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Local curvature mismatch may worsen the midterm functional outcomes of osteochondral allograft transplantation

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Abstract

Purpose This study aimed to determine the magnitude of local curvature matching in the sagittal plane between an implanted graft and the condylar region receiving the graft and to analyze its effect on clinical outcomes in patients undergoing osteochondral allograft transplantation (OCA).

Methods Patients who underwent knee OCA between 2016 and 2019 without circumferential step-off and were matched with a donor in accordance with the conventional matching process were included. The magnitude of donor-host local curvature matching was measured using postoperative sagittal magnetic resonance imaging data with Syngo (Siemens Medical Solutions, Forchheim, Germany) and GeoGebra (GeoGebra GmbH, Linz, AU) software. In addition to radiological evaluation, ROC analysis was performed to compare the patient-reported outcome measures (PROMs) obtained during the 2-year follow-up period among the patients in the SagA group, who had a graft match in the sagittal plane; SagB group, who had low convexity of the graft in the sagittal plane; and SagC group, who had high convexity of the graft in the sagittal plane in accordance with the determined indices.

Results The study included 27 patients who fulfilled the inclusion criteria, and the mean clinical scores of the SagC group were not statistically significantly higher than those of the other groups at any timepoint during the follow-up. The mean Tegner, IKDC, total KOOS and SF-12 physical and mental health scores of the SagC group were lower than those of the other two groups at various follow-up time points, particularly at month 24 ($p < 0.05$). There were no significant differences between the SagA and SagB groups in the PROMs at any of the follow-up time points (n.s.). The significant differences observed between the SagC group and the other groups in the mean KOOS scores for function in daily living and function in sport and recreation were also observed between the SagA and SagB groups at the follow-ups ($p < 0.05$).

Conclusion During OCA, a local curvature mismatch between the donor and the host involving large graft convexity may have a negative impact on midterm clinical outcomes. A preoperative analysis of the convexity relationship between the defect site and the graft region in the hemicondylar allograft to be used may enhance donor-host matching. The local analysis method described in the current study may also facilitate graft supply by ensuring donor-host matching without condyle-side and size matching.

Level of evidence III.

Keywords Osteochondral allograft · Articular cartilage · Knee · Curvature · Functional outcomes

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Introduction

Osteochondral allograft transplantation (OCA) is a cartilage restoration technique that involves cadaveric donor tissue and is generally preferred for larger lesions [7]. OCA has the advantages of a short operation time, a low risk of donor-site morbidity, and applicability to specific defect areas [9, 14]. Many studies have shown encouraging results of this technique [6, 8, 23]. It is of utmost importance to match the articular surface of the knee joint with the natural

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topographic anatomy during OCA [10–12, 30]. The failure to match these components may have a negative effect on the clinical outcomes [18]. Previous computer modeling and cadaver studies have shown that the contact pressure significantly increase when a graft is placed, with a 0.5–1 mm protuberance from neighboring cartilage tissue [10, 11].

Studies have been conducted to determine the most suitable graft site to enhance the topographic match between the donor and the host in autograft transfers [1, 19, 24, 26] and allograft transplantation [3, 17]. A condylar match is desired during the mentioned matching process since medial and lateral condyles differ in size, curvature and shape [13, 20]. Preoperative matching methods that can be considered alternatives to the conventional process have been proposed to improve donor-host matching. These methods were also developed to eliminate the challenges regarding the graft supply for medial lesions by enabling the use of condyles on different sides. In a cadaver study, it was shown that a graft-host match can be achieved well with the radius of curvature (RoC) technique, which is a method that addresses the femoral condyle as a whole. However, there were differences across condylar regions and graft sizes in the graft-host matching rates [3].

Although these studies have been conducted, no studies investigating the effects of a graft-host match in terms of curvature without circumferential step-off in the presence of a condylar side match have been conducted. This study may contribute to the existing literature by providing local matching information between donors and hosts in the defect region. In contrast to common conventional techniques, in which the condyle is considered as a whole, local matching is new and has not been defined in the literature. The results of this study may reveal the importance of local matching, and it may be possible to use the described method in the preoperative donor-host matching process. The local analysis method could also promote the graft supply by ensuring donor-host matching success without condyle-side and size matching. Thus, the local convexity relationship between the graft curvature and the condylar region receiving the graft was determined in the sagittal plane, and the effects of this relationship on clinical outcomes were analyzed. The hypothesis of this study was that a local curvature mismatch between the graft and the defect area where the graft is placed may adversely affect the clinical results, especially when the convexity of the graft is higher.

Materials and methods

This study was approved by the Yildirim Beyazit University Ethics Committee (approval no. B.30.2.YBU.006.06.01/108). The data collected from the patients who underwent OCA between 2016 and 2019 to treat cartilage damage in the knee by considering the condylar (medial to medial or lateral to lateral), laterality and size in the matching process were analyzed.

Inclusion criteria

The inclusion criteria for the present study were patients who (1) were between the ages of 18–45 years at the time of surgery, (2) were followed up for at least 24 months, (3) had isolated focal chondral or osteochondral lesions in the femoral condyle of the knee, (4) had International Cartilage Repair Society (ICRS) grade 3–4 lesions, (5) had lesions localized in the medial or lateral femoral condyles, (6) had traumatic or osteochondritis dissecans-related osteochondral lesions with bone loss of no more than 8 mm, (7) did not have a systemic or rheumatological disease, and (8) did not have a history or suspicion of infection in the knee joint.

