# Early Postoperative CT Scan Provides Prognostic Data on Clinical Outcomes of Fresh Osteochondral Transplantation of the Knee

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**Background:** There is a lack of information regarding the ability of imaging studies to predict clinical outcomes after fresh osteochondral allograft (FOCA) transplantation of the knee.

**Purpose:** To determine the value of computed tomography (CT) scans to predict the clinical outcome of FOCA transplantation using the assessment computed tomography osteochondral allograft (ACTOCA) score.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** We prospectively collected data from all consecutive patients who underwent FOCA transplantation for osteochondral knee lesions at one institution between August 2017 and August 2019. All patients were followed up for a minimum of 2 years. CT scans performed 6 months after surgery were evaluated by a musculoskeletal radiologist using the ACTOCA scoring system. The radiologist was blinded to the patient's medical history. Clinical outcomes were assessed preoperatively and at 12 and 30 months postoperatively using the International Knee Documentation Committee (IKDC) score, the Kujala score, the Tegner activity scale, and the Western Ontario Meniscal Evaluation Tool (WOMET) score.

**Results:** A total of 38 cases were included. The ACTOCA score at 6 months after surgery showed a statistically significant correlation with clinical results at 12 and 30 months. The correlation was better at 30 months, showing a high negative correlation with the IKDC score (−0.663) and a moderate negative correlation with the Kujala, WOMET, and Tegner scores (−0.593; −0.547, and −0.593, respectively) ($P < .001$).

**Conclusion:** A statistically significant correlation between the mean ACTOCA score on CT scans at 6 months and the clinical results measured by the IKDC, Kujala, WOMET, and Tegner scores at 30 months confirmed the predictive value of the ACTOCA score for use in clinical practice.

**Keywords:** cartilage repair; computed tomography scoring system; osteochondral allograft; prognostic value

Fresh osteochondral allograft (FOCA) transplantation is a useful treatment option for focal osteochondral lesions larger than 2 $cm^2$ in the knee. It achieves good clinical outcomes, including an improvement in range of motion (ROM) and a high probability of return to play.[6,23,26,29] Previous studies suggest that age, body mass index (BMI), previous surgical procedures in the involved knee, uncorrected malalignment, bipolar transplantations, and large (>10 $cm^2$) and chronic lesions are associated with less favorable results[9,10,20,22]; however, the ability to predict the clinical outcome is limited. Several imaging modalities have been performed to assess the transplanted allograft but none have yet been shown to clinically predict outcomes.

Imaging assessment of bone aspects, such as cystic changes and osseous integration, is key to determining graft survival after FOCA transplantation.[1,16] Magnetic resonance imaging (MRI), unfortunately, has not provided strong evidence to predict clinical outcomes after this procedure,[8,28] and computed tomography (CT) has demonstrated

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a considerably higher spatial resolution to accurately evaluate bone aspects like osseous integration and cystic changes.[24,27] Recently, a semiquantitative assessment computed tomography osteochondral allograft (ACTOCA) scoring system was developed and shown to be reliable.[11] This new score includes 5 CT features that are relative to the aspect of the host bone and the transplanted graft (graft signal density, osseous integration, surface percentage with a discernible cleft, cystic changes, and presence of intra-articular fragments). Early prediction of these FOCA features that will likely present lower clinical scores is of high clinical relevance.

The purpose of this study was to determine the value of CT scans using the ACTOCA score to predict the clinical outcome of FOCA transplantation of the knee. The hypothesis was that an early assessment after FOCA transplantations using the ACTOCA score would help to predict later clinical outcomes.

## METHODS

We performed a prospective case series study that included all consecutive patients who underwent cartilage repair with FOCA transplantation for osteochondral knee defects at an academic medical center between August 2017 and August 2019. All surgeries were performed by a single surgeon (P.E.G.).

The inclusion criteria were as follows: patients aged between 18 and 50 years who had a FOCA transplantation for osteochondral knee lesions. The main indication for FOCA transplantation was large, focal full-thickness chondral and osteochondral defects ($>2$ cm$^2$) on the femoral condyles, trochlea, and/or patella.

Concomitant realignment osteotomy was performed in the case of tibiofemoral FOCA with tibiofemoral malalignment $>3°$ from the neutral mechanical axis into the involved compartment. Patellofemoral maltracking was also addressed with tibial tubercle osteotomy if the TT-TG distance was $>15$ mm.

