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Total Knee Arthroplasty Following Unsuccessful Subchondroplasty

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ABSTRACT

Background: Subchondroplasty has been used as a non-arthroplasty solution for treating osteoarthritic knee pain.

Objective: To determine the results of primary total knee arthroplasty (TKA) following a prior subchondroplasty procedure.

Methods: A total of 344 patients who underwent subchondroplasty were identified from an institutional registry. Of the 344 patients, 86 (25%) progressed to TKA; among them, 62 were available for review. The average age of the patients was 63.32 years (± 10.68 years), and the average body mass index was 34 kg/m^2 (± 6.59 kg/m^2). The study group was matched 2:1 with a control group of 124 TKAs that had no prior subchondroplasty. Patient-reported outcome measures (PROMs) and complications were compared.

Results: Preoperative and postoperative Knee Injury and Osteoarthritis Outcome Score for Joint Replacement scores in the subchondroplasty group were lower compared to the control group (40.2 vs. 47 [$p = 0.07$] and 79.2 vs. 84.6 [$p = 0.06$], respectively). Preoperative and postoperative Knee Society Clinical Rating System knee scores were lower in the subchondroplasty group, at 38.9 vs. 44.9 ($p = 0.02$) and 88.2 vs. 93.5 ($p = 0.0004$), respectively. The two-year postoperative Forgotten Joint Score was lower in the study group, at 60.2 vs. 73.8 in the control ($p = 0.01$). There were no differences in revision incidence. The subchondroplasty group had three cases of aseptic loosening, compared to none in the control group ($p = 0.08$). Additionally, there were two intraoperative tibial fractures in the subchondroplasty group.

Conclusion: The indications for subchondroplasty should be re-evaluated, given the high incidence of failure leading to TKA. Patients undergoing TKA following subchon-

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droplasty demonstrated inferior results compared to the control group. Hence, surgeons should remove all cement during tibial broaching to minimize the risk of intraoperative fracture from retained cement.

Keywords: Bone marrow lesions, Intraoperative fractures, Patient-reported outcome measures, Primary total knee arthroplasty, Subchondroplasty, Total knee arthroplasty

INTRODUCTION

Osteoarthritis (OA) is a progressive degenerative joint disease that is characterized by the breakdown of articular cartilage, subchondral bone remodeling, and inflammation. OA is the most common cause of chronic pain and disability in older adults. Moreover, OA has been reported in 83% of cases in the knee joint, where it can severely affect both function and quality of life.[1] One of the key pathophysiological features of early knee OA is the presence of bone marrow lesions (BMLs). BMLs represent areas of abnormal fluid accumulation in the subchondral bone, which often correlate with pain and joint dysfunction.[2] These BMLs can be identified via magnetic resonance imaging by locating areas of low signal intensity on T1-weighted images, which correspond to high signal intensity on T2-weighted images.[3]

Patients with BMLs have a ninefold higher likelihood of undergoing a total knee arthroplasty (TKA) within three years compared to those without BMLs.[4] While TKA remains the most effective known treatment for end-stage OA,[5] some patients are dissatisfied with their TKA.[6,7,8] As a result, there has been an increasing investigation into treatment options aimed at slowing the progression of disease in patients with marrow lesions. One such treatment option, which emerged as early as 2007, is subchondroplasty.[9] Subchondroplasty is a procedure designed to treat BMLs by injecting calcium phosphate cement into the subchondral bone of an arthritic knee (**Figure 1A** and **B**).[9,10] The goal is to fill the lesion and promote healing by stimulating bone regeneration and stabilizing the bone structure.[10] Early reports have suggested that subchondroplasty can improve pain and function, offering a less invasive alternative to TKA for patients with early- to mid-stage knee OA.[2,11,12] Despite the potential of subchondroplasty to slow or delay the disease progression to TKA, questions remain about its long-term efficacy, safety, and outcomes in those who ultimately progress to TKA (**Figure 1C**).[13]

Indications for subchondroplasty remain controversial among surgeons. This is demonstrated through the large variations in patient demographics that undergo this procedure.[14] Several studies have demonstrated that 12–30% of patients progress to require TKA following subchondroplasty.[12,15] While most studies have investigated the outcomes of subchondroplasty alone, there is a paucity of literature examining the outcomes of subchondroplasty patients who undergo conversion to TKA. The purpose of this study was to compare clinical outcomes in patients who underwent TKA following subchondroplasty with a matched cohort of patients undergoing primary TKA without prior knee surgery.