Exclusion criteria

Patients who (1) had bipolar lesions and received multiple osteochondral plugs at the same or different defect locations, (2) had a history of revision due to a failed OCA, (3) had osteochondral lesions deeper than 8 mm, which may require additional grafting, (4) had nonfocal, degenerative cartilage injuries, (5) had malalignment or ligament injury in the lower limbs, (6) underwent corrective osteotomy, meniscal transplant surgery, ligament repair and such surgeries for concomitant pathologies, (7) were found to have meniscus lesions during intraoperative diagnostic arthroscopy or the magnetic resonance imaging (MRI) examination and received treatment for these lesions were excluded from the study. Patients in whom the level of cartilage around the allograft exhibited depression by more than 1 mm or a protuberance at any level relative to the neighboring cartilage tissue, as detected in the postoperative MRI examination, i.e., patients with circumferential step-off, were excluded from the study.

Surgical technique

The entire OCA procedure was performed by a single surgeon (MB) experienced in cartilage restoration in accordance with the technique described in the literature [5, 16, 29]. Upon evaluation of the intraarticular structures, the defect site was confirmed by diagnostic arthroscopy. A mini-arthrotomy was performed via a parapatellar incision on the side of the condyle with a lesion. The defect site was marked after the appropriate size was determined with cylindrical cannulated measurement equipment. After sizing, the defect site was reamed up to nearly 8–10 mm in depth until the normal bone bed was reached. The graft was prepared from an area of the hemicondyle allograft that corresponded to the defect localization. The depth of the defect site was measured at 4 points of the lesion and matched to the donor tissue by marking. The prepared graft was then placed by press-fit fixation, and efforts were made to avoid circumferential step-off with a depression of more than 1 mm or a protuberance at any level. None of the patients required additional fixation materials following the graft stability assessment.

Radiologic evaluation

Data were collected at postoperative week 8 using the following MRI technique to perform a detailed analysis of all the patients who satisfied the inclusion criteria.

All MRI exams were performed with a 3 T (3 T) MRI machine (Trio, Siemens, Erlangen, Germany) and 32-channel coil. During the MRI scan, the knee joint was in slight flexion, and the patients were placed in a feet-first supine position. With MRI, two-dimensional (2D) T1-weighted turbo spin-echo and 2D T2-weighted (W) turbo spin-echo (TSE) (TR /TE 4000/71 ms, slice thickness (sth) 4 mm) images were taken in the sagittal and coronal planes. Three-dimensional (3D) proton density W (3D-PDW) space (TR /TE 1200/32 ms, sth 0.5 mm) and 3D volume-interpolated breath-hold examination (3D-VIBE) (TR /TE 9.8/4.9 ms, sth 0.63 mm) images were taken in the sagittal plane. T2W Trufi 3D (TR /TE 8.8/3.8 ms, sth 0.4 mm) and T2 3D short tau inversion recovery (T2-STIR) (TR /TE 5100/42 ms, sth 0.63 mm) images were taken in the coronal plane. For all 3D sequences, isotropic voxel sizes ($< 1\ mm^3$) were used, and multiplanar reformatted images were also taken. The field of view (FOV) was 15–16 cm, and the matrix size was 256–512/256–512.

Measurement technique

Measurements concerning donor-host curvature matching were taken on the sagittal MR images for all patients included in the study with the commercially available post-processing software Syngo (version VA20B, Siemens Medical Solutions, Forchheim, Germany). The distal cartilage margins of the implanted graft and the graft circumference of the condyle that received the graft were identified in detail on the magnified images using a function that creates an arc with modifiable convexity and measurable length by using the intact cartilage as a reference and the projection of the cartilage margins of the condyle that was created within the graft-implanted area (Fig. 1). The arcs, whose lengths were known, for the articular cartilage margins of the graft and host condyle were transferred to the online geometry calculating platform GeoGebra (GeoGebra GmbH, Linz, AU) [2] in the Portable Network Graphics (.png) format, and tangents were created separately on each arc according to the measurement technique in Fig. 2. Based on fundamental calculus knowledge, the mean curvature of the arc (K) was calculated as the ratio of the angle between tangents ($\Delta\alpha$) to the length of the arc (Δs). Therefore, the curvature index (K_{index}) was calculated from the ratio of the mean curvature of the implanted graft (K_1) to the mean curvature of the condyle in the defect site (K_2):

$$K_{index} = \frac{K_1}{K_2} = \frac{\frac{\Delta\alpha 1}{\Delta s1}}{\frac{\Delta\alpha 2}{\Delta s2}}$$

Using the abovementioned measurement technique, the patients included in the study were divided into group SagA, which had a graft match in the sagittal plane; group SagB, which had low convexity of the graft in the sagittal plane; and group SagC, which had high convexity of the graft in the sagittal plane, according to the statistical analysis results of the $K_{\mathbf{index}}$ values for the surface convexity of the implanted allograft and the convexity of the condyle that received the graft. Double-blinded MRI measurements for each patient were conducted by four orthopedists (MB, SG, MES, MA). The arc index of measurement reliability was assessed using the intraclass correlation coefficient (ICC). The interobserver ICC was 0.84, and the intraobserver ICC was 0.86 for the K_1 index measurements. The interobserver ICC was 0.82, and the intraobserver ICC was 0.88 for the K_2 index measurements. Among all measurements, the highest margin of error was 0.4 for the K_1 index and 0.9 for the K_2 index.