The exclusion criteria were as follows: concomitant meniscal insufficiency; inflammatory arthritis; large degenerative lesions comprising all 3 compartments; BMI $>30$; systemic inflammatory diseases; infection or history of osteomyelitis in the graft recipient area; and active neoplasia.

The study was approved by the clinical research ethics committee at our institution (IIBSP-ALO-2018-21) and conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Informed consent was obtained from all individual participants included in the study.

### Surgical Technique

In all cases, a complete arthroscopic evaluation of all the compartments of the knee was conducted to confirm the size and depth of the lesion and to address any concurrent intra-articular pathology. Any anatomic or biomechanical alteration of the tibiofemoral and/or patellofemoral joints was corrected to avoid further cartilage degradation of the graft.

The local authorized tissue bank supplied the allografts and performed all the preoperative graft processing.[12-14] Osteochondral grafts were obtained from donors aged $<45$ years, with a mean age of 31 years (range, 18-44 years). Once a donor was available, grafts were harvested within the first 12 hours of death. The osteochondral allograft (OCA) was placed into a transport medium (lactated Ringer solution) and preserved and refrigerated between 4°C and 8°C. On arrival at the tissue bank, the graft was prepared and cleansed in a Class A clean room. Soft tissue and periosteum were then removed. High-pressure pulsatile lavage irrigation and dry centrifugation and centrifugation were performed with sterile phosphate-buffered saline. Microbiological testing was performed on both the graft and the last wash solution. The allograft was then placed in a solution with lactated Ringer solution and an antibiotic cocktail consisting of vancomycin (50 mg/mL), tobramycin (3 mg/mL), cotrimoxazole (160 mg/mL), and amphotericin (125 m g/mL). Five days later, microbiological testing was again performed on both the preservation solution and the graft. The graft was kept refrigerated between 4°C and 8°C until implant at a maximum of 3 weeks from harvesting.

After sizing the articular defect using a sterile ruler, we placed a reamer over the identified lesion and slowly advanced to a depth of approximately 8 to 10 mm with continuous cold saline irrigation. The FOCA was accordingly prepared and washed with high-strength pulsatile lavage to eliminate as many blood cells as possible. In cases of isolated defects with a well-circumscribed affected area in an easily accessible surface of the knee—such as the femoral condyle, midpatella, or trochlea—a bone-dowel technique was performed (JRF-Ortho Instrument Set, JRF Ortho). The shell technique was used for asymmetrical and extensive lesions, such as whole patellar and high-degree trochlear dysplasia. Press-fit fixation was obtained with bone-dowel techniques, whereas the shell technique required fixation with interfragmentary screws or bioabsorbable pins.[12-14]

Early progressive ROM exercises were performed on a continuous passive motion machine for 6 weeks. Weightbearing status and progressive ROM varied depending on the procedure; however, the goal was to avoid placing shear or compressive stress on the transplanted area. A gradual transition to weightbearing as tolerated was allowed after 6 to 8 weeks.[25]

### CT Assessment

To confirm that there were no technical errors in the surgical procedure, CT scans were performed on the day after surgery and at 6 months postoperatively. All CT scans were obtained on a 16-multidetector system (Brillance; Philips Healthcare) using a reduced dose protocol, with the minimum scan length required to include the allograft. Multiplanar reformatted 2-mm contiguous sagittal and coronal images were later obtained. In all cases, collimation was performed for all CT scans to improve image quality and reduce overall radiation exposure. The patients

TABLE 1
ACTOCA Scoring System[a]

| CT Features | CT Score |
|---|---|
| 1. Graft signal density relative to host bone | 0: Equivalent<br>1: Superior<br>2: Inferior |
| 2. Osseous integration at host-graft junction | 0: Crossing trabeculae<br>1: Discernible cleft ≤3 mm<br>2: Discernible cleft >3 mm |
| 3. Surface percentage with a discernible cleft at host-graft junction | 0: ≤30%<br>1: >30% |
| 4. Cystic changes of graft and/or host-graft junction | 0: Absent<br>1: Present ≤3 mm<br>2: Present >3 mm |
| 5. Presence of intra-articular fragments | 0: Absent<br>1: Present |

[a]ACTOCA, assessment computed tomography osteochondral allograft; CT, computed tomography.

were scanned from the superior pole of the patella to the proximal tibia. The dose-length products were between 55 and 90 mGy.cm.

