., in the segments which were more often without the bone part of the graft. Such a result is probably due to the so-called "windshield wiper effect" or micro movement of the ligament part of the graft in the transverse plane of the tibial tunnel [11]. However, regardless of the numerous impacts of mechanical and biological factors [3, 7–16] on the tibial tunnel and tibial part of the graft, in the group with BTB graft with partially removed soft tissue and periosteum, we got a significantly smaller enlargement of the bone tunnel of the tibia in all three segments (T1,T2 and T3) in both radiographic projections.

If the graft fixation point is more distant from the initial part of a bone tunnel, then its movement in the tunnel itself is higher and, consequently, a degree of osteolysis as well. Such movement of the graft in the bone tunnel in the longitudinal direction is marked as "bungee effect" (i.e., the effect of graft stretching or the effect of longitudinal displacement of the graft) [46]. This effect is stronger when using hamstring tendons in reconstruction of the LCA, but it is not exclusively a characteristic of anterior cruciate ligament reconstruction with these tendons. Contrary to this opinion Kobayashi et al. [47] believed that the way of graft fixation did not affect the degree of osteolysis of bone tunnels. They also believed that the movement of the graft inside the tunnel was not the only reason for the occurrence of this phenomenon. Within our study in both groups of patients, the fixation in the bone tunnels and femur and tibia was done with interferential titanium screws in the third of the tunnel which was nearest to the joint cavity and thus the effect of longitudinal displacement of the graft was reduced to minimum. The published data also showed that this method of fixation minimized the movement of the graft within the bone tunnels [48, 49]. Regarding the application of metal or titanium screws, it should be mentioned that although Maloney et al. [50] in *in vi-*

tro conditions demonstrated decreased cell proliferation with the increasing concentration of particles of titanium and aluminium alloys and chromium particles, no clinical study proved that the interference screws after the LCA reconstruction caused the enlargement of bone tunnel.

All the studies that were carried out, and so did ours, indicated that in the application of BTB graft the "windshield wiper effect" dominates with a significant enlargement of the tunnel [11]. Within our study, with the altered way of treatment of the BTB graft with the partially removed periosteum and soft tissue and its adequate positioning with the use of anteromedial portal we got statistically significantly smaller enlargement of the tunnel, both on the tibia and the femur, in comparison to the classical, uniform treatment of this most commonly used graft.

The most common form of bone tunnel enlargement on our sample was on both bones in both radiographic projections of conical type which was in accordance with the published data [51].

The accelerated rehabilitation protocol may result in the functioning of strong mechanical forces on the graft before its complete biological incorporation finishes [13]. In both groups of patients a uniform program of rehabilitation was conducted according to the so-called modified Schelbourne protocol [12] in order to prevent the possible influence of different physical procedures on bone tunnel enlargement in the femoral and tibial bones.

Non-anatomical position of the neoligament increases the intensity of the forces acting on it, and the cadaveric studies [14, 15] have shown that those forces are 3–4 times stronger than the forces that the natural LCA endures. Such mechanical forces increase the level of osteolysis especially at the beginning of bone tunnel where these forces are the strongest [10]. With all the patients included in this study the femoral tunnel on the profile images was located in the so-called green field [52], and on the tibia it was about 1 cm medially from tuberosity, drilled at the angle of 50–60 degrees with intraarticular position of about 7 mm in front of the rear cruciate ligament. With such a position of the graft we tried to maximally prevent the influence of its inappropriate position on bone tunnel enlargement. The size and the localization of the enlargement of bone tunnel in the femur and tibia depends, substantially, on the surgical techniques used in the reconstruction of the LCA. The variations in surgical techniques [53] can be the reason for different results when researching the effect of bone tunnel enlargement in the femur and tibia. Therefore, it is important to correlate and compare the size of osteolysis and the type of surgical techniques in order to obtain the best results in treatment of anterior cruciate ligament injuries. This was one of the aims of this study.

The study that we conducted has some potential flaws. The fact is that most authors believe that the computed tomography (CT) evaluation of this phenomenon is more precise than the radiographic. However, according to a study conducted by Webster et al. [54] in which they compared these two methods, the digital radiography was considered quite satisfactory and it was emphasized that its convenience was significantly lower price, especially in the research with a greater number of respondents (in our study 96 patients were monitored), and a lower dose of ionizing radiation to which the patients were exposed. Digital radiographic evaluation of bone tunnel enlargement in the femoral and tibial bone was absolutely comparable with the results in CT research with a better economic effect and shorter time needed to carry out the research on which Jo et al. [55] agreed in their study.

The most significant result of this prospective randomized experimental-clinical study was that we have improved the characteristics of the most common replacement for LCA and approached it more to the so-called "ideal graft" making revision surgery easier by reducing the bone tunnel in the femoral and tibial bone.

Conclusion

An application of BTB autograft with partially removed periosteum and soft tissue provides significantly better results in the reduction of the degree of osteolysis of bone tunnel in the femoral and tibial bones than using the classically treated graft of the anterior cruciate ligament. The use of such treated grafts significantly facilitates possible revision procedures whose number increases from year to year because of the increasing number of primary reconstructions of this ligament.

R E F E R E N C E S

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