Clinical evaluation

The patient-reported outcome measures (PROMs) obtained from the patients after they completed the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form; Knee injury and Osteoarthritis Outcome Score (KOOS) and KOOS subscales; Tegner Activity Index and 12-Item Short Form Health Survey (SF-12) Mental and Physical subscales preoperatively and throughout follow-up period were compared among the curvature index groups [21, 22, 25, 28].

Statistical analysis

Statistical analysis was performed using SPSS software (Version 17.0, SPSS Inc., Chicago, IL, USA). Normally distributed continuous variables are expressed as mean ± standard deviation values [$p > 0.05$ in Shapiro Wilk test ($n < 30$)], and the continuous variables that were not normally distributed are expressed as median values. Comparisons between the groups were performed using one-way ANOVA for the normally distributed data and the Kruskal–Wallis test for the data that did not have a normal distribution. For statistically

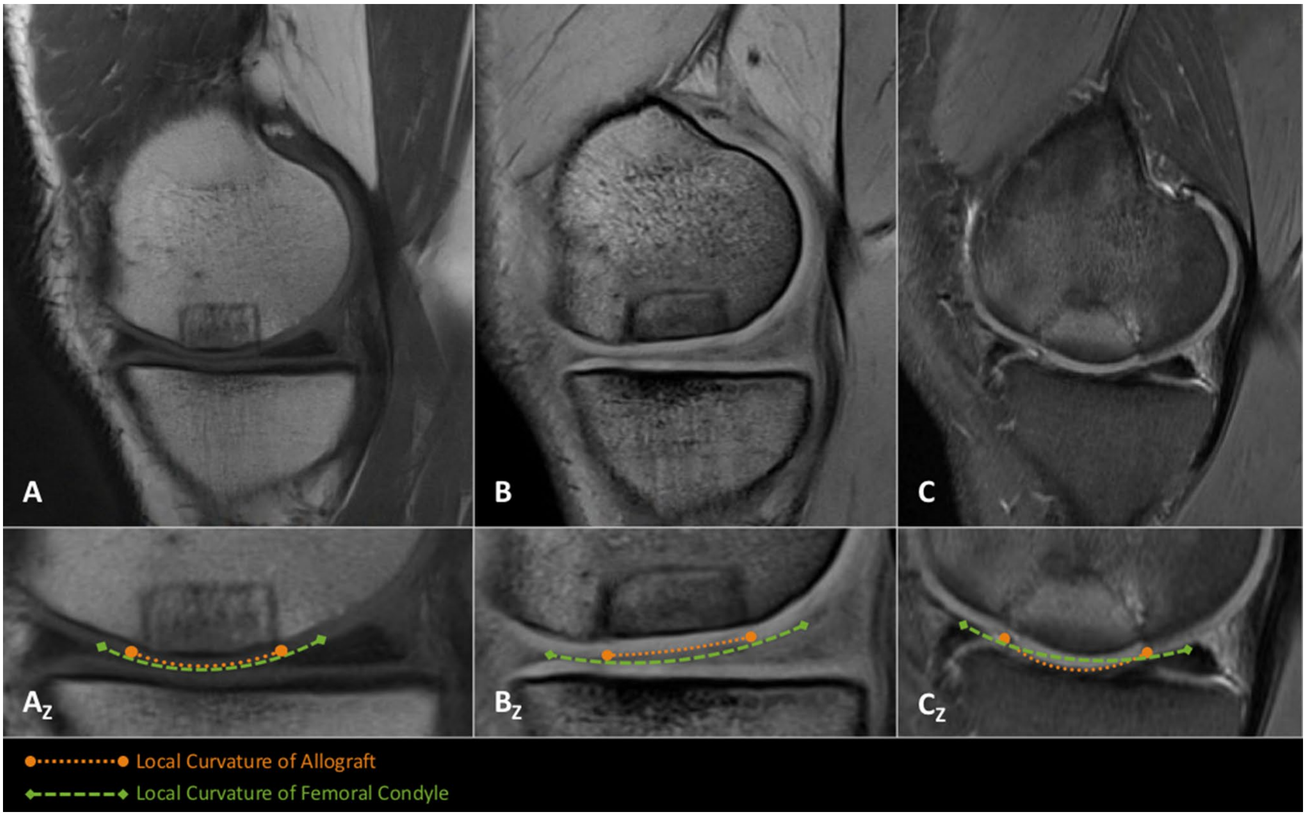

Fig. 1 From the analysis of the magnetic resonance imaging (MRI) data, (**a**) a sagittal MR image of a patient with curvature index match between the graft and condyle region and (A_Z) a drawing of the local curvature cartilage margins of the condyle and the graft made by magnifying the same image; (**b**) an image of a patient with lower graft convexity than that of the condyle and (B_Z) local curvature margins; (**c**) an image of a patient with a higher graft convexity than that of the condyle and (C_Z) local curvature margins. The orange arrows indicate the local curvature of the allograft, and the green arrows indicate the local curvature of the femoral condyle