For this imaging study, we used the recently published ACTOCA score, which has been shown to be reliable.[11] The ACTOCA scoring system includes 5 CT features relative to the aspect of the transplanted graft and the host bone—graft signal density, osseous integration, surface percentage with a discernible cleft, cystic changes, and presence of intra-articular fragments (Table 1). A lower total score indicates better incorporation of the graft, with possible scores ranging from 0 to 8. All CTs were evaluated by a musculoskeletal radiologist blinded to the patient's medical history (Figures 1 and 2).

## Functional Evaluation

Clinical results were collected preoperatively and at 12 and 30 months after surgery. All participants completed the following patient-reported outcome instruments to measure clinical results: the International Knee Documentation Committee form (IKDC); the Kujala score; the Western Ontario Meniscal Evaluation Tool (WOMET); and the Tegner activity scale.[15,17-19] Although this was not meniscal surgery, we chose the WOMET scale because it is widely used after meniscal surgery in young patients and because there are not any other scales specifically designed for OCA surgery.

## Secondary Outcomes

Sociodemographic questions were recorded at baseline to characterize the study sample and explore age, sex assigned at birth, side of the lesion (left, right), and BMI as potential confounding variables. Concomitant procedures (eg, osteotomy, ligamentous repair/reconstruction, and meniscal allograft transplantation) and OCA type (patellar, femoral, or tibial) were recorded at the time of surgery.

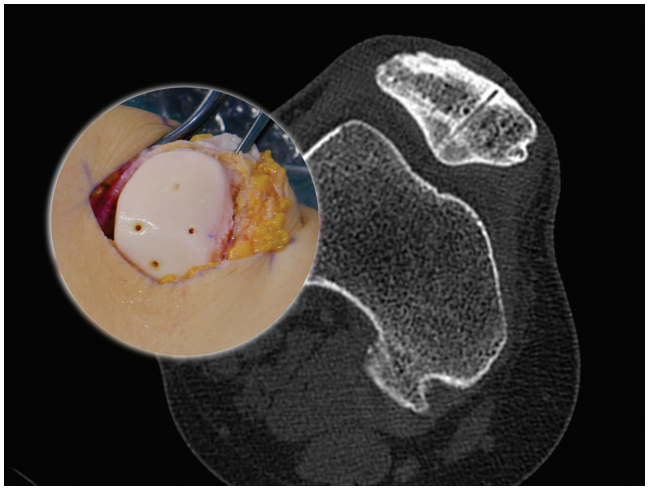

**Figure 1.** A computed tomography scan taken 6 months after surgery and a surgical image of a patellar fresh osteochondral allograft obtaining a low assessment computed tomography osteochondral allograft score (1 point—superior graft signal density relative to the host bone).

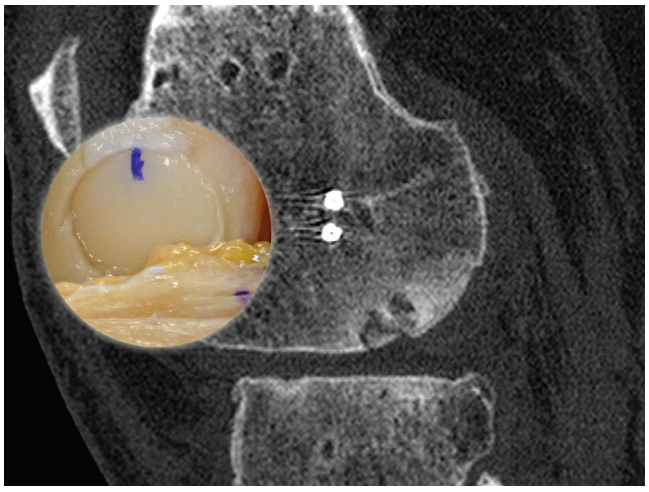

**Figure 2.** A computed tomography scan taken at 6 months after surgery and a surgical image of a medial femoral condyle fresh osteochondral allograft obtaining a high assessment computed tomography osteochondral allograft score (4 points—superior graft signal density relative to the host bone, discernible cleft ≤3 mm, cystic changes of graft >3 mm).

