Genij Ortopedii. 2022. Vol. 28, no. 5. P. 659-668.

Original article

https://doi.org/10.18019/1028-4427-2022-28-5-659-668

Mid-term results of autologous bone grafting for medial tibial defects in primary total knee arthroplasty

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Abstract

Introduction Repair of a bone defect in primary total knee arthroplasty remains one of the most common tasks that must be addressed intraoperatively. Autologous bone grafting is a good biological option to preserve the bone tissue for conservative revision. **The objective** of the study was to analyze the results of autologous bone grafting of the medial tibial defect in primary total knee arthroplasty. **Material and methods** Results of autografting a bone defect with cancellous bone obtained when forming a groove for the intercondylar box of the femoral component of the tibia during primary total knee arthroplasty were retrospectively analyzed (main group, n = 31). The control group (n = 31) was formed by leveling the heterogeneous clinical parameters identified in the initial data using the PSM method. The mean follow-up period was 72 months. The Mann-Whitney and Wilcoxon tests were used for statistical data analysis. Lower limb realignment and bone graft reconstruction were evaluated radiographically, and KSS and WOMAC questionnaires were used for physical evaluation. **Results** There were no significant differences in the baseline and postoperative clinical conditions of the realigned lower limbs and the number of identified non-progressive radiolucent lines no greater than 2 mm in the groups. There were significant differences in the severity of varus deformity at baseline. Each group had one case of aseptic loosening of the tibial component. One patient of the comparison group had a late periprosthetic joint infection that was arrested with two-stage revision treatment. **Discussion** There were significant differences in the size of the varus deformity with no significant differences in the scores at the baseline between the groups. There were no differences in the realigned lower limbs and in the scores reported in the groups postoperatively. **Conclusion** The method developed was shown to be safe, affordable and effective. The result obtained was confirmed by absent differences in clinical and radiological outcomes between groups.

Keywords: total knee arthroplasty, bone defect, autologous bone graft

For citation: Gurazhev M.B., Baitov V.S., Gavrilov A.N., Lukinov V.L., Korytkin A.A., Pavlov V.V. Mid-term results of autologous bone grafting for medial tibial defects in primary total knee arthroplasty. *Genij Ortopedii*, 2022, vol. 28, no. 5, pp. 659-668. DOI: 10.18019/1028-4427-2022-28-5-659-668.

ВВЕДЕНИЕ

Total knee arthroplasty (TKA) is the final treatment of degenerative joint diseases [1]. Primary TKA can be associated with bone deficiency of the bones that form the knee joint. Bone defects can occur in the lateral and medial aspects and are most common in the posterior-medial tibia due to a high incidence of the knee varus deformity [2, 3]. A good clinical result can be provided with reconstruction of the tibial condyles with existing bone defects and creation of a reliable and durable support for the tibial component.

The Insall J.N. classification [4] modified at the Vreden FGBU NMITs will be used to grade defects with three measurements of the defect to be made. Small defects are those with an area of the defect being not more than 1/3 of the surface of the condyle with the depth of not more than 5 mm. Medium defects are those with the area of the defect being not more than 1/2 of the surface of the condyle with the depth of 5 to 10 mm. Large defects are those with the area of the defect being 2/3 of the surface of the condyle and the depth of more than 10 mm. There are several surgical options to repair bone deficiency of the medial tibial condyle during primary TKA. Smaller bone defects can be repaired with autografts [5, 6] and bone cement [7-9]. Medium size defects can be addressed with metal blocks [10-12], bone alloplasty [13] and autografts [14-16]. Metal blocks [17-19] and bone allografts [20] can be offered for larger defects.

The existing options for bone defect replacement in primary TKA have the advantages and disadvantages [21]. Cement plasty being an economically beneficial and simple technique with reinforcement can be used for extensive bone defects [22, 23]. The cement is not a biological material and can cause burns to surrounding tissues during polymerization and can also shrink by 2 % [7]. A reliable primary support for endoprosthetic components with large defects can be provided with metal block augmentation [10, 11]. Processing the bone bed for the augment is associated with resection of healthy bone that would subsequently prevent a conservative revision and the method cannot be recommended for young patients [24–26].

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The advantages of the allograft include the biocompatibility and a significant amount of material to allow the surgeon to form a graft in accordance with the geometry and volume of the bone defect and avoid removal of the patient's bone [13, 20]. The use of allobone carries the risk of transmitting infectious diseases [27, 28], and a bone bank may be unavailable with a medical institution. There is a paucity of publications on the use of the method in primary TKA.