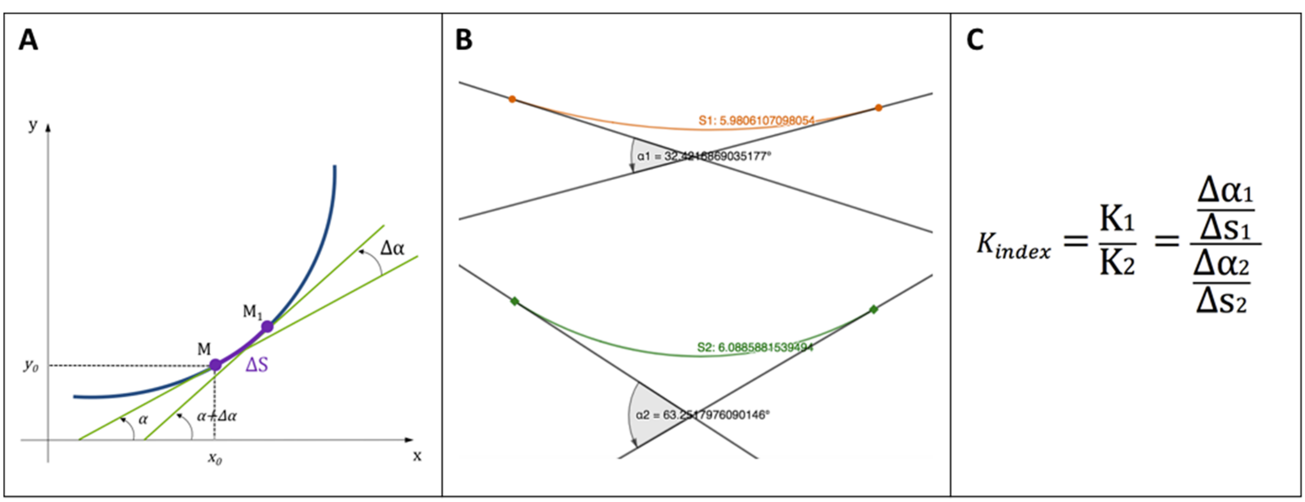

Fig. 2 **a** Schematization of the method used to calculate the mean curvature for each plane arc by radiologic evaluations of the curvature match. Based on fundamental calculus formulas, the mean curvature (K) of the plane arc between the points of M and M1 was calculated as the ratio of the angle between tangents (Δα) passing through M and M1 to the length of the arc (Δs). (**b**) The arcs for the articular cartilage margins of the graft and host condyle obtained in the postprocessing software environment from the MR images were transferred to the online geometry calculating platform GeoGebra (GeoGebra GmbH, Linz, AU), and the measurements were conducted separately for each arc in accordance with the technique shown in Fig. 1a. **c** The curvature index (K_{index}) for a patient was calculated according to the provided equation using the mean curvature values of the graft (K_1) and the defect site in the condyle (K_2)

significant effects identified by analysis of variance, comparisons were performed using the post hoc Bonferroni test. The categorical variables were compared between the groups using the Chi square test. Prepost data comparisons were performed using the Greenhouse Geisser test for repeated measures. When significant effects were identified by analysis of variance, comparisons were performed using the paired *t* test or Wilcoxon test. Receiver operating characteristic (ROC) curve analysis was performed to determine the cutoff values for the groups. $P<0.05$ was considered statistically significant. Bonferroni correction was used to adjust the p value for each hypothesis (0.05/groups). $P<0.017$ was considered statistically significant. A post hoc power analysis for detecting differences in measurements between the three groups was conducted. The statistical software G*Power (Erdfelder, Faul, Germany, 2014) was used for power analyses. Based on the ANOVA results, an effect size of 0.86 ($\alpha=0.05$), and a sample size of 29 patients, the statistical power was calculated to be 0.88.

Results

Of the 33 patients who underwent OCA transplantation, the following patients were excluded from the study: (1) two patients who underwent corrective osteotomy, (2) one patient who underwent meniscal allograft transplantation and (3) three patients who had and received treatment for meniscal and anterior cruciate ligament pathologies. A total of 27 patients (19 male, 7 female) who met the inclusion criteria were included in the study. A summary of the demographic characteristics of the patients who were included stratified by group is provided in Table 1. There were no statistically significant differences between the groups in the baseline characteristics of the patients ($p>0.05$).

According to the ROC curve analysis of the obtained curvature measurements, the donor-host curvature match was considered suitable with 100% probability, 100% sensitivity and 100% specificity if the condition $0.830<K_{index}<1.257$ was satisfied (Fig. 3). According to the statistical analysis, the cutoff values for the patients grouped according to the donor-host match were as follows: $K_{index}=0.83–1.257$ for group SagA ($n=14$), with a graft match in the sagittal plane; $K_{index}<0.83$ for group SagB ($n=7$), with low graft convexity in the sagittal plane; and $K_{index}>1.257$ for SagC ($n=6$), with high graft convexity in the sagittal plane.

The mean clinical scores of the SagC group were not significantly higher than those of the other groups at any time point during the follow-up period. The mean Tegner, IKDC, total KOOS and SF-12 physical and mental health scores of the SagC group at different follow-up time points were significantly lower than those of the other two groups, and the difference was statistically significant ($p<0.05$). There were no statistically significant differences between the SagA and SagB groups at any of the follow-up time points (n.s.) (Table 2 and Fig. 4). According to the detailed analysis of the KOOS subscales, the mean KOOS subscores of the SagC group were significantly lower than those of the other two groups, similar to the results shown in Table 2, except the KOOS function in daily living (KOOS ADL) and function in sport and recreation (KOOS Sport/Rec) between the SagB and SagC groups. Significant differences in terms of the mean KOOS function in daily living (KOOS ADL) and function in sport and recreation (KOOS Sport/Rec) scores were also observed between the SagA and SagB groups at postoperative follow-up periods ($p<0.05$) (Table 3 and Fig. 5).