## Statistical Analysis

The statistical analysis was performed using the statistical package SPSS Version 26.0 (IBM Corp). Descriptive statistics were used to determine patient and lesion characteristics. For categorical data, the results are given as the number of cases and/or percentage; and, for quantitative variables, as mean, standard deviation, and range. Variables repeated during the trial (functional scales) were

TABLE 2
Clinical Scores[a]

| | Preoperative | 12 Months | 30 Months | Greenhouse-Geisser, *P* Value |
|---|---|---|---|---|
| IKDC | 31.26 ± 9.4 (15-53) | 53.76 ± 16.7 (21-83) | 64.68 ± 20.52 (20-89) | <.001 |
| Kujala | 38.84 ± 12.46 (17-63) | 63.21 ± 16.4 (29-96) | 72.13 ± 19.09 (26-98) | <.001 |
| WOMET | 38.74 ± 14.87 (13-79) | 59.05 ± 17.2 (19-90) | 70.47 ± 19.3 (24-98) | <.001 |
| Tegner | 1.97 ± 0.91 (1-4) | 2.58 ± 1.03 (1-5) | 2.92 ± 1.12 (1-5) | <.001 |

[a]The values are given as mean ± SD (range). IKDC, the International Knee Documentation Committee; WOMET, Western Ontario Meniscal Evaluation Tool.

TABLE 3
Correlation Between Total ACTOCA Score at 6 Months and Clinical Outcomes Scores at 12 Months[a]

| | Pearson Correlation Coefficient | *P* Value |
|---|---|---|
| IKDC | −0.507 | .001[b] |
| Kujala | −0.439 | .006[b] |
| WOMET | −0.407 | .011[b] |
| Tegner | −0.465 | .003[b] |

[a]ACTOCA, assessment computed tomography osteochondral allograft; IKDC, International Knee Documentation Committee; WOMET, Western Ontario Meniscal Evaluation Tool.
[b]Significant—clinical outcomes at 12 months.

TABLE 4
Correlation Between Total ACTOCA Score at 6 Months and Clinical Outcomes Scores at 30 Months[a]

| | Pearson Correlation Coefficient | *P* Value |
|---|---|---|
| IKDC | −0.663 | <.001[b] |
| Kujala | −0.597 | <.001[b] |
| WOMET | −0.547 | <.001[b] |
| Tegner | −0.593 | <.001[b] |

[a]ACTOCA, assessment computed tomography osteochondral allograft; IKDC, International Knee Documentation Committee; WOMET, Western Ontario Meniscal Evaluation Tool.
[b]Significant—Clinical outcomes at 30 months.

analyzed by analysis of variance tests for repeated measures with Greenhouse-Geisser correction to avoid sphericity. The correlation between clinical results and imaging results was analyzed using the Pearson correlation coefficient. The overall level of significance was set at .05 for 2-sided tests.

## RESULTS

This study included 38 patients. The mean postoperative follow-up was 38 months (range, 30-48 months). The mean age was 36.63 ± 6.6 years (range, 18-46 years), and the mean BMI was 23.9 ± 2.6 (range, 20-30). Also, 63% of the patients (n = 24 cases) were men.

The most frequent location of the lesion was the patellofemoral joint (n = 23 cases; 60.5%), followed by the femoral condyle (n = 15 cases; 39.5%) divided into 67% medial femoral condyle and 33% lateral femoral condyle. Also, 31 patients (81.6%) received unipolar FOCA transplants and 7 patients (18.4%) received bipolar transplants—defined as involving 2 opposing articulating surfaces, including the tibial-femoral condyle and the patella-trochlea. A bone-dowel technique was performed in 65.8% of the cases. A shell technique was done in the remaining 34.2% of the cases. Concomitant procedures were performed in 14 patients (36.8%), including tibial tubercle osteotomy in 7 cases (18.4%) and high tibial osteotomy in another 7 cases (18.4%).

### Clinical Scores Evolution

The preoperative and postoperative comparisons of the scores showed significant improvements according to the IKDC, Kujala, WOMET, and Tegner scores at 12 and 30 months postoperatively ($P < .001$) (Table 2).

### ACTOCA Scores

All CT scans were performed 6 months after surgery. The mean total ACTOCA score was 1.34 ± 1.21 points (range, 0-4 points).

### ACTOCA Prognostic Value

The total ACTOCA score at 6 months correlated with clinical results at 12 and 30 months (Tables 3 and 4).

The total ACTOCA score at 6 months showed a moderate negative correlation with the IKDC score at 12 months (Pearson correlation coefficient, −0.507; $P = .001$) and a high negative correlation at 30 months (Pearson correlation coefficient, −0.663; $P < .001$).

