Bilateral knee osteoarthritis treated with medial open-wedge high tibial osteotomy using two types of β-tricalcium phosphate with differing placements in each knee: A report of two cases

Hiromi Mochizuki 1, Tomokazu Yoshioka 2, Naoya Kikuchi 3,4, Masashi Yamazaki 5,6

1. Department of Orthopaedic Surgery, Tsukuba Central Hospital, Ushiku, JPN 2. Division of Regenerative Medicine for Musculoskeletal System, Institute of Medicine, University of Tsukuba, Tsukuba, JPN 3. Department of Orthopaedic Surgery, Institute of Medicine, University of Tsukuba, Tsukuba, JPN 4. Orthopaedic surgery, University of Tsukuba Hospital, Tsukuba, Ibaraki, JPN 5. Department of Orthopaedic Surgery, Institute of Medicine, University of Tsukuba, Tsukuba, JPN 6. Orthopaedic Surgery, University of Tsukuba, Tsukuba, JPN

Corresponding author: Tomokazu Yoshioka, tymd99@tsukuba-seikei.jp

Abstract

In medial open-wedge high tibial osteotomy (MOWHTO) for knee osteoarthritis, synthetic bone is commonly used as a replacement material for the opening gap. Unidirectional porous β-tricalcium phosphate (UDPTCP) and spherical porous β-tricalcium phosphate (SPTCP) have been widely used. In general, the two prostheses are placed parallel to the osteotomy opening gap. In this report, we describe MOWHTO performed for bilateral knee osteoarthritis in a 63-year-old woman and in a 51-year-old man. Both patients had experienced bilateral knee pain. In each patient, UDPTCP was placed anteriorly and SPTCP was placed posteriorly in one knee, with the placement reversed in the other knee. The remodeling of each type of β-TCP was evaluated using computed tomography immediately after surgery and one year postoperatively. The postoperative corrective loss and clinical outcomes were also evaluated. Remodeling with β-TCP was faster with UDPTCP than with SPTCP, even though the anteroposterior placement differed laterally in each patient. Furthermore, there was no correction loss, and the clinical outcomes were comparable, regardless of the placement of β-TCP.

Introduction

In medial wedge opening wedge high tibial osteotomy (MOWHTO) for knee osteoarthritis, an osteotomy of the proximal tibia is performed, and two synthetic bones are placed in the opening gap, one at the front and the other at the back. These resorbable bone substitutes have sufficient strength and internal fixation materials to allow early weight bearing [1]. Synthetic bones include hydroxyapatite and β-tricalcium phosphate (β-TCP), among which spherical porous β-tricalcium phosphate (SPTCP) is widely used [2]. SPTCP is an artificial bone with excellent stability and bone remodeling and is resorbed and replaced with bone after implantation [3]. Unidirectional porous β-tricalcium phosphate (UDPTCP) is a novel synthetic bone material composed of communication holes arranged in a single direction. UDPTCP produces an appropriate balance between bone formation and material resorption because of its unique frosted columnar structure [4]. Excellent clinical outcomes using UDPTCP have been reported in orthopedic surgery [5-8]. Kikuchi et al. [9] reported that bone remodeling occurred earlier in cases with UDPTCP than in cases with SPTCP placed in the open gap for OWHTO.

In this report, we describe two cases in which MOWHTO was performed for bilateral knee osteoarthritis, with different anterior–posterior placements of two different types of β-TCP in each knee.