Discussion

The most important finding of the present study is that when the convexity of the graft placed during OCA is higher than the convexity of the condyle, the midterm functional outcomes are negatively impacted. Moreover, it was observed that the convexity of the graft being lower than that of the

Table 1 Baseline Characteristics

	SagA ($n=14$) Mean ± SD	SagB ($n=7$) Mean ± SD	SagC ($n=6$) Mean ± SD	*p* value
Age (years)	30.1 ± 8.5	32.6 ± 10.2	27.2 ± 6.4	n.s
BMI (kg/m^2)	26.7 ± 3.7	27.8 ± 5.3	24.8 ± 3.8	n.s
Defect: condyle Ratio	0.24 (0.1–0.4)	0.24 (0.2–0.4)	0.24 (0.2–0.3)	n.s
Graft Size (mm)	21.4 ± 2.7	21.0 ± 3.5	21.8 ± 2.8	n.s
Follow-up (months)	30.2 ± 4.7	30.3 ± 5.0	29.7 ± 4.9	n.s
Sex (F/M)	5/9	1/6	1/5	n.s
Knee Side (L/R)	3/11	1/6	3/3	n.s
Condyle (L/M)	5/9	2/5	3/3	n.s

BMI Body mass index, *F/M* Female/Male, *L/R* Left/Right, *L/M* Lateral/Medial, *n* Number of Patients, *SD* Standard Deviation

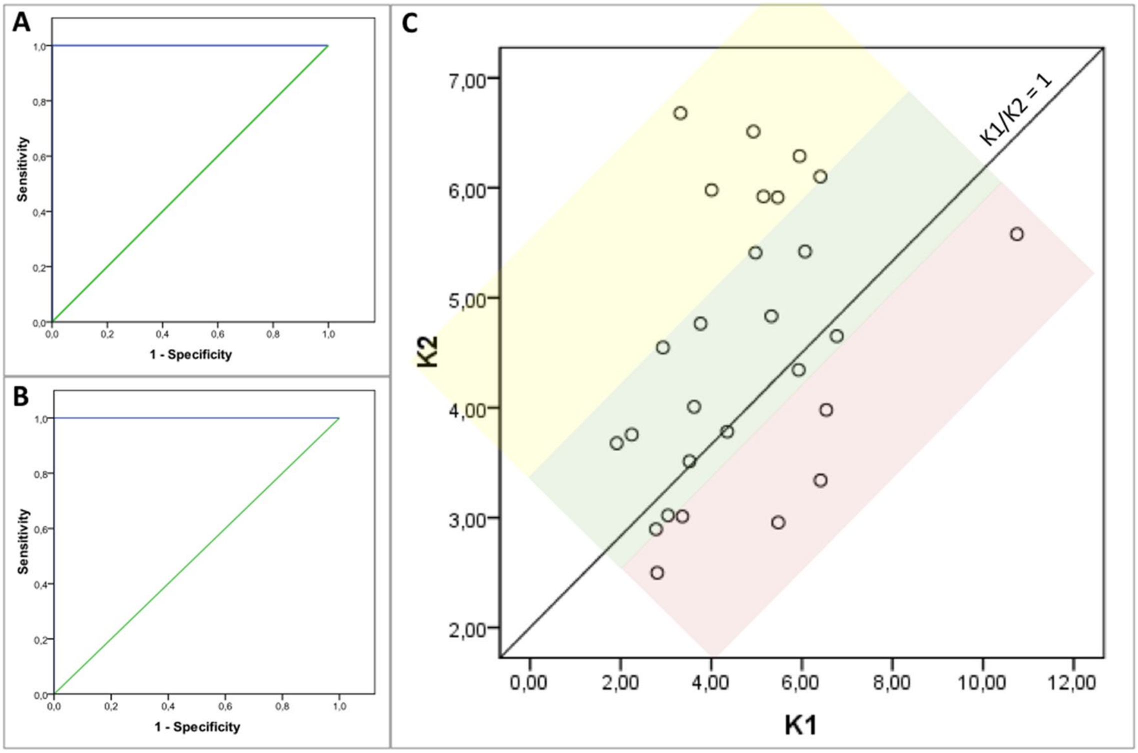

Fig. 3 A graph of the receiver operating characteristic (ROC) curve analysis that was conducted to determine the (**a**) lower and (**b**) upper cutoff values for the donor-host match groups in accordance with the curvature index (K_{index}) values between the surface convexity of the implanted allograft and the convexity of the condyle that received the graft. **c** Dot graph showing the index values with respect to the ratio of the mean curvature of the implanted graft (K_1) to the mean curvature of the condyle in the defect site (K_2). The green area indicates the SagA group, with a graft match in the sagittal plane; the yellow area indicates the SagB group, with low convexity of the graft; and the red area indicates the SagC group, with high convexity of the graft in accordance with the determined indices

condyle did not affect the functional outcomes. These results reveal the effect of local matching between the donor and host on clinical outcomes. The preoperative magnitude of donor-host matching in the patients included in the study was determined according to conventional techniques in which the dimensions of the entire condyle were considered. In conventional matching, the local measurement method described in the current study for assessing local matching in the defect region could not be fully achieved. This issue may affect the clinical results, especially when the graft has a large convexity.

