

A modified technique for tibial bone sparing in unicompartmental knee arthroplasty

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Abstract

Background: Previously, the authors modified the surgical technique to preserve tibial bone mass for Oxford unicompartmental knee arthroplasty (UKA). The purpose of this study was to determine the clinical outcomes and values of this modified technique.

Methods: Clinical data of 34 consecutive patients who underwent the unilateral modified UKA technique (modified group, 34 knees) were retrospectively analyzed. To compare the outcome, a match-paired control group (conventional group, 34 knees) of an equal number of patients using the conventional technique system in the same period were selected and matched with respect to diagnosis, age, pre-operative range of motion (ROM), and radiological grade of knee arthrosis. Clinical outcomes including knee Hospital for Special Surgery (HSS) score, ROM, and complications were compared between the two groups. Post-operative radiographic assessments included hip-knee-ankle angle (HKA), joint line change, implant position, and alignment.

Results: The mean follow-up time was 38.2 ± 6.3 months. There was no difference in baseline between the two groups. The amount of proximal tibial bone cut in the modified group was significantly less than that of the conventional group (4.7 ± 1.1 mm vs. 6.7 ± 1.3 mm, $t = 6.45$, $P < 0.001$). Joint line was elevated by 2.1 ± 1.0 mm in the modified group compared with -0.5 ± 1.7 mm in the conventional group ($t = -7.46$, $P < 0.001$). No significant differences were observed between the two groups after UKA with respect to HSS score, VAS score, ROM, and HKA. Additionally, the accuracy of the post-operative implant position and alignment was similar in both groups. As for implant size, the tibial implant size in the modified group was larger than that in the conventional group ($\chi^2 = 4.95$, $P = 0.035$).

Conclusions: The modified technique for tibial bone sparing was comparable with the conventional technique in terms of clinical outcomes and radiographic assessments. It can preserve tibial bone mass and achieve a larger cement surface on the tibial side.

Keywords: Unicompartmental knee arthroplasty; Tibial bone cut; Surgical technique; Radiologic; Clinical outcome

Introduction

Unicompartmental knee arthroplasty (UKA) is a promising treatment option for osteoarthritis of the knee medial compartment due to its many advantages such as a smaller incision, less soft tissue injury, and more rapid recovery.^[1-4] Despite the advantages and excellent results of UKA, many knee replacement registries still report higher failure and revision rate for UKA.^[5-7] Bone defects usually occur in revision of a failed UKA to total knee arthroplasty (TKA).^[8-10] In most cases of UKA failure, residual femoral defects are generally small and contained. However, tibial bone loss, primarily due to the native tibial bone cut (usually 5 mm more than TKA in medial side),^[8] is a large concern in a failed UKA. At revision to TKA, the patient will require a metal block/wedge or a bone graft in the medial tibial side. If the defect is larger than 10 mm, a tibial stem might be needed.^[11,12]

We recently modified the surgical technique of Oxford medial UKA to preserve tibial bone mass. The aim of the present study was to determine the clinical outcomes and radiographic results using this modified method and to determine the value of the tibial bone sparing technique. We hypothesized that this modification of Oxford medial UKA can preserve the tibial bone mass and lead to a similarly successful result.

Methods

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 *Helsinki declaration* and its later amendments or comparable ethical standards. Informed consent

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was obtained from all individual participants included in the study.

Patients

Clinical data of 34 consecutive patients who underwent the unilateral modified UKA were retrospectively analyzed. All the operations were conducted from July 2014 to July 2016. To compare the clinical outcome, a match-paired control group of an equal number of patients using the conventional technique system in the same period were selected and matched with respect to diagnosis (identical), age (± 3 years), pre-operative range of motion (ROM) ($\pm 5^\circ$), and radiological grade of knee arthrosis (identical). All UKA procedures were performed by the senior surgeons with the mobile Oxford medial UKA device (Oxford[®] Unicompartmental Knee; Biomet, Bridgend, UK). The pre-operative diagnosis was knee anteromedial osteoarthritis in all patients. The indications for UKA were severe knee pain of the medial compartment and considerable difficulty in walking and other daily activities. Radiograph could demonstrate loss of articular cartilage medially by showing that the medial joint width became narrower. The other indications were an intact anterior cruciate ligament, varus deformity $<15^\circ$, flexion contracture $<15^\circ$, and an intact lateral compartment.^[13]