The method of autoplasty carries a "plus bone tissue strategy", and not a minus – as in the methods of cement and metal plasty, due to the fact that autoplasty allows replacement and preservation of the bone tissue of the condyle. There are increased chances for a conservative revision rather that progressive procedure. The principles of conservative revision include no-use of revision components minimizing aggressive effects on intact adjacent tissues and bone structures that is important for younger patients [5, 29, 30]. The limited volume of the autograft and the risk of absent restructuring and failed union with the recipient's bone are disadvantages of autografting [3].

There is a paucity of publications reporting medium-term results of autografting that does not require additional fixation [6].

Our goal was to review autografting of the medial tibial defect in primary TKA and to compare clinical and radiological results with standard TKA without restoration of bone defects. Bone defects were repaired with the technique using the autograft that needed no additional metal fixation (patent RU 2 607 189 C1).

The review included a comparison of radiological and clinical findings of both groups of patients. All results obtained were statistically evaluated.

The hypothesis was that the comparison of the two groups of patients would show a significant preoperative difference in the varus deformity at baseline with probably no differences in preoperative clinical questionnaires. And there would be no differences in the realigned limbs postoperatively between the two groups with identical results of clinical surveys at mid-term.

MATERIAL AND METHODS

Grouping of patients

Medical reports of patients who were surgically treated for grade 3 gonarthrosis with primary arthroplasty at the FGBU NNIITO between 2014 and 2016 were reviewed. The inclusion criterion was all cases of implantation of a three-component endoprosthesis of one manufacturer (DePuy Sigma PS), and the operation was performed by a single surgical team. The review included all patients who underwent bone autografting according to the technique developed. There were 276 procedures identified for the specified period. The exclusion criterion was gonitis in the history (n = 6), a systemic disease (n = 30), valgus deformity of the lower limb (n = 15) and a malunited fracture of the femur and/or tibia (n = 10). Patients who had cement augmentation of tibial defect were excluded from the review (n = 13). Given the exclusion criteria there were total 202 cases identified. Of these, two comparison groups were identified. The first group consisted of 31 patients who underwent bone autografting to replace the defect. The second group consisted of 171 patients who were treated with primary standard TKA. Gender, age, body mass index (BMI), operating time, blood loss, side of the operation, preoperative contracture of the joint and the range of active motion were identified in the patients of the groups. Heterogeneous parameters revealed in the initial data of the control and study groups included operating time, preoperative contracture, and the side of the operation to be aligned using the PSM method (Propensity Score Matching) [31]. The review included 31 participants of the study group and 31 controls. The study design is shown in Figure 1.

Use of clinical and radiological assessment methods

All patients were examined clinically and radiologically in the preoperative and postoperative periods. Clinical assessment was performed using the KSS [32], WOMAC [33] questionnaires. Radiography of the knee joint in two projections and an axial image of lower limbs (from the femoral head to the ankle joint) were obtained for radiological evaluation.

The range of active range of motion and preoperative contracture were measured in the supine position using a goniometer and a zero-passing system [34].

The KSS questionnaire consisted of two parts: a general assessment of the knee joint (KSS knee score) and joint function assessment (KSS function score). The WOMAC questionnaire consisted of three parts: pain, stiffness, function.

The axis of the lower limb, presence of radiolucent lines and bone graft restructuring were assessed with radiographs. The authors agreed that varus deformity was assigned a negative (-) value, valgus deformity was assigned a positive (+) value, and the anatomical femorotibial angle (aFTA) and the hip-knee-ankle angle (HKA) [35] (Table 1).

Radiolucent lines (RLLs), lines passing at the interface between bone and cement, were evaluated using the roentgenographic knee evaluation system (RKES, 1989) [36, 37].