Practices that do not require condyle-specific matching have also been discussed to overcome challenges in medial graft supply. Wang et al. compared 50 orthotopic (lateral-to-lateral condyle or medial-to-medial condyle) and 27 non-orthotopic (lateral-to-medial condyle or medial-to-lateral condyle) OCA procedures [27]. In that study, there were no statistically significant differences between the nonorthotopic group and the orthotopic group in terms of the reoperation and failure rates, as well as the SF-36 and IKDC scores and KOOS, during the mean follow-up duration of 4 years. In their study, Wang et al. only used condyle size for donor-host matching and reported that the grafts were placed without a step-off. However, the study did not provide a detailed analysis of the graft-host relationship between the groups. The results of this study suggest that condylar matching, which is considered an important parameter in conventional matching, is not the most important criterion and that there may be other criteria more important for clinical success.

Yanke et al. conducted a detailed topographic analysis of the same and different condyle applications with different combinations of size matches and mismatches in computed tomography (CT)-based computer modeling study involving 22 (11 medial and 11 lateral) femoral hemicondyles. Although there were no statistically significant differences between the groups in terms of prominence with respect to the femoral condyle surface, the modeling results showed that the extent of mismatching increased with the graft diameter [31]. In the mentioned study, it was also shown that condylar (medial–lateral) matching may not be the most important parameter for donor-host matching. Additionally, considering that defect size may affect matching in the presence of condyle size matching, preoperative local curvature analysis may be useful to improve donor-host matching in the defect region.

Table 2 The changes in clinical outcomes that occurred over the follow-up period and comparisons between the groups

	SagA (*n* = 14) Mean ± SD	SagB (*n* = 7) Mean ± SD	SagC (*n* = 6) Mean ± SD	*p* value	$p_{A\&B}$	pA&C	pB&C
Tegner Lysholm							
Preop	30.2 ± 4.5	30.6 ± 5.6	31.8 ± 5.0	n.s	–	–	–
F/U 12th	73.4 ± 5.6	72.6 ± 6.4	61.3 ± 9.9	0.004	n.s	0.004	0.022
F/U 24th	85.7 ± 8.9	82.0 ± 9.2	68.3 ± 11.9	0.004	n.s	0.004	0.045
IKDC							
Preop	31.3 ± 7.9	31.9 ± 3.4	31.2 ± 4.6	n.s	–	–	–
F/U 12th	63.8 ± 8.7	63.8 ± 3.7	57.1 ± 8.1	n.s	–	–	–
F/U 24th	79.7 ± 7.6	76.4 ± 8.2	62.2 ± 12.1	0.029	n.s	0.006	0.046
KOOS							
Preop	29.9 ± 12.3	30.8 ± 11.8	30.1 ± 6.5	n.s	–	–	–
F/U 12th	74.9 ± 5.3	73.6 ± 11.8	67.1 ± 7.7	n.s	–	–	–
F/U 24th	82.6 ± 7.9	79.3 ± 7.1	70.3 ± 10.9	0.021	n.s	0.016	0.045
SF-12 Physical							
Preop	36.5 ± 9.7	35.4 ± 3.0	35.2 ± 7.3	n.s	–	–	–
F/U 12th	49.2 ± 5.9	45.7 ± 4.5	43.2 ± 4.6	n.s	–	–	–
F/U 24th	53.6 ± 5.4	49.7 ± 6.8	44.7 ± 7.2	0.038	n.s	0.042	0.019
SF-12 Mental							
Preop	37.2 ± 10.5	38.3 ± 2.6	38.7 ± 3.4	n.s	–	–	–
F/U 12th	55.6 ± 6.7	53.6 ± 4.5	47.2 ± 4.7	0.01	n.s	0.004	0.022
F/U 24th	57.9 ± 6.1	55.6 ± 5.9	50.0 ± 4.9	0.021	n.s	0.008	0.009

n Number of patients, *SD* Standard Deviation, *F/U* Follow-up month, *n.s* nonsignificant, *IKDC* International Knee Documentation Committee Subjective Knee Form, *KOOS* Knee injury and Osteoarthritis Outcome Score, *SF-12* 12-Item Short Form Health Survey