MATERIALS AND METHODS

This was an Institutional Review Board (IRB)-approved retrospective study (IRB#23.0926). The study was approved with a complete waiver of authorization; therefore, subject consent was not required. Following IRB approval, a total of 344 consecutive patients were identified from an institutional registry who underwent a subchondroplasty procedure for knee pain from 2015 to 2021. Of the 344 patients who underwent subchondroplasty, 86 (25%) progressed to TKA (**Figure 2**). Of the 86 patients who progressed to TKA, 24 were excluded because of loss of follow-up, leaving 62 for final review. The 62 patients in the study group were matched 2:1 to a consecutive cohort of patients with no history of prior knee surgery who underwent primary TKA. Patients within the control group were selected using frequency matching based on age, body mass index, and gender to achieve comparable group distributions of these variables. Standard mean differences were calculated to compare demographic variables between the two cohorts (**Table 1**). All patients receiving TKA in this study were treated at the same institution with the same anesthesia and postoperative protocols. All patients underwent primary TKA using a Triathlon™ cementless implant (Stryker, United States). In patients who underwent the subchondroplasty procedure, the average time between subchondroplasty and conversion to TKA was 23.2 months (range: 4–54 months). The average follow-up for the primary TKA group following subchondroplasty was 49.4 months (range: 24–80 months), whereas the average follow-up for the control TKA group was 36 months (range: 24–65.2 months). All patients in both cohorts had a minimum of two years of clinical follow-up. There were no significant differences in age, gender, or body mass index between the two groups (**Table 1**).

Clinical outcomes, patient-reported outcomes measures (PROMs), including Knee Society Knee Score (KSS Knee), Knee Society Function Score (KSS Function), Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR), and patient satisfaction were evaluated using a five-point Likert scale (1 = Very dissatisfied; 2 = Dissatisfied; 3 = Neutral; 4 = Satisfied; & 5 = Very satisfied). PROM mean clinically important difference values were as follows, based on prior published studies: KSS Knee, 5.3–5.9; KSS Function, 6.1–6.4; FJS-12, 10.8; and KOOS-JR, 14.[16,17,18] Clinical data, including preoperative and postoperative range of motion, were assessed. Complications and revisions were recorded via electronic medical records.

A two-tailed independent *t*-test was used to compare all continuous variables with normal distribution using Microsoft Excel (version 2408). Chi-square analysis was used to compare categorical variables. Statistical significance was defined as $p < 0.05$.

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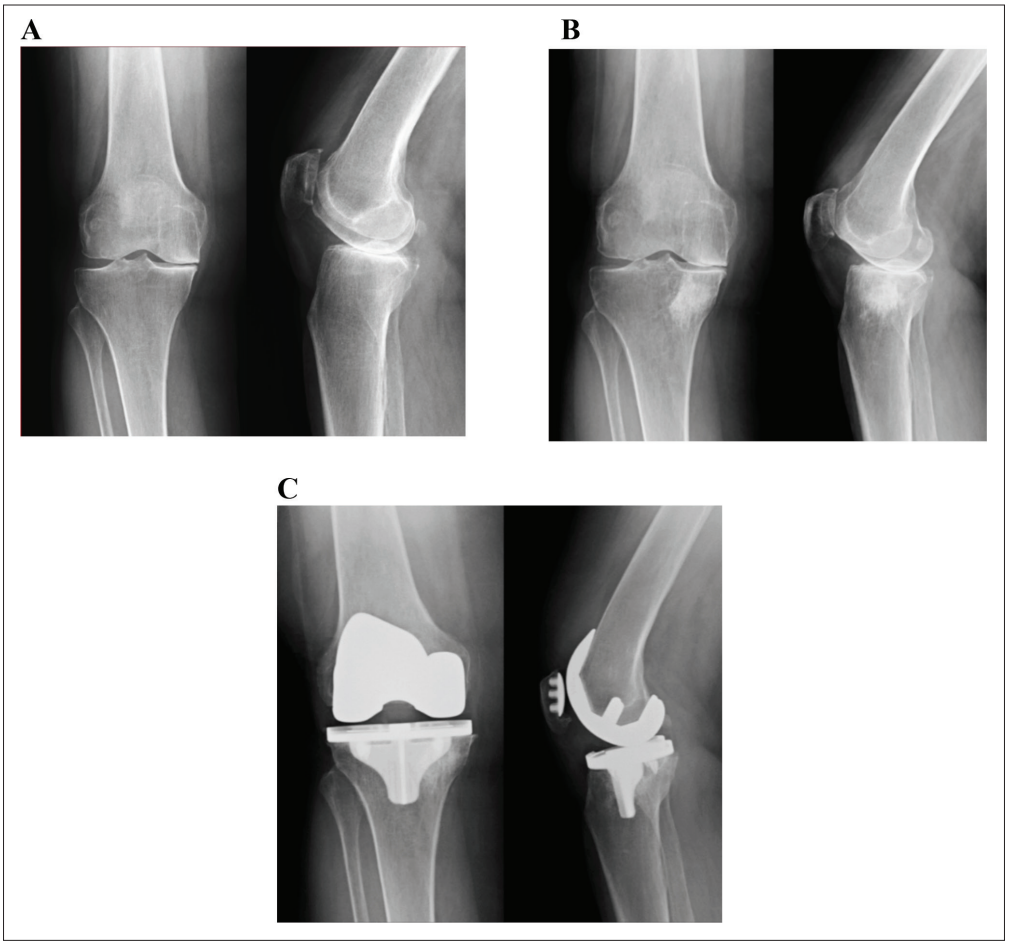