Modified technique for tibial bone sparing

Following the Oxford UKA surgical procedure, the knee joint was exposed through a small incision with quadriceps sparing and no patellar eversion. Medial release for ligament balancing or realignment was not performed. Tibial osteotomy was performed first to allow for femur preparation and gap control. With knee in flexion, the femoral sizing spoon was inserted to assess the ligament tension. A tibial saw guide was applied with its shaft parallel with the long axis of the tibia in both planes. Next, the G-clamp was locked with the femoral sizing spoon and tibial saw guide to ensure access to the pin holes. Once the tibial saw guide was pinned in place, the G-clamp was

unlocked and removed along with the femoral sizing spoon. The proposed level of resection was then confirmed to be correct with 0 mm of tibial shim as usual. We then replaced it with 2 mm tibial shim to reduce the tibial bone cut by 2 mm. The saw cut should be made 1 or 2 mm below the deepest part of the erosion to prepare the baseplate. However, if the erosion is very deep, then the cut should be made directly above the bottom of the defect. Cartilage was not allowed left. Otherwise, we would increase tibial bone cut. A reciprocating saw with a stiff narrow blade was then used to make a vertical tibial saw cut. Following the vertical tibia cut, a horizontal resection of the tibia was performed according to the determined level. Next, the tibial resection fragment was removed, and the medial meniscus was cut. A feeler gauge was then used to measure the flexion gap. This gap was usually about 5 mm. The Oxford tibial component + bearing height was 7 mm. Hence, the medial femoral posterior resection was performed for 2 mm to achieve a 7 mm flexion gap. With the knee in 90° flexion, measure the flexion gap with a 7-mm feeler gauge. The feeler gauge should be able to be fully inserted and sit flat on the resected tibia to ensure that the appropriate amount of bone has been resected, and that the axial alignment was correct. Next, the intramedullary rod was inserted and the distal femoral holes were drilled. The posterior resection guide was then inserted into the drilled holes, and the posterior femoral condyle was excised. Milling was then performed on the distal femoral condyle to balance the flexion and extension gap [Figures 1 and 2]. The inserted polyethylene bearing was checked to ensure that the ligaments were restored to normal tension without any impingement or instability. Then, the femoral bone surface was prepared to enhance cement interdigitation by drilling multiple small holes. Lastly, cement was used to fix the components [Supplementary Video 1, <http://links.lww.com/CM9/A109>].

Clinical outcomes and radiograph assessment

Patients were followed up at 3, 6, and 12 months post-operatively and yearly thereafter. Clinical outcomes were

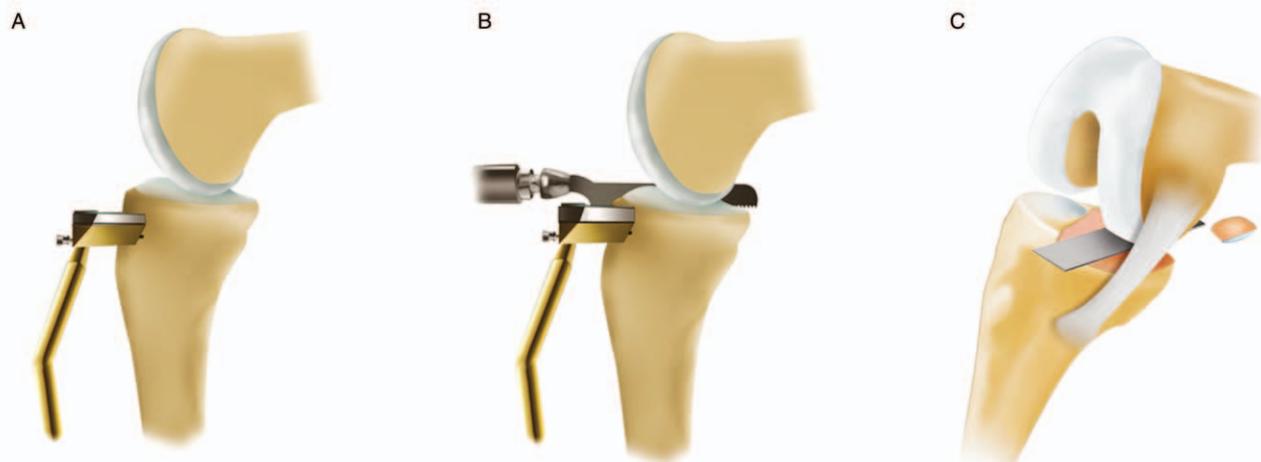


Figure 1: Demonstration of the modified technique. (A) Following the Oxford UKA surgical procedure, the conventional bone cut level was confirmed with 0 mm tibial shim. (B) The modified technique replaced 0 mm with 2 mm tibial shim to reduce the tibial bone cut by 2 mm. (C) With the knee in 90° flexion, 2 mm posterior femoral condyle bone was cut parallel to tibial cut before drilling the distal femoral holes. UKA: Unicompartmental knee arthroplasty.