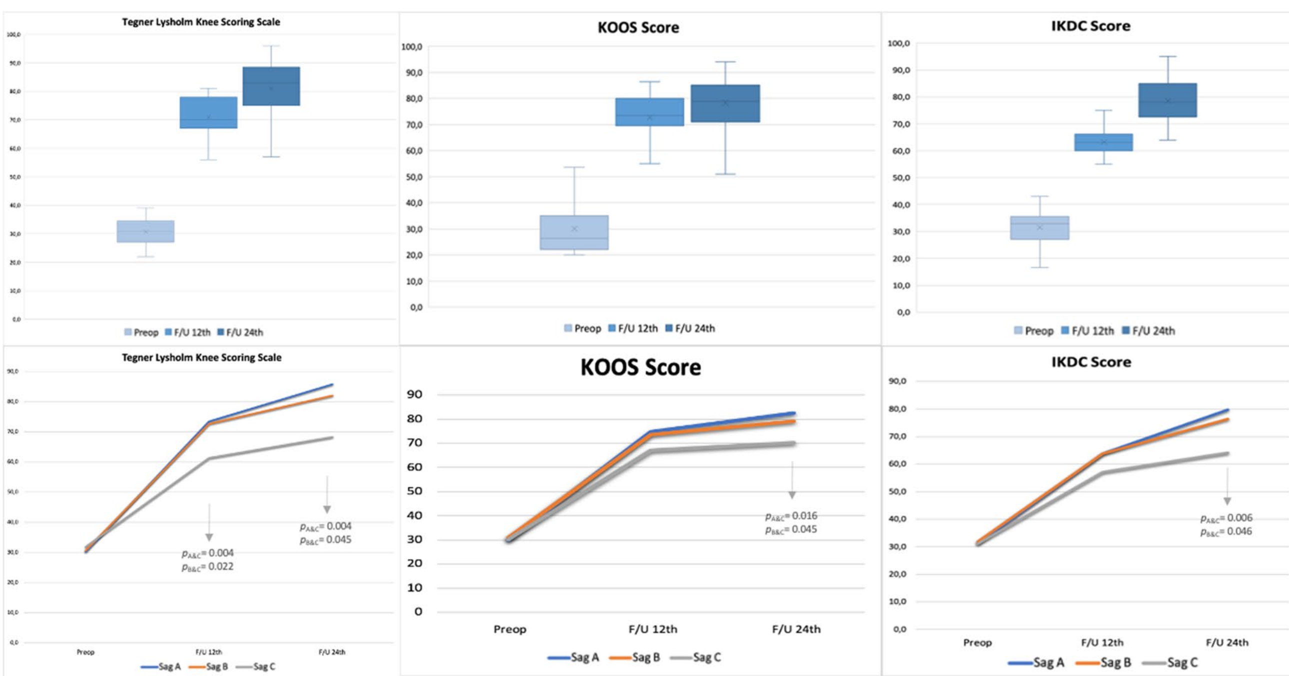

Fig. 4 The changes in the patient-reported outcome measures (PROMs), including (**a**, **d**) the Tegner Activity Index; (**b**, **e**) knee injury and osteoarthritis outcome score (KOOS) and (**c**, **f**) International Knee Documentation Committee (IKDC) subjective knee score at the follow-up (F/U) time points. The arrows indicate the statistically significant differences between groups at the time intervals

Table 3 The changes in the Knee injury and Osteoarthritis Outcome Score (KOOS) subscores that occurred over the follow-up period and comparisons between the groups

	SagA (*n* = *14*) *Mean* ± *SD*	SagB (*n* = *7*) *Mean* ± *SD*	SagC (*n* = *6*) *Mean* ± *SD*	*p* value	$p_{A\&B}$	pA&C	pB&C
Symptoms							
Preop	27.4 ± 4.3	27.1 ± 4.1	28.8 ± 4.3	n.s	–	–	–
F/U 12th	77.6 ± 3.7	74.9 ± 4.9	65.7 ± 6.4	0.0001	n.s	0.001	0.005
F/U 24th	88.3 ± 3.9	85.9 ± 5.1	70.3 ± 9.2	0.0001	n.s	0.0001	0.0001
Pain							
Preop	22.5 ± 1.9	22.9 ± 3.6	22.5 ± 4.8	n.s	–	–	–
F/U 12th	68.5 ± 8.2	66.8 ± 6.6	60.4 ± 9.4	n.s	–	–	–
F/U 24th	83.1 ± 5.1	77.9 ± 4.6	66.5 ± 9.7	0.0001	n.s	0.001	0.010
ADL							
Preop	23.8 ± 3.1	24.1 ± 2.1	24.1 ± 5.1	n.s	–	–	–
F/U 12th	70.2 ± 1.9	60.2 ± 9.5	58.1 ± 8.1	0.003	0.031	0.001	n.s
F/U 24th	82.6 ± 5.8	71.9 ± 5.6	66.5 ± 11.9	0.001	0.022	0.0001	n.s
Sport/Rec							
Preop	12.3 ± 5.4	12.1 ± 4.2	13.3 ± 4.4	n.s	–	–	–
F/U 12th	67.3 ± 8.9	53.6 ± 11.6	43.7 ± 9.3	0.001	0.001	0.0001	n.s
F/U 24th	84.0 ± 8.8	72.0 ± 12.5	64.3 ± 10.7	0.016	0.001	0.0013	n.s
QoL							
Preop	15.6 ± 4.5	15.8 ± 2.6	16.5 ± 3.6	n.s	–	–	–
F/U 12th	75.1 ± 5.7	73.4 ± 4.6	59.0 ± 14.4	0.001	n.s	0.001	0.012
F/U 24th	79.4 ± 14.9	75.2 ± 12.9	68.0 ± 9.1	n.s	–	–	–

n Number of patients, *SD* Standard Deviation, *F/U* Follow-up month, *n.s* nonsignificant, *ADL* Function in Daily Living, *Sport/Rec* Function in Sport and Recreation, *OoL* Quality of Life