Figure 1. Osteoarthritis in a patient initially treated with subchondroplasty, followed by total knee arthroplasty without complication. (A) Preoperative radiographs of a patient with osteoarthritis prior to subchondroplasty. (B) Postoperative radiographs of the same patient following subchondroplasty. (C) Postoperative radiographs one year postoperative total knee arthroplasty following failed subchondroplasty.

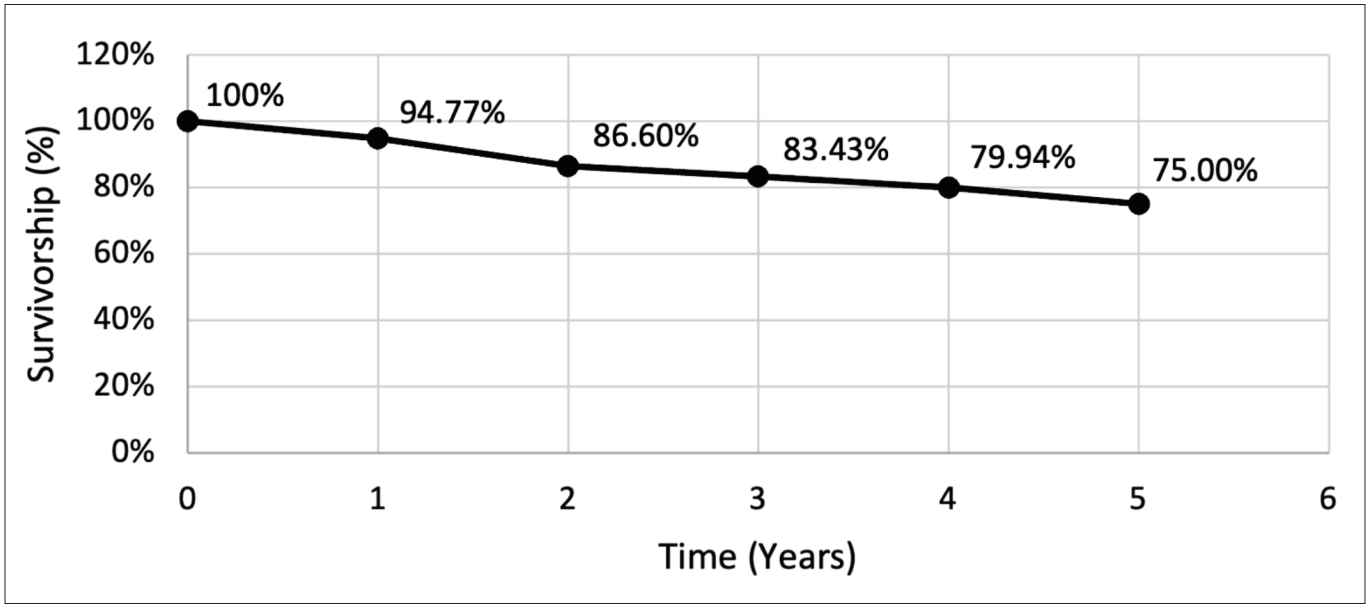

Figure 2. Kaplan–Meier curve showing the percentage of survivorship following subchondroplasty with total knee arthroplasty as the endpoint over time.