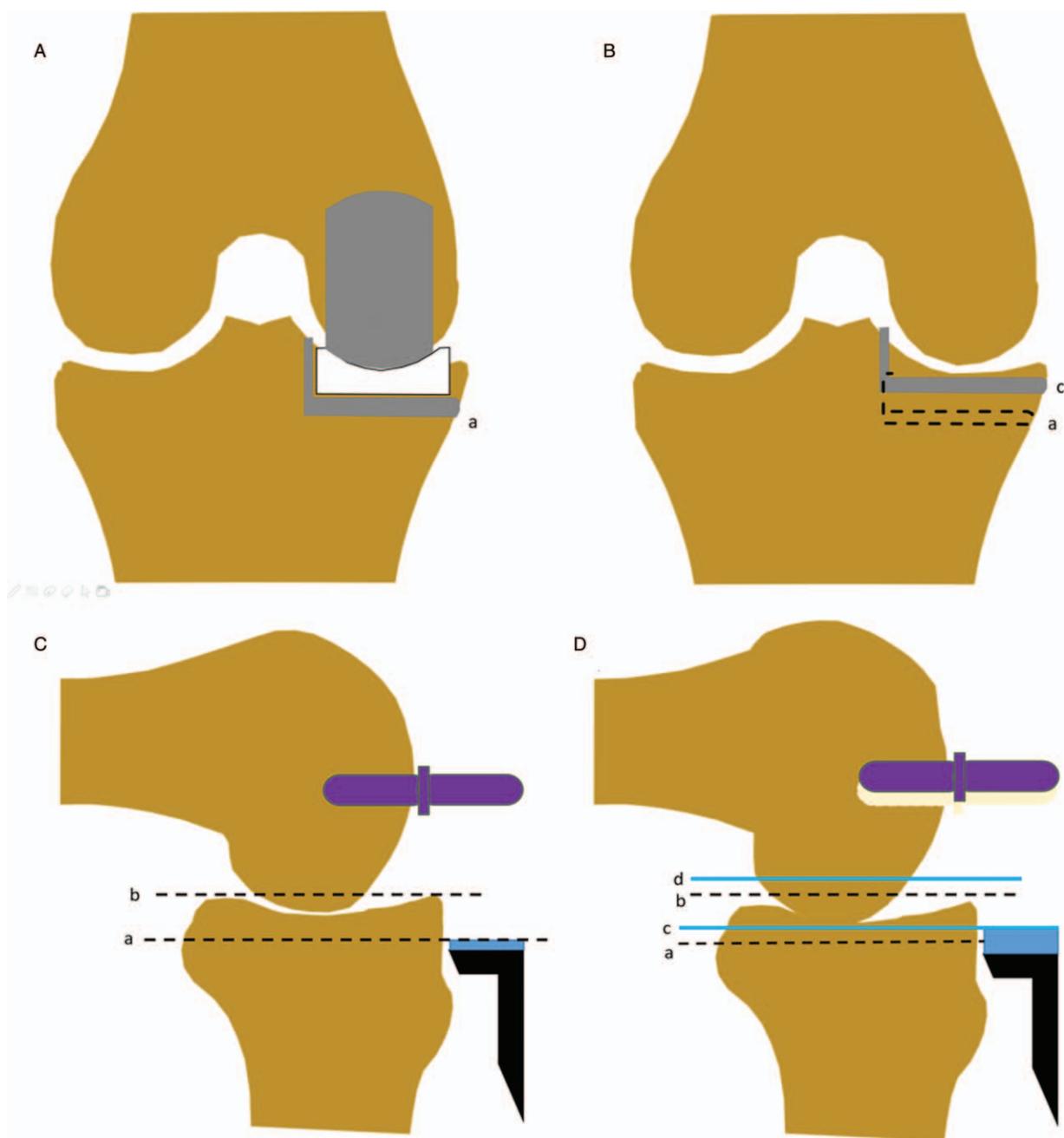


Figure 2: A schematic illustration of the modified technique. (A) The anteroposterior schematic diagram of the conventional group; (B) the anteroposterior schematic diagram in the modified group; (C) the lateral schematic diagram in the conventional group; (D) the lateral schematic diagram in the modified group. Dotted line a and b represented the conventional bone cut on tibial and femoral sides. Solid lines c and d represented the modified bone cut on tibial and femoral sides. The modified technique replaced 0 mm with 2 mm tibial shim to reduce the tibial bone cut by 2 mm. Two more millimeters of bone was cut in the posterior femoral condyle to create enough flexion gap for the implants. Additionally, the intra-medullary rod was elevated by 2 mm. The picture (B) also illustrated that the smaller tibial cut could allow for a larger tibial size.

evaluated in terms of knee Hospital for Special Surgery (HSS) score, visual analog scale (VAS) for pain, knee ROM, and presence of any complications. Any complications such as deep venous thrombosis, pulmonary embolus, deep infection, arthritis of the lateral compartment, or loosening were also recorded. Additionally, the final assessment was recorded for analysis.