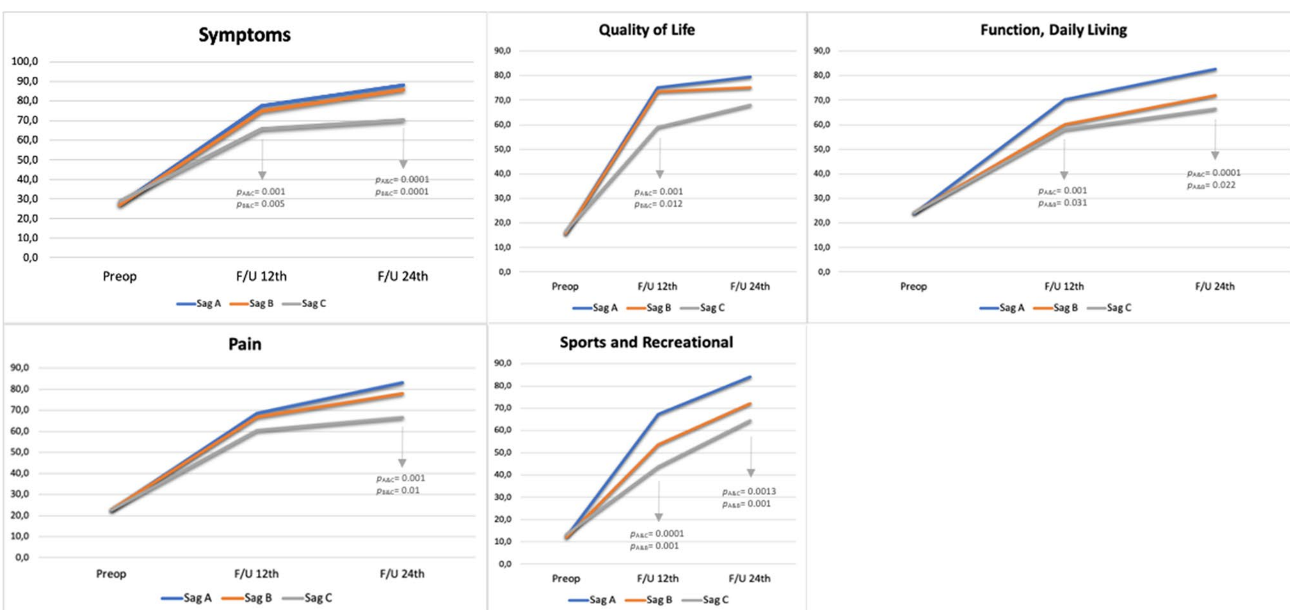

Fig. 5 The changes in knee injury and osteoarthritis outcome score (KOOS) subscores at the follow-up (F/U) time points. The arrows indicate the statistically significant differences between groups at the time intervals

In the present study, it was shown that conventional matching methods such as side, laterality and size matching may still lead to a mismatch between the graft curvature and the local curvature at the defect site, even without circumferential step-offs and that this issue could negatively impact the clinical outcomes. The functional outcomes were significantly poorer at various follow-up time points when the graft convexity was higher than the convexity of the local curvature at the defect site of the femoral condyle ($p < 0.05$).

Bernstein et al. [3] conducted a study with the hypothesis that a donor-host matching process conducted according to the radius of curvature (RoC) technique, which weighs the femoral condyle curvature more heavily than does the conventional matching process, would improve the donor-host matching results and investigated the level of matching between the graft and condyle using a high-resolution laser scanner following procedures performed on cadavers. The mentioned study demonstrated that 100% matches could be achieved with a defect diameter of 20 mm; however, the match rate decreased as the diameter of the defect increased. Overall, it was stated that the RoC technique provided a 3.2-fold higher match rate than did the conventional technique.

As seen in these two studies [3, 31], variables such as defect size and morphometric characteristics of the condyle may limit donor-host matching, particularly with the conventional method as well as the other available alternative methods. The results of the current study also showed that such a mismatch may affect the outcomes. Preoperative evaluations of the surface curvature properties of the graft area that is to be harvested from the allograft and the defect site performed using the computer modeling technique employed in the abovementioned study by Yanke et al. [31], the measurements made on MR images in the present study or similar measurement techniques may help improve the donor-host matching results. The importance of considering cartilage thickness in local curvature matching measurements should also be noted for future developments. The thickness of the articular cartilage can differ according to the condyle (medial, lateral) and the location on the condyle (anterior, middle, posterior) [4, 15]. Measurements conducted only on radiographs may neglect the cartilage thickness, thereby possibly leading to a surface topography mismatch.

A strength of this study was that it investigated the effects of the differences between graft and condyle local curvatures on clinical outcomes regarding matching in accordance with the conventional parameters, which have not been mentioned previously in the literature. Another strength of this study was that it described a method of assessing local curvature mismatches that is easy to perform and relies on the differences in convexity, and this method also has the potential to become commonly used for preoperative analysis and may improve donor-host matching. In addition, the present study had some limitations. The major limitations of the study were that the number of patients was small and the follow-up period was relatively short. The small number of patients in the groups is thought to cause unexplained changes in functional scores due to issues in statistical analysis. Another important limitation of the study is its retrospective design. The effectiveness of the described method should be evaluated by a prospective study in which donor-host matching is determined according to the method described in the current study. Although none of the patients exhibited failure within the 2-year follow-up period, the study did not include radiologic data that allowed the detection of possible changes throughout the patient follow-up period, which was another important limitation. The other limitations of the study include the absence of detailed data for the preoperative matching of the patients included in the study and the lack of analysis in the coronal plane in addition to the sagittal plane.

In addition to donor-host matching techniques that consider the whole condyle, the local measurement method described in this study may improve the local donor-host curvature matching results. In addition, it can help to overcome the graft supply issue, which is one of most important issues in allograft transplantation, by facilitating the identification of the allograft that fits locally to the defect area, without the need to determine the condyle side and size compatibility, as with conventional techniques.

Conclusion

Local curvature mismatching involving particularly large graft convexity between the donor and the host may negatively impact the midterm clinical outcomes of OCA. A preoperative analysis of the convexity relationship between the local curvature of the defect site and the graft region in the hemicondylar allograft could be performed in order to improve donor-host matching.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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