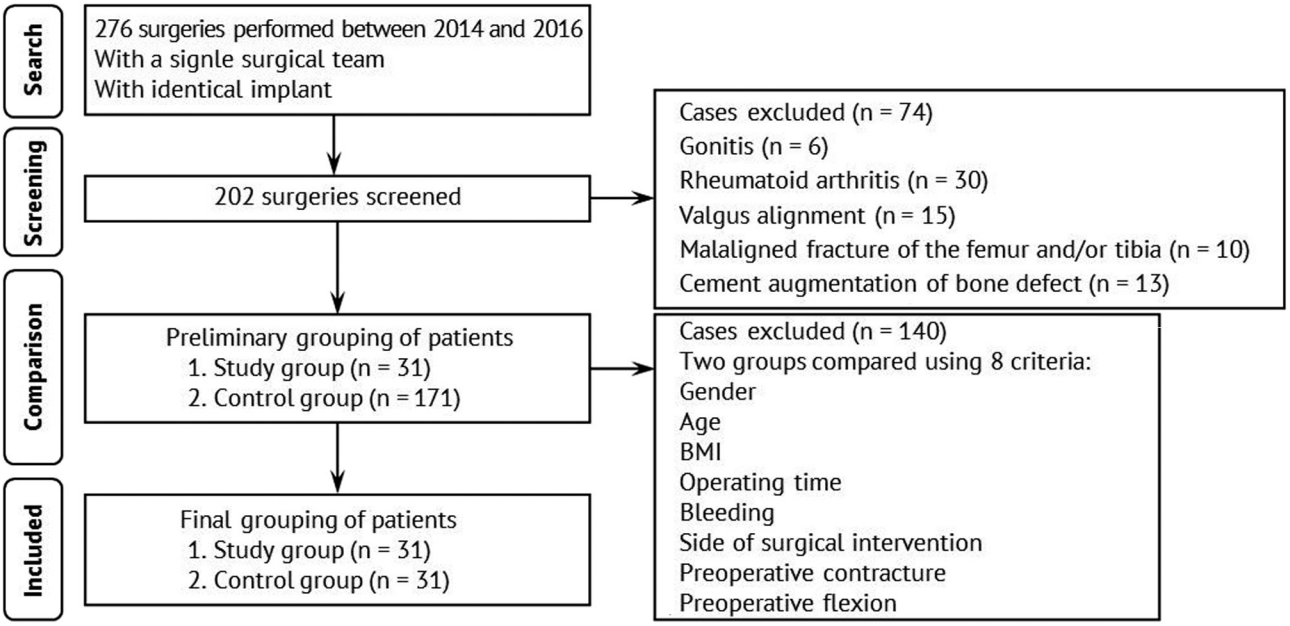

Fig. 1 Study design

Table 1

Angular assessment of the lower limb axis

Angles	Varus	Neutral	Valgus
aFTA	Less than 2.4°	2.5° to 7.2°	More than 7.2°
HKA	Less than -3°	-3° to 3°	More than 3°

The bone reconstruction of the graft was assessed first by the appearance of bridging trabeculation at the interface between the graft and the bone, and, ultimately, by the disappearance of the border [38, 39]. The data at the patient discharge from the hospital were the first postoperative point of the study with subsequent intermediate points at 6, 12, 24, 36 months. The end point was 60 months postoperatively. Patients from other cities sent X-rays by mail, and filled in the surveys by phone.

Surgical technique

With the patient in the supine position arthrotomy of the knee joint was performed under a pneumatic tourniquet using the anteromedial approach. The tibial plateau was released and extramedullary tibial guide placed on the lateral condyle with the resection depth of 8 mm with an anteroposterior inclination of 0-3º. The articular surface was resected and the residual bone measured with a metric ruler using the modified Insall classification [4]. Plastic surgery was performed for small and medium defects detected. The cancellous graft was harvested from a bone fragment obtained during formation of a groove for the intercondylar box of the femoral component. Qualitative processing of the defective sclerotic bone included modeling of unconfined defect into a confined one creating a support like a Russian lock and achieving "blood dew" on the walls of the recipient bed. Autograft of the size needed was made in the defect considering the size of the supporting area. The graft was tightly fixed in the recipient bed by soft impaction. The attention was focused on minimizing traumatic effects on the graft to avoid destruction of the bone tissue and disruption of the spatial orientation of the bone trabeculae. The graft emerging over the proximal tibial bonesaw was carefully resected with an oscillating saw. The graft could be fixed with a tupfer if needed. Intraoperative photos and a diagram of the method offered are shown in Figures 2, 3. DePuy Sigma PS implant and cement fixation without an extension stem was used with the technique. The drainage was removed after two days of surgery and strengthening exercises were encouraged for the muscles of the lower limbs. Patients were recommended to walk using crutches and assistance from exercise therapy instructors after three days. Patients were discharged after 5 to 6 days of surgery with recommendations for the use of crutches for the next 6 weeks.