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Table 1. Demographics of the total knee arthroplasty cohorts			
Demographic characteristics	**Subchondroplasty group**	**Control group**	**Standardized mean difference**
Total knee arthroplasty (TKA)	62	124	-
Age (years), mean (range)	63.32 (40–87)	65.66 (51–85)	–0.23
Body mass index (kg/m^2), mean (range)	34.5 (18.5–49.6)	32.8	0.22
Gender (women/men)	35/27	74/50	–0.06
Mean follow-up from time of TKA diagnosis (months)	49.4 (21.5–80.1)	35.9 (20.9–65.2)	1.04

A post hoc power analysis was performed using $\alpha = 0.05$, an effect size of 0.05, and a sample size of 62 and 124 for the study and control groups, respectively. The analysis demonstrated a power of 0.89, indicating sufficient power to detect small differences between groups (SPSS version 28).

RESULTS

Preoperative KOOS-JR scores in the subchondroplasty study group were lower at 40.2 compared to 47.4 in the primary TKA group ($p = 0.07$). Following TKA, postoperative KOOS-JR scores in the study group were also lower at 79.2 compared to 84.6 in the control group ($p = 0.06$) (**Table 2**); however, this difference was not statistically significant. Preoperative KS Knee scores were significantly lower in the subchondroplasty group at 38.9 compared to 44.9 in the primary TKA group ($p = 0.02$). Postoperative KS Knee scores were also significantly lower in the subchondroplasty group at 88.2 compared to 93.5 in the primary TKA group ($p = 0.004$). There was no significant difference in preoperative KS Function scores between the subchondroplasty group at 49.3 and the control group at 50.4 ($p = 0.639$). Postoperative KS Function score was not significantly different between the subchondroplasty group at 82.7 and the control group at 86.1 ($p = 0.292$). The two-year postoperative FJS-12 scores were significantly lower in the subchondroplasty TKA group, at 60.2, compared to 73.8 in the primary control TKA group ($p = 0.01$). There was no difference in patient satisfaction, as measured by the Likert score, between the subchondroplasty group (4.7) and the control TKA group (4.6) ($p = 0.395$) (**Table 2**).

There was no significant difference in preoperative knee extension between the groups, with the subchondroplasty group having 1.7° of knee extension compared to the control group, which had an average of 0.84° of extension preoperatively ($p = 0.167$). Postoperatively, there was no significant difference in extension values, with the subchondroplasty group having an average extension of 0.01° and the control group reaching an average extension of 0.05° ($p = 0.493$). Preoperative flexion was slightly lower in the subchondroplasty group, with an average maximal flexion of 111.5° compared to 115.2° in the primary TKA group ($p = 0.047$). Postoperatively, flexion was slightly lower in the subchondroplasty group, at 115.7°, compared to 120.9° in the primary TKA group ($p = 0.0009$) (**Table 3**); however, the clinical significance of this difference may not be relevant.

In total, there were four TKA revisions in the subchondroplasty group compared to five revisions in the control group ($p = 0.504$). Only one patient underwent manipulation under anesthesia in the subchondroplasty group compared

Table 2. Pre- and postoperative metrics			
Metric	**Subchondroplasty group**	**Control group**	***p*-value**
Preoperative KS knee score	38.9	44.9	0.024*
Preoperative KS function score	49.3	50.4	0.639
Two-year postoperative KS knee score	88.2	93.5	0.004*
Two-year postoperative KS Function score	82.7	86.1	0.292
Preoperative KOOS-JR scores	40.2	47.4	0.07*
Postoperative KOOS-JR Scores	79.2	84.6	0.064*
Preoperative extension ROM (°)	1.7	0.84	0.167
Preoperative flexion ROM (°)	111.5	115.2	0.047*
Postoperative >1 year extension ROM (°)	0	0.05	0.493
Postoperative >1 year flexion ROM (°)	115.7	120.9	0.0009*
Patient satisfaction (Likert scale 1–5)	4.7	4.6	0.395

Note: * Indicates significant values ($p < 0.05$).
Abbreviations: FJS: Forgotten joint score; KOOS-JR: Knee injury and osteoarthritis outcome score for joint replacement; KS: Knee society; PROMIS: Patient-reported outcomes measurement information system; ROM: Range of motion.