Weight-bearing anteroposterior, lateral, and full-length radiographs were obtained at our institution both pre-operatively and post-operatively. Care was taken to ensure

that each patient stood with their patellae facing forward, to minimize rotational variation among anteroposterior radiographs. Post-operative implant position and alignment were assessed according to the guideline proposed by the Oxford group. The medial tibial bone cut and joint-line change were measured on weight-bearing anteroposterior radiographs using the following method: on the pre-operative radiograph, both the anatomical axis of the tibia (line a) and a line perpendicular to the anatomical axis from the lowest point of the medial tibia (line b) were drawn. The distance from line b to the peak point of the

tibial vertices was measured (distance α). On the post-operative radiograph, the perpendicular line (line c) to the anatomical axis (line a) from the bottom of tibia implant was drawn. Similarly, the perpendicular line (line d) to the anatomical axis (line a) from the top surface of the bearing was also drawn. The distance β and γ from the same peak point of the tibial vertices to the lines c and d were measured. The difference between distance α and distance β was defined as the medial tibial bone cut amount. The difference between distance α and distance γ was defined as the joint line change [Figure 3].

Statistical analysis

All data were analyzed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA). Data are reported as the mean with the standard deviation. The Chi-square test and Student's *t* test were used to determine whether statistically significant differences existed between the groups. A *P*-value <0.05 was considered statistically significant.

Results

All 68 patients were included at the final follow-up in October 2018. Twenty knees (29.4%) were from male

patients and 48 knees (70.6%) were female patients. The mean follow-up was 38.2 ± 6.3 months and was at least 2 years for all patients (range, 27–51 months). At baseline, the mean age at the time of the operation was 68.4 ± 7.5 years (range, 54–81 years). The mean body mass index was 25.2 ± 2.7 kg/m². In total, 36 UKA procedures were performed on the right knee while 32 were performed on the left knee. The mean pre-operative ROM was $121.4^\circ \pm 10.2^\circ$, which was improved to $127.7^\circ \pm 6.6^\circ$ at the final follow-up ($t = -4.55$, $P < 0.001$). The mean HSS knee score increased from 58.7 ± 7.7 to 92.4 ± 5.1 at the time of the final follow-up ($t = -27.72$, $P < 0.001$). The mean VAS score was reduced from 6.8 ± 0.9 to 2.0 ± 0.8 ($t = 34.81$, $P < 0.001$). The mean pre-operative HKA on weight-bearing radiographs was $174.0^\circ \pm 3.3^\circ$, which was corrected to $177.3^\circ \pm 2.1^\circ$ on the post-operative radiographs ($t = -9.37$, $P < 0.001$) [Table 1].

There were no significant differences in age, sex distribution, body mass index, pre-operative ROM, HSS score, VAS score, and HKA between the two groups. For the modified group and conventional group, the mean follow-up time was 38.2 ± 6.2 months and 38.2 ± 6.6 months, respectively ($t = -0.01$, $P = 0.992$), and the mean post-operative ROM was $128.1^\circ \pm 7.0^\circ$, $127.4^\circ \pm 6.2^\circ$, respectively ($t = -0.44$,