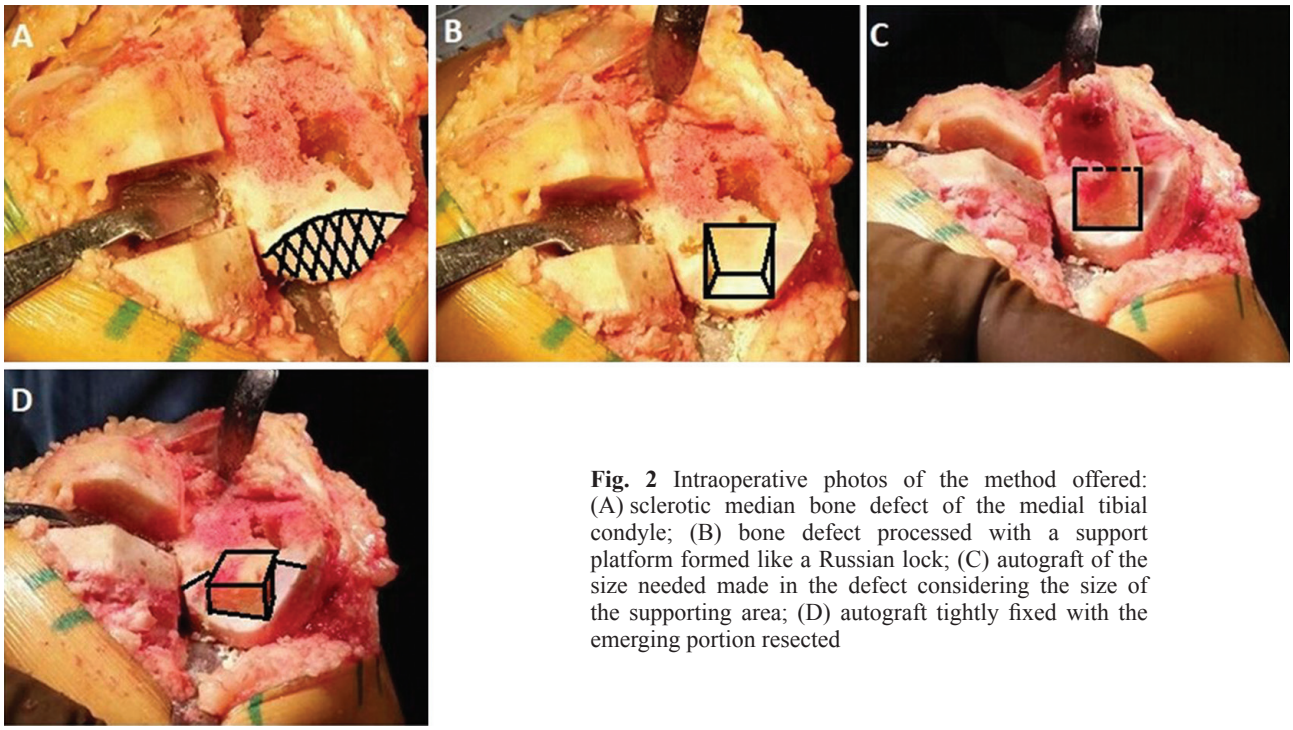

Fig. 2 Intraoperative photos of the method offered: (A) sclerotic median bone defect of the medial tibial condyle; (B) bone defect processed with a support platform formed like a Russian lock; (C) autograft of the size needed made in the defect considering the size of the supporting area; (D) autograft tightly fixed with the emerging portion resected

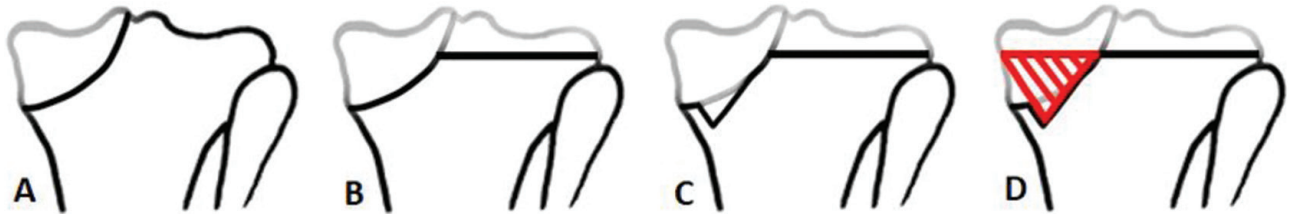

Fig. 3 Diagram showing formation of the recipient bed for the autograft: (A) medial bone defect of the medial tibial condyle prior to standard distal resection of the tibia; (B) bone defect after standard distal resection of the tibia; (C) simulation of an existing unconfined defect into a confined one creating a support similar to a Russian lock; (D) autograft placed in the bed formed by the recipient after resection of the emerging portion