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Table 3. Complications requiring revision of total knee arthroplasty			
Complication	**Subchondroplasty group**	**Control group**	***p*-value**
Total revisions	4	5	0.504
Stiffness/Arthrofibrosis	1	1	0.656
Instability	0	4	0.045*
Aseptic loosening	3	0	0.083
Note: * indicates significant values ($p < 0.05$).			

to six patients in the control group ($p = 0.220$) (**Table 4**). The subchondroplasty group had a higher incidence of aseptic loosening, with three patients compared to none in the primary TKA group ($p = 0.08$) (**Table 3**). Both the subchondroplasty and the control groups had one patient who developed arthrofibrosis leading to revision surgery ($p = 0.656$). Four patients (3.2%) in the control primary TKA group underwent revision due to instability. There were no cases of instability in the subchondroplasty group ($p = 0.045$). Additionally, there were two intraoperative tibial plateau fractures in the subchondroplasty TKA group, one of which occurred during the keel preparation of the tibial component and the other during insertion of the cementless tibial baseplate, versus none in the control TKA group ($p = 0.49$).

DISCUSSION

Subchondroplasty is a surgical technique designed to treat symptomatic BMLs in the subchondral bone, which are commonly associated with pain and functional decline of the knee. The procedure involves the injection of a flowable, synthetic calcium phosphate bone substitute material into areas of subchondral insufficiency, aiming to reinforce the weakened bone structure and promote remodeling over time.[10] Some studies have demonstrated that subchondroplasty may offer short-term improvements in pain and function by addressing the underlying biomechanical insufficiency of the subchondral bone, potentially delaying progression to arthroplasty.[12]

Proponents of the subchondroplasty procedure emphasize its potential to delay TKA in patients with early onset of knee osteoarthritis and associated BMLs.[10] In the present study, 86 of 344 patients (25%) who underwent subchondroplasty necessitated conversion to TKA. This conversion incidence aligns with existing literature reporting a 12–30% likelihood of progression to TKA.[2,12,14,15] Wood *et al.*[15] identified age over 50 years as a risk factor for conversion. In our study, the average age of the study group was 63.32 years, with conversion to TKA occurring up to 54 months following the subchondroplasty procedure. Given the high incidence of conversion to TKA, the indications for subchondroplasty warrant re-evaluation, with consideration for more stringent selection criteria.

The range of motion with respect to knee extension was similar between groups both before and after TKA. However, the subchondroplasty group demonstrated decreased flexion at both time points. The clinical significance of this deficit remains unclear. Both preoperative and postoperative KS Knee scores were significantly lower in the subchondroplasty group, compared to the control group undergoing primary TKA ($p = 0.02$). This suggests that patients undergoing TKA following subchondroplasty present with more severe preoperative symptoms and tend to have inferior outcomes compared to the control group undergoing primary TKA.

Prior knee surgeries in patients undergoing primary TKA can result in diminished PROMs compared to patients without prior knee surgery.[19,20] The subchondroplasty procedure with retained bone cement may alter the normal biologic process of the knee. The presence and degradation products of calcium phosphate cement could contribute to persistent pain and diminished function, as suggested in prior studies.[10,12,13] Fokter *et al.*[26] demonstrated both histologic and morphologic evidence of this derangement in joint biology in a patient undergoing TKA four years after subchondroplasty. Their patient demonstrated significant synovitis clinically and microscopically following subchondroplasty.[26] This hypothesis warrants further investigation and falls beyond the scope of this research.