Case Presentation

Case 1: A woman visited the orthopedic outpatient clinic complaining of right knee pain and underwent MOWHTO for the right knee at 63 years of age. Left knee pain began after the right knee surgery and gradually increased. At 64 years of age, she underwent MOWHTO for the left knee. The preoperative radiographic parameters were femorotibial angle (FTA) 177.3°, medial proximal tibial angle (MPTA) 89.7°, and posterior tibial slope (PTS) 13.6° for the right knee, and FTA 178.3°, MPTA 86.5°, and PTS 14.4° for the left knee (Table 1). She was treated conservatively with a diagnosis of medial knee osteoarthritis, but OWHTO was performed because of the lack of improvement in pain. Preoperative Japanese Orthopaedic Association score for knee osteoarthritis (JOA scores) were 70 and 80 for the right and left knees, respectively.
Case 2: A man visited the orthopedic outpatient clinic complaining of left knee pain for which he underwent MOWHTO at 51 years of age. Right knee pain began after the left knee surgery and gradually increased. At 53 years of age, he underwent MOWHTO for the right knee. The preoperative radiographic parameters were FTA 178°, MPTA 87.7°, and PTS 9.7° for the left knee and FTA 179.3°, MPTA 86.5°, and PTS 12.1° for the right knee (Table 1). He was treated conservatively for a diagnosis of medial knee osteoarthritis; however, MOWHTO was performed because of the lack of improvement in pain. The preoperative JOA scores were 75 and 70 in the left and right knees, respectively.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Body mass index (kg/m²)</th>
<th>FTA (°)</th>
<th>MPTA (°)</th>
<th>PTS (°)</th>
<th>Opening gap (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>F</td>
<td>32.1</td>
<td>U-S</td>
<td>177.3</td>
<td>89.7</td>
<td>13.6</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>M</td>
<td>26.7</td>
<td>U-S</td>
<td>170.0</td>
<td>87.7</td>
<td>9.7</td>
</tr>
<tr>
<td>3</td>
<td>53</td>
<td>M</td>
<td></td>
<td>S-U</td>
<td>179.3</td>
<td>88.5</td>
<td>12.1</td>
</tr>
</tbody>
</table>

**TABLE 1: Demographic and preoperative radiographic data of each case**

M: Male, F: Female, SPTCP: spherical porous β-tricalcium phosphate; UDPTCP: unidirectional porous β-tricalcium phosphate. U-S: UDPTCP was implanted anteriorly, and SPTCP was implanted posteriorly. S-U: SPTCP was implanted anteriorly, and UDPTCP was implanted posteriorly.

Both patients were operated on and evaluated as described below. At the time of surgery, a 7-cm longitudinal incision was made on the proximal-medial side of the tibia, and an osteotomy was performed. A bone saw and chisel were used for bialate osteotomy: one plane from the proximal medial side of the tibia toward the fibular head, and the other plane parallel to the tibial shaft behind the tibial tuberosity. The gap was gradually opened until the planned preoperative opening distance was achieved. The target for the functional axis was approximately 62.5% [10]. UDPTCP (Affinos®, Kuraray Co., Tokyo, Japan) and SPTCP (Osferion 60®, Olympus Thermo Biomaterials, Tokyo, Japan) were used as spacers in the opening gap. Each section was cut into wedges and placed parallel to the anterior and posterior parts. The right or left knee was implanted with UDPTCP anteriorly and SPTCP posteriorly and was defined as the U-S knee. The other knee was defined as the S-U knee, with SPTCP implanted anteriorly and UDPTCP implanted posteriorly. A locking compression plate (TriS Medial HTO Plate System, Olympus Thermo Biomaterials, Tokyo, Japan) was used for internal fixation. The patients used a cane to avoid weight bearing for one week, followed by partial weight bearing. Full weight bearing was allowed four weeks postoperatively.

To evaluate bone remodeling, computed tomography (CT) was assessed one week and one year postoperatively. CT images parallel to the osteotomy plane were acquired using the method reported by Tanaka et al. [11]. The image at the center of the osteotomy plane was divided into two regions, UDPTCP and SPTCP, and the CT values (Hounsfield units; HU) of each region were analyzed using Osirix® (Pixmeo Inc., Geneva, Switzerland) (Figure 1). To evaluate correction loss, the following radiographic parameters were measured: FTA, MPTA, and PTS at one week and one year postoperatively. Correction loss was defined as the numerical difference between the values of the radiographic parameters obtained one week and one year postoperatively (specifically, the value at one year postoperatively minus the value at one week postoperatively). Clinical outcomes were evaluated using the JOA score [12] preoperatively and one year postoperatively.