The total ACTOCA score at 6 months showed a moderate negative correlation with the Kujala score at 12 months (Pearson correlation coefficient, −0.439; $P = .006$) and a moderate negative correlation at 30 months (Pearson correlation coefficient, −0.597; $P < .001$).

TABLE 5
Subgroup Analysis[a]

| | BMI *P* | Age *P* | Sex *P* |
|---|---|---|---|
| CT, 6 mo | .608 | .761 | .260 |
| IKDC, 12 mo | .178 | .627 | .823 |
| IKDC, 30 mo | .385 | .541 | .777 |
| Kujala, 12 mo | .034 | .309 | .427 |
| Kujala, 30 mo | .376 | .182 | .643 |
| WOMET, 12 mo | .339 | .186 | .520 |
| WOMET, 30 mo | .292 | .272 | .273 |
| Tegner, 12 mo | .219 | .212 | .800 |
| Tegner, 30 mo | .48 | .156 | .622 |
| | OCA Type *P* | Tibial Tubercle Osteotomy *P* | High Tibial Osteotomy *P* |
| CT, 6 mo | .939 | .971 | .167 |
| IKDC, 12 mo | .873 | .580 | .740 |
| IKDC, 30 mo | .195 | .797 | .685 |
| Kujala, 12 mo | .329 | .076 | .685 |
| Kujala, 30 mo | .272 | .555 | .632 |
| WOMET, 12 mo | .723 | .768 | .506 |
| WOMET, 30 mo | .929 | .768 | .317 |
| Tegner, 12 mo | .551 | .395 | .416 |
| Tegner, 30 mo | .606 | .854 | .265 |

[a]BMI, body mass index; CT, computed tomography; IKDC, International Knee Documentation Committee; OCA, osteochondral allograft; WOMET, Western Ontario Meniscal Evaluation Tool.

The total ACTOCA score at 6 months showed a moderate negative correlation with the WOMET score at 12 months (Pearson correlation coefficient, −0.407; $P = .011$) and a moderate negative correlation at 30 months (Pearson correlation coefficient, −0.547; $P < .001$).

The total ACTOCA score at 6 months showed a moderate negative correlation with the Tegner score at 12 months (Pearson correlation coefficient, −0.465; $P = .003$) and a moderate negative correlation at 30 months (Pearson correlation coefficient, −0.593; $P < .001$).

### Subgroup Analysis

No statistically significant differences were noted for the ACTOCA or functional scales (IKDC, Kujala, WOMET, and Tegner) according to BMI (all BMI <30), age, sex at birth, OCA type, or concomitant procedures (Table 5).

## DISCUSSION

The ACTOCA score evaluating CT at 6 months showed a statistically significant correlation with clinical outcomes, particularly at 30 months. We found a high negative correlation with the IKDC score and a moderate negative correlation with the Kujala, WOMET, and Tegner scores at 30 months, confirming the study's hypothesis that the ACTOCA score has a prognostic value.

There is a paucity of studies predicting clinical outcomes of the FOCA based on imaging modalities. Wang et al[28] reviewed clinical outcomes and MRI scans from 36 patients who underwent FOCA, with a minimum follow-up of 2 years; the mean postoperative follow-up was 3.5 years. The clinical outcomes obtained at the last follow-up were correlated with MRI scans performed around 1 year after surgery. The mean total Osteochondral Allograft MRI Scoring System (OCAMRISS) score, one of the most widely used MRI scores,[4] showed a slight correlation (Pearson correlation coefficient, −0.36; $P = .035$) with the 36-Item Short Form Health Survey (SF-36) physical function score. No other section of the SF-36 or other scores showed any correlation with this MRI evaluation. In another study, Lin et al[21] studied 20 patients after a FOCA transplant of the patella using femoral condylar allografts. MRI scans were obtained at a mean of 11.4 months (range, 6-22 months) postoperatively and clinical outcomes were collected at a mean of 46.5 months (range, 24-85 months) postoperatively. They found no statistically significant correlation between OCAMRISS scores and clinical scores. Along the same lines, other authors have also reported no correlation between MRI scores and clinical results.[2,8] Few studies[3,5] have evaluated FOCA transplantation using CT and none of them reported a correlation between CT and clinical results. Unlike the findings in these studies, we found a statistically significant correlation between ACTOCA scores at 6 months and clinical scores at 30 months. This finding supports the prognostic value of this score. It is of note that the correlation was better at the 30-month follow-up than at the 12-month follow-up. This was probably because the functional scores were still in the ascending curve toward a more stable and favorable outcome at the longer follow-up evaluation.