Statistical method

Distributions of continuous parameters were tested for agreement with the law of normal distribution using the Shapiro-Wilk test. Rank criteria used for the abnormal distribution of data to compare continuous parameters included the Mann-Whitney U-test for comparing groups at the same time point and the Wilcoxon test for comparing the dynamics in aFTA, HKA and quality of life scores with use of the KSS, FSKSS, WOMAC questionnaires within groups. The median [first quartile; third quartile] (MED [Q1; Q3]) and mean ± standard deviation (AVG ± SD) of continuous parameters were calculated with descriptive statistics; quantity (percentage) for categorical and binary data, for binary data, a 95 % confidence interval (95 % CI) was calculated using the Wilson formula. Fisher's exact two-tailed test was used to compare categorical and binary parameters. The elimination of errors in the multiple comparison of categories was carried out by correcting the levels of p using the Benjamini-Hochberg method [31].

Elimination of inhomogeneities identified in the operating time, the side and contracture between the control and experimental groups was carried out by PSM (Propensity Score Matching) using the Nearest Neighbor Matching method with a caliber value of 0.25 (caliper), without preliminary screening of unsuitable patients in groups (discarding) , with a given ratio of the desired groups 1:1. Finally 31 patients were selected for each group [31]. Statistical hypotheses were tested at a critical significance level $p = 0.05$, i.e. the difference was considered statistically significant at $p < 0.05$.

RESULTS

The mean follow-up period was 72 months (range, 60–84 months). The baseline data of patients from the two groups showed no significant difference in the statistical analysis, except for the operating time (p = 0.001), preoperative flexion contracture (p = 0.007) and the side of the operation (p = 0.078). The parameters of the initial data between groups before alignment and after alignment for heterogeneous parameters using the PSM method [31] are presented in Table 2.

As agreed by the authors, varus deformity was assigned a negative value (-) measuring aFTA and FKA, and valgus deformity (+) became the exclusion criterion, and preoperative measurements of the angles had a negative value or null in all patients. Data on the number of patients with preoperative varus deformity in relation to the range of aFTA and FKA are presented in Tables 3 and 4.

Based on the measurements of the femoro-tibial (aFTA) and femoro-knee-ankle (FKA) angle a significant difference was observed in the varus deformity (both angles, p < 0.001) at baseline with more severe varus in the autograft group. No significant statistical differences in the measurements were observed (p = 0.257; 0.075) postoperatively in the groups and there was a neutral correction of the lower limb axis in both groups (Table 5).

Table 2

Comparison of baseline data between groups before and after alignment using PSM (Propensity Score Matching)

Patients characteristics		Comparison of baseline data between groups								
		before alignment using PSM					after alignment using PSM			
		controls (n = 171)		study group (n = 31)		P value	controls (n = 171)		study group (n = 31)		P value
		abs.	%	abs.	%		abs.	%	abs.	%	
Sex	F	134	78.4	25	80.6	> 0.999	26	83.9	25	80.6	> 0.999
	M	37	21.6	6	19.4		5	16.1	6	19.4	
Blood loss, mL	20	1	0.6	0	0	20: > 0.999, > 0.999	1	3.2	0	0	0.734
	25	1	0.6	0	0	25: > 0.999, > 0.999	0	0	0	0	
	30	2	1.2	0	0	30: > 0.999, > 0.999	0	0	0	0	
	50	150	87.7	24	77.4	50: 0.155, 0.466	24	77.4	24	77.4	
	100	13	7.6	7	22.6	100: 0.018*, 0.111	5	16.1	7	22.6	
	150	4	2.3	0	0	150: > 0.999, > 0.999	1	3.2	0	0	
Side of surgery	Left	84	49.1	21	67.7	**0.078**	18	58.1	21	67.7	0.600
	Right	87	50.9	10	32.3		13	41.9	10	32.3	
Age		65 [60; 72] 64.99 ± 9.13		65 [62; 68] 64.42 ± 9.03		0.875	64 [57; 66.5] 62.32 ± 9.79		65 [62; 68] 64.42 ± 9.03		0.289
BMI		32.44 [28.32; 37.23] 32.53 ± 6.26		31,62 [28.94; 34.29] 31.67 ± 5.01		0.435	33,28 [25.14; 37.52] 31.71 ± 6.71		31,62 [28.94; 34.29] 31.67 ± 5.01		0.816
Operating time, min		60 [55; 70] 62.6 ± 10.38		70 [60; 72.5] 69.19 ± 10.65		**0.001***	65 [60; 75] 68.71 ± 10.41		70 [60; 72.5] 69.19 ± 10.65		0.847
Preoperative contracture, °		9 [4,5; 13] 8.92 ± 5.21		12 [9; 14] 11.74 ± 3.27		**0.007***	12 [9; 15] 12.19 ± 3.6		12 [9; 14] 11.74 ± 3.27		0.745
ROM , °		90 [86; 95] 90.9 ± 6.6		89 [86; 92] 89.26 ± 4.58		0.156	90 [87; 95] 90.23 ± 5.78		89 [86; 92] 89.26 ± 4.58		0.435