Case 1: MOWHTO was performed with the right knee as the U-S knee and the left knee as the S-U knee, with opening distances of 10.0 mm and 12.0 mm, respectively. Postoperative radiographic parameters and correction losses are shown in Tables 2 and 3. The mean CT values of the area implanted with UDPTCP one week after surgery and at the last observation were 1,570 and 1020 HU, respectively. The mean CT values of the area implanted with SPTCP at 1 week after surgery and at the last observation were 1,225 and 1417 HU, respectively, in the right knee (U-S knee). The mean CT values of the area implanted with UDPTCP one week after surgery and at the last observation were 1,586 and 925 HU, respectively. The mean CT values of the area implanted with SPTCP one week after surgery and at the last observation were 1,303 and 1,347 HU, respectively, in the left knee (S-U knee) (Figures 1 and 2). The JOA scores improved from 70 to 85 for the U-S knee and from 80 to 85 for the S-U knee.
FIGURE 1: CT images of the center of the osteotomy plane for Case 1 show the mean CT value (HU) of the area implanted with UDPTCP (yellow rectangle) and the area implanted with SPTCP (blue rectangle). (a, b) CT images of the U-S knee at one week and one year postoperatively. (c, d) CT images of the S-U knee at one week and one year postoperatively.

CT, computed tomography; HU, Hounsfield units; SPTCP, spherical porous β-tricalcium phosphate; UDPTCP, unidirectional porous β-tricalcium phosphate. U-S: UDPTCP was implanted anteriorly and SPTCP was implanted posteriorly. S-U: SPTCP was implanted anteriorly and UDPTCP was implanted posteriorly.

FIGURE 2: CT attenuation values (HU) of UDPTCP (red) and SPTCP (blue) in Case 1 at one week and one year postoperatively.

CT, computed tomography; HU, Hounsfield units; SPTCP, spherical porous β-tricalcium phosphate; UDPTCP, unidirectional porous β-tricalcium phosphate. U-S: UDPTCP was implanted anteriorly and SPTCP was implanted posteriorly. S-U: SPTCP was implanted anteriorly and UDPTCP was implanted posteriorly.
<table>
<thead>
<tr>
<th>Case</th>
<th>FTA (°)</th>
<th>MPTA (°)</th>
<th>MPTA (°)</th>
<th>PTS (°)</th>
<th>PTS (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year post-operation</td>
<td>1 week post-operation</td>
<td>1 year post-operation</td>
<td>1 week post-operation</td>
<td>1 year post-operation</td>
</tr>
<tr>
<td>1</td>
<td>U-S 173.8</td>
<td>93.5</td>
<td>50.7</td>
<td>14.6</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>S-U 167.7</td>
<td>96.7</td>
<td>96.1</td>
<td>13.7</td>
<td>13.5</td>
</tr>
<tr>
<td>2</td>
<td>U-S 173.6</td>
<td>95.0</td>
<td>50.7</td>
<td>12.5</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>S-U 174.7</td>
<td>94.9</td>
<td>94.2</td>
<td>11.2</td>
<td>10.6</td>
</tr>
</tbody>
</table>

**TABLE 2: Postoperative radiographic parameters in each case**

SPTCP: spherical porous β-tricalcium phosphate; UDPTCP: unidirectional porous β-tricalcium phosphate. U-S: UDPTCP was implanted anteriorly, and SPTCP was implanted posteriorly. S-U: SPTCP was implanted anteriorly, and UDPTCP was implanted posteriorly.

<table>
<thead>
<tr>
<th>Case</th>
<th>MPTA (°)</th>
<th>PTS (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year post-operation</td>
<td>1 week post-operation</td>
</tr>
<tr>
<td>1</td>
<td>U-S 0.8</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>S-U 0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>U-S 1.3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>S-U 0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**TABLE 3: Changes in the medial proximal tibial angle (MPTA) and posterior tibial slope (PTS)**

SPTCP: spherical porous β-tricalcium phosphate; UDPTCP: unidirectional porous β-tricalcium phosphate. U-S: UDPTCP was implanted anteriorly and SPTCP was implanted posteriorly. S-U: SPTCP was implanted anteriorly, and UDPTCP was implanted posteriorly.