The KOOS-JR scores were also lower in the subchondroplasty group and trended toward significance both preoperatively ($p = 0.07$) and following conversion to TKA ($p = 0.06$). Notably, changes in KOOS-JR scores from preoperative to postoperative were similar between the subchondroplasty and control groups. However, patients undergoing TKA after subchondroplasty

Table 4. Complications requiring non-revision procedures			
Complication	**Subchondroplasty group**	**Control group**	***p*-value**
Total non-revision procedures	57	119	-
Contracture requiring manipulation under anesthesia	1	6	0.220
Wound dehiscence requiring irrigation and debridement	0	1	0.319
Capsulitis/ Patellar clunk requiring arthroscopic lysis of adhesions	0	1	0.319

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should be counseled that while the range of motion may be similar, satisfaction and PROMs may be lower compared to those undergoing primary TKA without a history of prior subchondroplasty procedure. This finding aligns with existing literature indicating that prior knee surgeries are associated with reduced satisfaction in future surgical procedures in the same joint.[19,20,21,22]

Component revision rates were similar between groups, with four revisions in the subchondroplasty group and five in the primary group ($p = 0.504$), indicating that subchondroplasty does not significantly increase the incidence of revisions. However, the incidence of aseptic loosening was higher in the subchondroplasty group (3 cases vs 0; $p = 0.08$). Although not statistically significant, this trend is clinically important, given that aseptic loosening is a common cause of TKA failure.[21] Calcium phosphate cement is degraded by osteoclasts, which may initially weaken the underlying bone surface.[23] However, calcium phosphate has proven to be osteoinductive, which should result in stronger subchondral bone.[24.] Additionally, other studies have demonstrated significant bone formation months after calcium phosphate injection in animal models.[25] In human patients, previous studies do not demonstrate local resorption of host bone, even years after implantation.[26] This makes it even more perplexing as to why patients in the subchondroplasty group developed aseptic loosening. All patients in this study underwent cementless TKA, and the potential for ingrowth may have been compromised by the subchondroplasty procedure, leading to the three failures due to aseptic loosening, all of which occurred within the tibia. All instances of aseptic loosening occurred within one year of index TKA.

Two intraoperative tibial plateau fractures occurred in the subchondroplasty group, while none were observed in the control group. Both fractures occurred at the site of the cement injection at the proximal tibial plateau, one during the preparation of the cementless tibial keel and the other during insertion of the cementless tibial baseplate (**Figure 3A–C**). Both tibial plateau fractures were minimally displaced and converted to cement fixation and did not require additional fixation. They were also managed with a period of protected weight bearing postoperatively. Although the fracture incidence was not statistically significant ($p = 0.49$), it raises concerns about the structural integrity of the tibia during preparation for the TKA. Calcium phosphate cements exhibit minimal plastic deformation.[27] The result is rapid force propagation through the cement, which can generate a fracture extending into the cortical bone. Based on these findings, we recommend a thorough removal of any residual cement located at the site