Table 3

Number of patients with preoperative varus deformity in relation to the range (degrees) of femorotibial angles (aFTA)

Preop (aFTA)	Study group (n = 31)	Controls (n = 31)
	Number of patients	
0 – -10 degrees	10	25
-11 – -20 degrees	12	5
-21 – -30 degrees	5	1
-31 – -40 degrees	4	0
-41 – -50 degrees	0	0

Table 4

Number of patients with preoperative varus deformity in relation to the range (degrees) of femoral-knee-ankle angles (FKA)

Preop (FKA)	Study group (n = 31)	Controls (n = 31)
	Number of patients	
0 – -10 degrees	0	18
-11 – -20 degrees	14	7
-21 – -30 degrees	9	5
-31 – -40 degrees	4	1
-41 – -50 degrees	4	0

Table 5

Statistical values of radiological measurements of the lower limb axis in autograft group (study group) and no-autograft group (control group)

Angles	Study group (n = 31)			Controls(n = 31)			Mann-Whitney U test
	median [Q1; Q3]	mean ± SD	min/max	median [Q1; Q3]	mean ± SD	min/max	
Preop (aFTA)	-14 [-23.5; -9]	-16.71 ± 9.17	-35 – -4	-6 [-9; -3]	-7.03 ± 6.04	-28 – 0	P < 0.001*
Preop (FKA)	-25 [-31; -15]	-23.9 ± 10.3	-44 – -10	-9 [-14.5; -8]	-11.35 ± 7.78	-34 – 0	P < 0.001*
Preop (aFTA	4 [3; 5.5]	4.39 ± 1.63	2–8	5 [3; 6]	4.94 ± 1.79	3 – 9	P = 0.257
Preop (FKA)	-2 [-3; -0.5]	-1.42 ± 2.53	-7 – 4	-1 [-2.5; 2]	-0.23 ± 2.58	-4 – 5	P = 0.075

AFTA, femorotibial angle; FKA, femoro-knee-ankle angle; * statistically significant differences.

Clinical outcomes measured postoperatively with KSS and WOMAC improved in both groups and showed no statistical differences compared with the preoperative period. Two groups were statistically homogeneous in the preoperative and postoperative periods despite a large difference in the varus deformity in the study group at baseline. The results of the questionnaires are presented in Table 6.

Restructuring of the autograft was initially accompanied by radiological signs of sclerosis and heterogeneous zones of partial resorption were noted at the graft-bone interface with signs of bridging trabeculation at the area of contact within 6-18 months, and the graft-bone interface completely disappeared within 24 months (range, 12-36 months) (Fig. 4).

Non-progressive radiolucent lines < 2 mm were observed in 6 autograft cases and in 8 no-autograft cases. Radiolucent lines exceeding 2 mm were not found in any group. Loosening of the tibial component were noted in three cases. A single-stage revision surgery was performed in autograft group for aseptic loosening of the implant at 4 months after the operation. Two revision surgeries was performed for controls. A two-stage revision surgery was performed for septic loosening at 19 months, another one-stage revision surgery was produced for aseptic loosening at 45 months. Total 4,83 % of patients of both groups underwent revision surgery.

Table 6

Preoperative and postoperative clinical outcomes

Surveys	Preoperative		p value	Postoperative		p value
	study group	controls		study group	controls	
KSS*	50.58 ± 9.06	52.61 ± 8.92	0.334	78 ± 6.06	79.06 ± 6.02	0.432
KSSfs**	61.58 ± 5.03	63.06 ± 5.12	0.283	80.65 ± 4.67	81.1 ± 4.77	0.656
WOMAC, pain	16.81 ± 2.68	15.87 ± 2.09	0.138	5.32 ± 1.72	5.48 ± 1.63	0.688
WOMAC, stiffness	4.45 ± 1.65	4.32 ± 1.51	0.769	1.81 ± 0.91	1.81 ± 0.79	0.389
WOMAC, function	43.26 ± 8.17	42.16 ± 7.79	0.568	8.55 ± 1.29	8.52 ± 1.55	0.873

* KSS, KSS knee score, ** KSSfs, KSS function score.