We also performed a CT at 6 months postoperatively and determined clinical scores at 12 and 30 months postoperatively in all patients. The fact that we conducted these follow-ups at the same time postoperatively in all patients is of particular interest, as it provided a more accurate and reproducible follow-up. The availability of a predictive tool that can help to adjust treatment as early as 6 months after the FOCA procedure allows the surgeon to adjust expectations and identify potential failures. A failure was considered any reoperation resulting in the removal of the graft, such as allograft revision or any form of arthroplasty.[9]

The ACTOCA score has recently been shown to have high reproducibility.[11] In the present study, this score also confirmed its prognostic value to evaluate outcome after FOCA transplantation. Knowing the parameters that are related to poorer clinical outcomes is of great importance. Frank et al[10] reviewed 180 patients treated with OCA transplantation at a minimum follow-up of 2 years. They found a 37% reoperation rate and an 87% allograft survival rate at a mean of 5 years after a FOCA transplant. They observed that a greater number of previous ipsilateral surgical procedures (3.75 vs 2.28; $P < .001$) and higher BMI (29.42 vs 26; $P = .003$) were independently predictive of failure. Familiari et al[9] reported the results of

a systematic review of clinical outcomes after OCA transplantation in the knee. They concluded that revision cases, patellar lesions, and bipolar lesions were associated with worse survival rates. Nuelle et al[22] retrospectively reviewed 75 patients who underwent a FOCA transplant. They found that active patients and those with a BMI <35 were significantly more likely to have a successful outcome than minimally active patients ($P = .023$; $P = .01$). In contrast, in our study, we did not note any statistically significant differences for the ACTOCA or functional scales (IKDC, Kujala, WOMET, and Tegner) according to sex at birth, age, BMI (all BMI <30), concomitant procedures, or osteochondral allograft type.

In relation to the Tegner scale results, the mean preoperative Tegner score increased from 1.97 ± 0.91 points (range, 1-4 points) to 2.58 ± 1.03 points (range 1-5 points) at 12 months postoperatively and to 2.92 ± 1.12 points (range, 1-5 points) at 30 months postoperatively. Despite postoperative improvement, 2.5 is considered a low activity level. In similar studies, Tegner scores have shown considerably larger improvement after surgeries.[10,29] However, while these previous studies compared the immediate preoperative Tegner score, we considered the preinjury activity level.

Similar to our results, several reviews in the literature have found good clinical and functional outcomes after FOCA transplantation in the knee.[7,9] In the present study, comparing the preoperative and postoperative clinical scores at 30 months, we also found a statistically significant improvement in the IKDC, Kujala, WOMET, and Tegner scores ($P < .001$).

Our study has some limitations. First, there was no comparison group and the sample size was small. Second, 36.8% of patients had an osteotomy in addition to a FOCA transplant. However, we do not consider this to be a limitation, as it allows a comparable alignment in all of the cases after surgery. Third, CT scans were evaluated by only 1 musculoskeletal radiologist. In a recent study, however, it was shown that the ACTOCA provides a moderate to substantial interobserver agreement and a moderate to almost perfect intraobserver agreement.[11] Fourth, even though we did not note any statistically significant differences between the ACTOCA and functional scales (IKDC, Kujala, WOMET, and Tegner) according to sex at birth, age, BMI, concomitant procedures, or osteochondral allograft type, the sample size is likely insufficiently powered to perform subgroup analysis. Fifth, as failure was defined as requiring reoperation, any patients with clinical failure who did not choose to have reoperation could have been missed. Sixth, patients whose BMI was >30 were excluded; thus, the study cannot comment on this group of patients. Seventh, the ACTOCA score has been shown to be reliable in previous studies, but it has not been fully validated. And eighth, CT scans expose patients to high doses of radiation. This limitation, however, was significantly reduced with an optimal collimation protocol.

## CONCLUSION

The mean ACTOCA score on CT at 6 months showed a statistically significant correlation with the clinical results in the IKDC, Kujala, WOMET, and Tegner scores at 30 months, confirming the predictive value of the ACTOCA score for use in clinical practice.

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