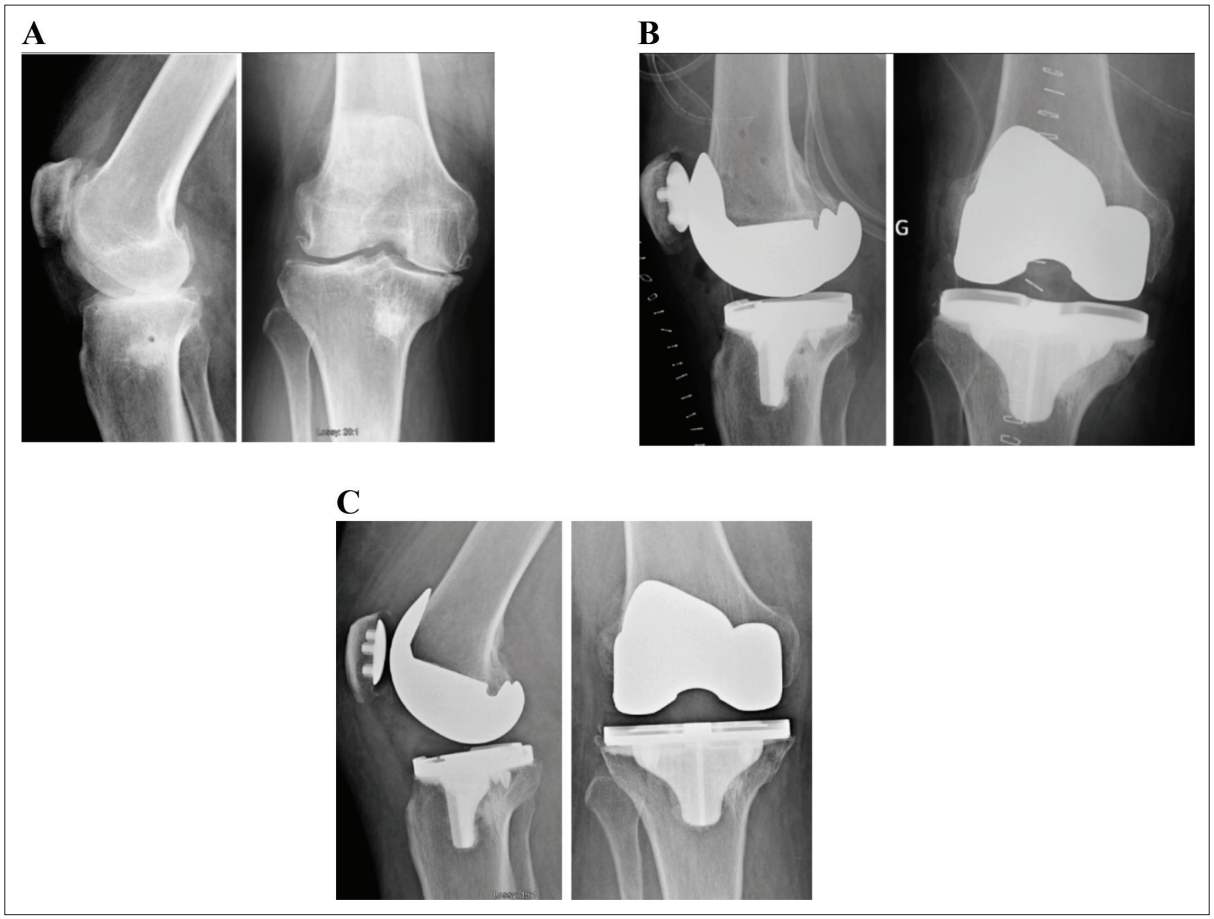

Figure 3. Radiographs of a 67-year old female who underwent total knee arthroplasty following subchondroplasty complicated by intra-operative fracture. (A) Preoperative radiographs of a 67-year-old female, three years following a subchondroplasty procedure, demonstrating progression of disease with end-stage osteoarthritis of the right knee. (B) Immediate postoperative radiographs demonstrating a cemented tibial baseplate in the patient with a non-displaced fracture at the medial tibial plateau. (C) Postoperative radiographs two years following the index right cemented tibia baseplate, demonstrating well-fixed total knee arthroplasty components.

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of preparation of the tibial component during TKA.

This study has several limitations. First, its retrospective nature introduces potential biases. Second, subchondroplasty is frequently performed in conjunction with arthroscopy to enhance injection accuracy and address intra-articular pathology (e.g., meniscal tears, loose bodies, chondral flaps, & synovitis).[2] Our analysis did not account for these concurrent procedures, which may have influenced the outcomes. There was also a significant difference in follow-up time between groups, with the subchondroplasty group having a longer duration of follow-up. This could have provided a longer time for complications, like aseptic loosening, to develop in this cohort. This study was conducted at a single institution using uniform TKA techniques and perioperative protocols. While this improves consistency, it may limit generalizability to other settings.

CONCLUSION

In this study, 25% of patients who underwent a subchondroplasty procedure ultimately progressed to TKA. Subchondroplasty failures leading to TKA in the patients occurred within five years of the index procedure, with an average time to conversion of less than two years. Patients who underwent TKA following subchondroplasty had diminished PROMs compared to the control group. Patients undergoing primary TKA following subchondroplasty should be counseled on the potential risk for increased fracture incidence during TKA due to the presence of calcium phosphate cement in the tibial plateau. We would suggest the removal of the calcium phosphate cement prior to tibial component preparation during TKA. The indications for subchondroplasty should be re-evaluated, given the high incidence of failure leading to conversion to primary TKA.

AUTHORS' DISCLOSURE

All other authors declare no competing interests. No funding was received to assist with the preparation of this manuscript. This is an Institutional Review Board-approved retrospective chart review study with a waiver of informed consent. This study was reviewed by the University of Louisville Institutional Review Board (IRB# 23.0926) and determined by the Chair/Vice-Chair of the IRB that the study is exempt according to 45 CFR 46.101(b) under Category 4: Secondary research for which consent is not required.

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