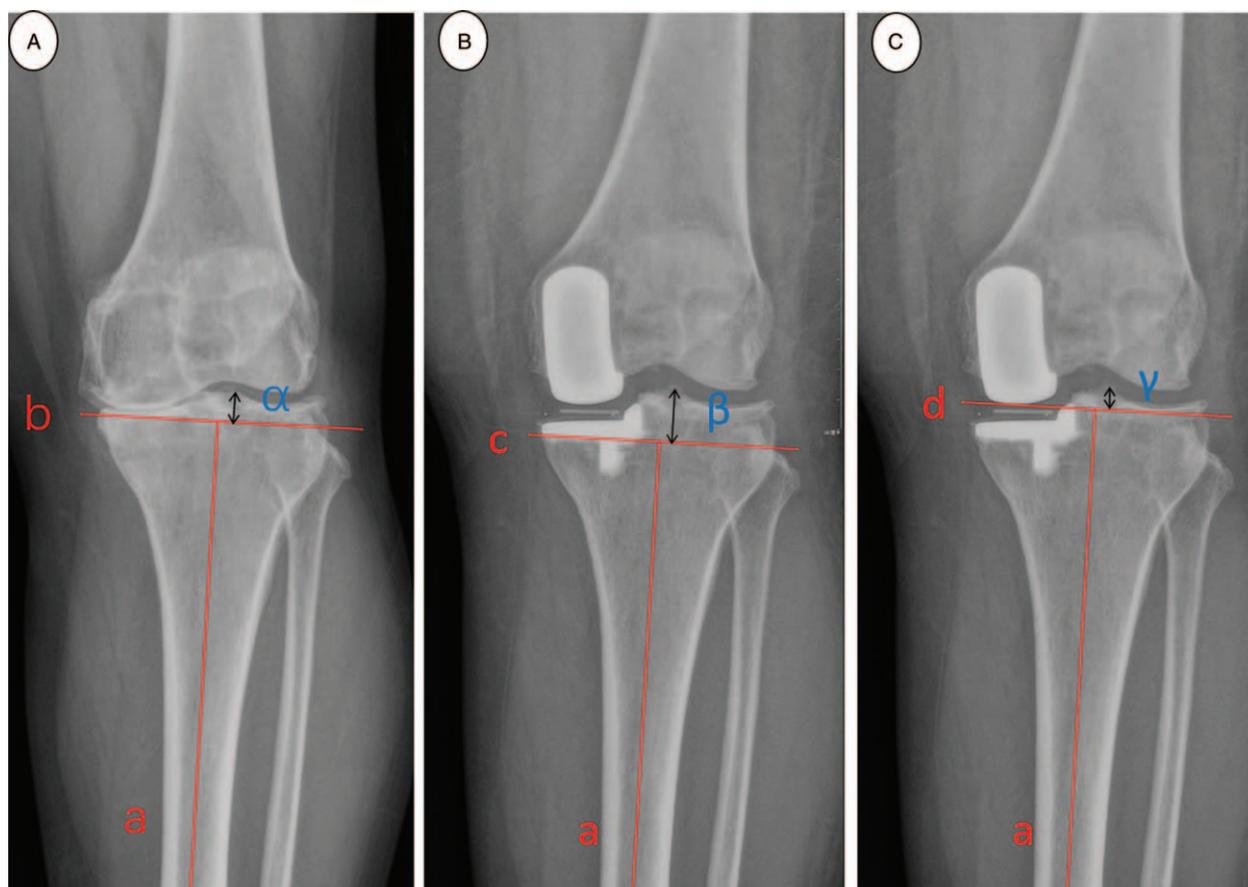


Figure 3: The measurement methods of medial tibial bone cut and joint line change. (A) An anatomical axis of the tibia (line a) and a line perpendicular to the anatomical axis from the lowest point of the medial tibia (line b) were drawn on a pre-operative radiograph. The distance from line b to the peak point of the tibial vertices was measured (distance α). (B) On the post-operative radiograph, the perpendicular line (line c) to the anatomical axis (line a) from the bottom of the tibia implant was drawn. (C) Similarly, the perpendicular line (line d) to the anatomical axis (line a) from the top surface of the bearing was drawn. The distance β and γ from the same peak point of the tibial vertices to the lines c and d were measured. The difference between distance α and distance β was defined as the medial tibial bone cut amount. The difference between distance α and distance γ was defined as joint line change.

Table 1: Demographic characteristics and data analysis in the modified group and the conventional group.

Characteristics	Overall (n = 68)	Modified group (n = 34)	Conventional group (n = 34)	t	P
Sex (male/female)	20/48	10/24	10/24	–	–
Mean follow-up time (months)	38.2 ± 6.3	38.2 ± 6.2	38.2 ± 6.6	–0.01	0.992
Age (years)	68.4 ± 7.5	69.1 ± 7.5	67.8 ± 7.4	–0.75	0.459
BMI (kg/m ²)	25.2 ± 2.7	25.6 ± 2.8	24.8 ± 2.6	1.24	0.219
Pre-operative ROM (°)	121.4 ± 10.2	120.1 ± 10.2	122.8 ± 10.1	1.10	0.277
Post-operative ROM (°)	127.7 ± 6.6	128.1 ± 7.0	127.4 ± 6.2	–0.44	0.659
Pre-operative HSS knee score	58.7 ± 7.7	59.0 ± 8.7	58.4 ± 6.8	–0.28	0.781
Post-operative HSS knee score	92.4 ± 5.1	91.3 ± 4.8	93.4 ± 5.2	1.69	0.095
Pre-operative VAS score	6.8 ± 0.9	6.7 ± 1.1	7.0 ± 0.8	1.18	0.240
Post-operative VAS score	2.0 ± 0.8	2.1 ± 0.8	1.8 ± 0.8	–1.65	0.104
Pre-operative HKA (°)	174.0 ± 3.3	173.5 ± 3.0	174.5 ± 3.5	1.26	0.210
Post-operative HKA (°)	177.3 ± 2.1	177.4 ± 1.9	177.1 ± 2.4	–0.62	0.535
Proximal tibial bone cut (mm)	5.7 ± 1.6	4.7 ± 1.1	6.7 ± 1.3	6.45	<0.001
Distal femoral bone mill (mm)	4.1 ± 1.1	4.9 ± 0.8	3.4 ± 0.9	–7.83	<0.001
Joint line change (mm)	0.8 ± 1.9	2.1 ± 1.0	–0.5 ± 1.7	–7.46	<0.001

Data are shown as *n* or mean ± standard deviation. BMI: Body mass index; ROM: Range of motion; HSS: Hospital for Special Surgery; VAS: Visual analog scale; HKA: Hip-knee-ankle angle; –: Not applicable.

Table 2: The implant size in the modified group and the conventional group.