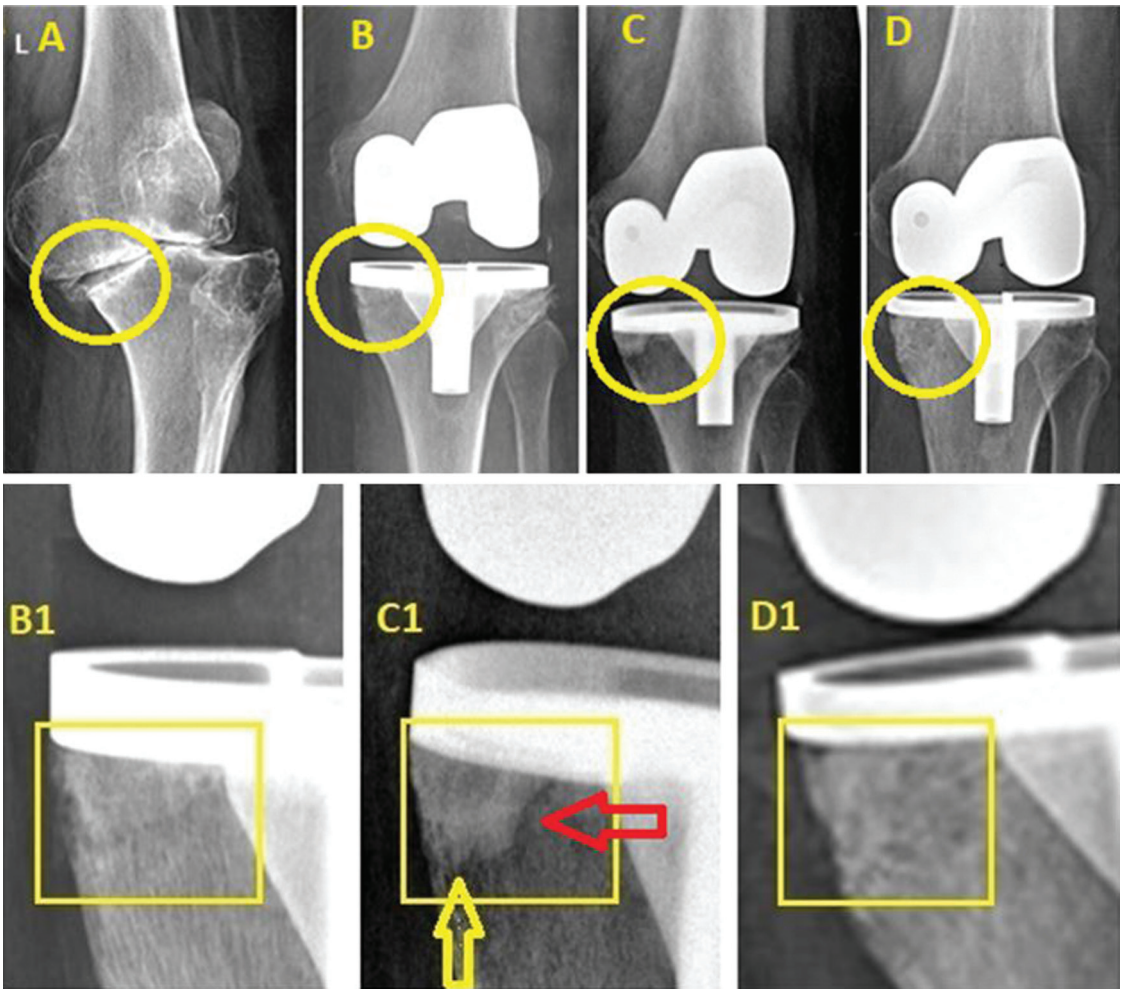

Fig. 4 Scale 1:1.1: (A) preoperative radiograph showing a bone defect of the medial tibial condyle; (B) control radiograph prior to discharge of the patient from the hospital (5-6 days after the surgery); (C) radiograph 7 months after surgery; (D) radiograph 24 months after surgery. Scale 1:4: (B1) no graft migration observed due to tight fixation at the area formed. The contact border seeb between the graft and the bone; (C1) partial sclerosis of the graft and bridge-like trabeculation formed in the distal direction (yellow arrow). Partial resorption observed at the identifiable graft-to-bone interface (red arrow); (D1) the graft completely reconstructed in the bone with no border seen between the graft and the bone