Case 2: MOWHTO was performed with the left knee as the U-S knee and the right knee as the S-U knee, with opening distances of 13.0 mm and 14.0 mm, respectively. Postoperative radiographic parameters and correction losses are shown in Tables 2 and 3. The mean CT values of the UDPTCP one week after surgery and at the last observation were 1,496 and 767 HU, respectively, in the right knee. The mean CT values of the SPTCP one week after surgery and at the last observation were 1,247 and 1,251 HU, respectively, in the left knee (U-S knee). The mean CT values of the area implanted with UDPTCP one week after surgery and at the last observation were 1,525 and 824 HU, respectively, in the left knee. The mean CT values of the area implanted with SPTCP one week after surgery and at the last observation were 1,254 HU and 1,319 HU, respectively, in the right knee (S-U knee) (Figure 3). The JOA scores improved from 75 preoperatively to 90 at one year postoperatively for the U-S knee and from 70 to 80 for the S-U knee.
FIGURE 3: CT attenuation values (HU) of UDPTCP (red) and SPTCP (blue) in Case 2 at one week and one year postoperatively.

CT, computed tomography; HU, Hounsfield units; SPTCP, spherical porous β-tricalcium phosphate; UDPTCP, unidirectional porous β-tricalcium phosphate. U-S: UDPTCP was implanted anteriorly and SPTCP was implanted posteriorly. S-U: SPTCP was implanted anteriorly and UDPTCP was implanted posteriorly.

Discussion

MOWHTO was performed for bilateral varus knee osteoarthritis, and two types of prostheses, UDPTCP and SPTCP, were placed anteriorly and posteriorly. In all knees, the CT values of UDPTCP were higher than those of SPTCP in the first postoperative week in both patients; however, at the last observation, they were lower than those of SPTCP and close to those of cancellous bone (100-200 HU). Furthermore, there was no correction loss in any knee, and the clinical outcomes were improved.

A previous report [13] compared MOWHTO implanted with UDPTCP anteriorly and SPTCP posteriorly with MOWHTO implanted with SPTCP anteriorly and UDPTCP posteriorly in unilateral knee osteoarthritis and observed early bone remodeling with UDPTCP, regardless of anterior or posterior placement. In this report, the CT values were lower with UDPTCP than with SPTCP, regardless of patient or anterior/posterior placement. The porosities of UDPTCP and SPTCP were 57% and 60%, respectively. Knabe et al. [14] reported that a higher porosity of SPTCP was more favorable for bone formation, and Tanaka et al. [15] measured the CT values in MOWHTO using SPTCP with different porosities (60% and 75%). They found that SPTCP with 60% porosity showed higher CT values than cancellous bone six years after surgery, whereas SPTCP with 75% porosity showed the same CT values as cancellous bone and was completely resorbed and converted to bone. In the present study, UDPTCP exhibited lower CT values than SPTCP at the last observation, although the porosity of UDPTCP was almost the same as that of SPTCP. Animal experiments have found that blood permeates more rapidly in UDPTCP than in SPTCP because of its structure [16], and the structure of UDPTCP may contribute to early bone remodeling.

There was no correction loss, and the clinical score was improved at one year postoperatively in all knees. The compressive strength of UDPTCP was greater than 14 MPa parallel to the direction of the pores, whereas that of SPTCP was 20 MPa.

In the present study, MOWHTO with different anteroposterior placements of the prosthesis in each knee of the same patient was evaluated. No correction loss was observed in any of the four knees at one year postoperatively. A meta-analysis [17] showed no difference in the rate of correction loss in MOWHTO with or without synthetic bone, whereas Takeuchi et al. [18] reported that in MOWHTO using a tibial bone model, the stress on the plate and lateral cortical hinge was reduced in groups in which SPTCP (60% porosity, 20 MPa compressive strength) was implanted anteriorly and posteriorly in the opening gap, compared with groups in which no synthetic bone was implanted.

Tanaka et al. [15] reported no correction loss at two years postoperatively in MOWHTO, with the implantation of SPTCP with 60% porosity and 20 MPa compressive strength into the medial cortical defect, where the contact stress was the greatest, and SPTCP with 75% porosity and 3 MPa compressive strength into the trabecular bone defect. Few studies have investigated the biomechanics of synthetic bone, especially UDPTCP in MOWHTO, and further investigation is needed to determine how UDTCPT contributes to stability.

Conclusions

Two cases of MOWHTO with two different prosthesis placements for bilateral knee osteoarthritis showed earlier bone remodeling with UDPTCP than with SPTCP, regardless of the placement position. In addition, there was no correction loss one year postoperatively, and the clinical scores improved in all four knees.
Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: Masashi Yamazaki declare(s) a grant from Kuraray Co., Ltd. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References