Items	Modified group (n = 34)	Conventional group (n = 34)	χ ²	P
Tibial size			4.95	0.035
AA	1 (2.9)	5 (14.7)		
A	15 (44.1)	19 (55.9)		
B	12 (35.3)	7 (20.6)		
C	5 (14.7)	3 (8.8)		
D	1 (2.9)	0		
Bearing size			1.34	0.569
3 mm	9 (26.5)	13 (38.2)		
4 mm	23 (67.6)	20 (58.8)		
5 mm	2 (5.9)	1 (2.9)		
Femoral size			0.76	1.000
X-small	2 (5.9)	3 (8.8)		
Small	27 (79.4)	27 (79.4)		
Medium	3 (8.8)	3 (8.8)		
Large	2 (5.9)	1 (2.9)		

Data are shown as *n* (%).

$P = 0.659$). There were no significant differences in post-operative HSS score (91.3 ± 4.8 vs. 93.4 ± 5.2 , $t = 1.69$, $P = 0.095$) and VAS score (2.1 ± 0.8 vs. 1.8 ± 0.8 , $t = -1.65$, $P = 0.104$) between the two groups. Furthermore, no significant differences were found in the pre-operative and post-operative HKA between the two groups (pre-operative, $173.5^\circ \pm 3.0^\circ$ vs. $174.5^\circ \pm 3.5^\circ$, $t = 1.26$, $P = 0.210$; post-operative, $177.4^\circ \pm 1.7^\circ$ vs. $177.1^\circ \pm 2.4^\circ$, $t = -0.62$, $P = 0.535$) [Table 1].

Significant differences were noted between groups with respect to the proximal tibial bone cut, distal femoral bone mill, and joint line change in the coronal planes. The amount of proximal tibial bone cut was significantly less in the modified group than in the conventional group (4.7 ± 1.1 mm vs. 6.7 ± 1.3 mm, $t = 6.45$, $P < 0.001$). Correspondingly, there was a significant difference in

distal femoral bone mill (4.9 ± 0.8 mm vs. 3.4 ± 0.9 mm, $t = -7.83$, $P < 0.001$). The joint line of medial compartment was slightly elevated by 2.1 ± 1.0 mm in the modified group compared with -0.5 ± 1.7 mm in the conventional group ($t = -7.46$, $P < 0.001$) [Table 1]. The tibial implant size in the modified group was larger than that in the conventional group ($\chi^2 = 4.95$, $P = 0.035$), whereas the bearing size and femoral size were similar in the two groups ($\chi^2 = 1.34$, $P = 0.569$; $\chi^2 = 0.76$, $P = 1.000$, respectively) [Table 2].

No patients in either group underwent conversion to TKA or experienced serious adverse events related to the operation in both groups, such as death, periprosthetic joint infection, pulmonary embolism, or a cardio-cerebral vascular incident. One bearing dislocation occurred 2 months after surgery in the conventional group because

of hyperflexion trauma. This bearing was replaced by a thicker one. One patient in the modified group reported persistent unexplained knee pain.

According to the guidelines proposed in the surgical manual of the Oxford group, the post-operative radiographic assessments showed that the accuracies of the post-operative position and alignment of implanted prostheses were comparable between the two groups. Clinically acceptable overall implant alignment and position were achieved in 97.1% of patients in each group. In the modified group, one femoral component tilted in the coronal plane with a post-operative radiographic angle $>10^\circ$. In the conventional group, one case was under-corrected in the coronal alignment along with a posterior tibial slope $>12^\circ$ in the sagittal plane. Neither of these patients with implant failure had clinical symptoms at the last follow-up.

Discussion

The most important finding of the present study is that the modified technique for tibial bone sparing is reliable and has many advantages. The modified technique can reduce the amount of tibial bone cut, which is useful in reducing the tibial bone defect in revision. Furthermore, it can help to achieve a larger cement surface on the tibial side, which would benefit patients of smaller size. Finally and most importantly, the modified technique is comparable with the conventional technique in terms of clinical outcomes and radiographic assessments.

The major advantage of the tibial bone sparing technique in UKA is that it preserves the tibial bone mass by about 2 mm, which is useful in reducing the tibial bone defect during revision. According to the national registry report, UKA had a relatively high revision rate compared with TKA.^[5] Furthermore, Chawla *et al*^[14] reviewed 124 studies and reported that the annual revision rate of UKA was 1.07%, which was 2.18-fold of TKA. Among the many other failure modes, aseptic loosening was the main failure mode in UKA.^[15,16] In most cases of UKA failure, bone defects occur on the tibial side and require revision devices such as metal augments, bone grafts, and stems when converting to TKA.^[8] The femoral bone defects are usually small and contained, and they may only require autologous morselized bone grafts in most cases. However, the tibial side bone loss in a failed UKA is a major problem, especially when a metal-backed implant has been used.^[8] Possible causes of bone loss include loosening with component subsidence, osteolysis from wear, removal of the components and cement, the metal-backed design, and the bone cut in the primary operation; among these, the most prominent causes were the metal-backed design and the bone cut. Therefore, a more primary tibial bone cut might result in a large bone defect if UKA fails in future.^[17] As described in the pre-operative X-ray image of the primary TKA brochure, the tibial bone horizontal cut line usually lies 8 to 10 mm below the lateral compartment surface in varus knee. Namely, the amount of the proximal tibial cut is 2 mm below the surface of the medial side in anteromedial knee osteoarthritis. In conversion to TKA, if the tibial bone horizontal cut line is drawn below the tibial