DISCUSSION

The use of modular metal blocks or cement to compensate for bone deficiency in primary TKA creates the conditions for a significant bone defect in subsequent revision surgeries. This is primarily due to the fact that neither the augment nor the cement can be incorporated into the bone tissue, and augmentation is associated with resection of a healthy bone providing less chances for subsequent conservative revision with the two methods. The plasty technique offered for tibial medial condyle defect facilitates good results of primary TKA with small and medium defects as graded by Insall without additional autograft fixation. The literature reports methods with the autograft to be additionally fixed with different metal constructs during primary TKA [14, 40–44]. Additional fixation of the autograft can destroy the cancellous bone like a scaffold disturbing the spatial arrangement of the bone trabeculae. In contrast, the bone autograft is not subjected to destruction of bone trabeculae with metal constructs using the method offered, and the most favorable conditions can be created for the migration of cellular elements (bridge migration) with subsequent transformation into a single trabecular architecture that can be examined radiologically. This was provided with three conditions: creation of a bone lock for strong and tight fixation of the graft, maximum preservation of the spatial orientation of the graft bone trabeculae and the presence of "blood dew" in the recipient bed. The method developed involves no donor beds from other anatomical areas of the skeleton, and the autograft is harvested from the bone structure during standard resection of the femur preparing the intercondylar

groove for the femoral component. Rehabilitation of patients who underwent autografting of the medial tibial defect during primary TKA were identical to those recommended for no-autograft patients.

The disadvantages of autograft include a limited use of the volume of the graft and a risk of nonunion with the recipient's bone, as in the case of an allograft [3, 14]. The timing of the disappearance of the "graft-bone" interface depends on the defect characterization and the patient's regenerative potential, that is, the larger the defect and the older the patient, the longer the time for complete reconstruction of the graft. Radiolucent lines greater than 2 mm is a predictor of early loosening of endoprosthetic components [45]. Non-progressive radiolucent lines, not exceeding 2 mm were observed in both groups with equal cases in each of the groups. There was no significant difference in the risk of component loosening in both groups. One autograft patient was diagnosed with aseptic medial dislocation of the tibial component at 4 months and underwent one-stage revision surgery. Primary arthroplasty in the patient was performed in 2014, at an early stage of performance. Early full weight-bearing on the lower limb caused the displacement of the graft. Postoperative instructions of careful use of the lower limb became part of the treatment protocol. One revision surgery was performed (0.31 %) in the study group and two revisions produced (0.62 %) for controls with no significant difference in the risk of revision in the study group.

Of the heterogeneous criteria used for comparison with the PSM method to form the control group, operating time and preoperative contracture of the knee were essential. The difference in the operating time in the autograft group was caused by additional minutes for processing the recipient bed and shaping the autograft. It was more difficult to explain why the preoperative contracture of the knee became heterogeneous in the baseline comparisons, and the ROM appeared to be a homogeneous criterion. The discrepancy could be explained by the presence of a bone defect in the posterior tibia. Increased flexion space in the knee joint of the study group occurred due to a posteromedial defect of the tibia and biomechanical posterior backspace of the medial femoral condyle during flexion. The medial femoral condyle shifted to the defect during flexion with increased flexion of the knee joint. With the defect located posteromedially, the medial femoral condyle rested on the anterior edge of the tibial defect that resulted in limited extension in the joint. There was a more pronounced flexion contracture in the study group and the same ROM compared to the controls. The method used to compare heterogeneous data PSM (Propensity Score Matching) in two groups facilitated more correct statistical postoperative comparison. The study confirmed our hypothesis with a significant difference in varus deformity and no differences in the scores of preoperative clinical questionnaires between the groups at baseline. There were no significant differences in the realigned axis of the lower limbs and in the scores of clinical questionnaires between the groups after the surgical treatment.

CONCLUSION

The technique we developed for the replacement of the medial tibial defect showed good results based on clinical and radiological examinations at 72 weeks. The use of autologous bone graft appeared to be a safe, affordable, inexpensive and effective method for small and medium medial tibial defects in primary TKA.

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The article was submitted 11.04.2022; approved after reviewing 30.05.2022; accepted for publication 30.08.2022.

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