component, it does not influence the TKA procedure. However, this was not found to be the case in our practice. In the clinical practice of primary Oxford UKA, the thickness of bone removed from the tibia must be enough to accommodate a tibial tray (3 mm) and a bearing that is usually 4 mm thick. Therefore, the amount of tibial side gap after bone cut in Oxford UKA is about 7 mm, not including the tibial groove. For this reason, conversion from Oxford UKA to TKA is very different from primary TKA and is more technically difficult to perform successfully.^[18,19] In the case shown in Figure 4, the tibial bone loss in a failed UKA was usually 5 mm more than that in a primary TKA, which is primarily due to the native tibial bone cut (usually 5 mm more than TKA on the medial side).^[8] If a surgeon cuts more bone in the primary operation and the tibial bone defect is larger than 10 mm in the revision, then the revision might need a metal block/wedge, a bone graft, or a tibial stem.^[11,12] Hence, it is very important to preserve the tibial bone mass. As shown in the present study, the modified cutting technique can preserve the tibial bone mass by about 2 mm, which decreases the tibial bone defect by about 2 mm in the revision. Reducing the tibial bone cut by 2 mm might result in a revision without the need for a stem or bone graft.

Another advantage of reducing the tibial bone cut is increased medial support and decreased pain during medial stress. The bone strength of the tibia significantly decreases as the distance from the subchondral resection surface increases.^[20] A significant tibial bone cut leads to a weaker bone bed for the tibial component. This modified technique advances the tibial bone cut closer to the joint space, thus basing it on an optimal tibial bone surface. Additionally, it can help to achieve a larger tibial plate on the tibial side, which is crucial in dispersing stress. Although no consensus has been reached regarding the tibial bone cut thickness in UKA, it is better to minimize the amount of tibial osteotomy to prevent tibial fracture and decrease the risk of implant subsidence or loosening. Excessive tibial resection may increase the forces on the tibia surface and cause pain.^[21] In a biomechanical study, Simpson *et al*^[22] demonstrated that after UKA, the mean strain on the proximal tibial cortex increased by 6%, 13%, and 18% when tibial resection levels of 2, 4, and 6 mm were modeled, respectively. Furthermore, Small *et al*^[21] demonstrated similar results: 4 mm increased distal bone cut increased tibial strain variance by 35%. Therefore, surgeons must be particularly careful to avoid an overly-excessive tibial bone cut.

A third advantage of the tibial bone sparing technique in UKA is that a smaller tibial cut allows for a larger tibial size. Because the proximal tibial bone is an inverted triangle in the coronal plane, a larger amount of bone cut will lead to a smaller tibial surface. Hence, a smaller tibial cut could allow for a larger tibial surface. As a result, the tibial implant size could potentially be larger. The advantage is obvious for Asian patients who have a relatively small body size. Statistically speaking, in the Asian population, smaller values have been reported for the medial tibia, where the only available size of tibia prosthesis is sometimes too large.^[23] In the present study, size A was used on the tibial side in most cases. In Chinese

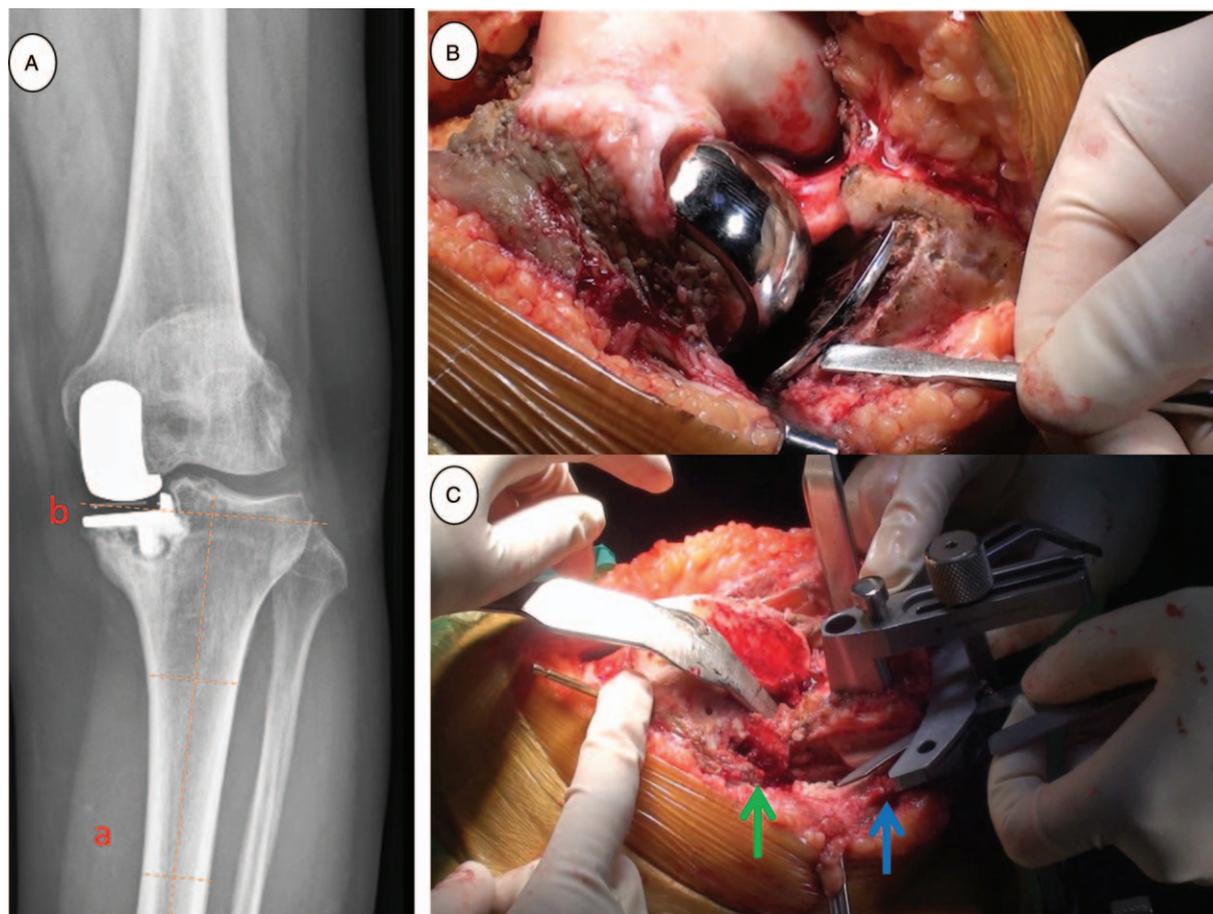


Figure 4: A TKA revision case of a 61-year-old woman with tibial aseptic loosening 6 years after UKA. (A) On pre-operative X-ray image of TKA revision, the tibial cut line (line b) orthogonal to the mechanical axis (line a) which was drawn 10 mm below the joint line of the unaffected compartment lied outside the tibial component. (B) At revision, the tibial side loosening was confirmed. (C) A significant bone defect was found in the medial tibial side after the component remove (blue arrowed line) while the femoral bone defect was smaller and more contained (green arrowed line). TKA: Total knee arthroplasty; UKA: Unicompartmental knee arthroplasty.

patients with a small body size, the smallest tibial size (size AA) has been reported to overhang. This overhanging tibial component will irritate the synovial membrane and eventually cause pain.^[24] Additionally, large tibial coverage has been shown to disperse stress. Small tibial coverage may induce a collapse or loosening of the tibial plateau.^[25,26] Hence, a smaller tibial cut will result in a larger tibial size and greater coverage, which will largely benefit patients with a small body size by reducing stress and pain.

Most importantly, the modified technique is comparable with the conventional technique in terms of the clinical outcomes and radiographic assessments. Although the joint line was slightly elevated in the modified technique group of the present study, there were no significant differences in the HSS score, VAS score, ROM, or radiographic assessments between the two groups. Clinically acceptable overall implant alignment and position were achieved in 97.1% of patients in each group. No conversion to TKA or any serious operation-related adverse events had occurred after a minimum 2-year follow-up. Notably, these acceptable outcomes depend on a slight joint line change. A significant joint line elevation

may influence the knee kinematics, alignment, ROM, and overall results.^[27,28] Although the acceptable amount of joint line elevation is controversial, Takayama *et al*^[29] found that a medial tibial joint line elevation of >5 mm restrained the improvement in the knee extension angle in UKA.

This study has several limitations. First, this study was limited to early post-operative results. Further studies are required, including those that provide subsequent clinical results and revision reports. Second, the sample size of this experiment was relatively small. A well-designed randomized controlled study with a larger sample size might provide more significant results. Third, the sample in this study was limited to the Chinese population. Whether this method is also applicable in patients who generally have a larger body size, such as the European and American populations, remains unclear. For more significant and generalizable results, a random sample taken from multiple populations is; therefore, required.

Despite these limitations, the clinical relevance of the present study is that the modified tibial bone sparing technique is reliable and easily performed. The post-

operative radiographic and clinical results are equally as good as those in the current conventional technique.

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Conflicts of Interest

None.

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