Primary total knee arthroplasty assisted by computed tomography-free navigation for secondary knee osteoarthritis following massive calcium phosphate cement packing for distal femoral giant-cell bone tumor treatment: a case report

Akihiko Takeuchi*, Norio Yamamoto, Takaaki Ohmori, Katsuhiro Hayashi, Shinji Miwa, Kentaro Igarashi, Takashi Higuchi, Kensaku Abe, Hirokata Yonezawa, Sei Morinaga, Yoshihiro Araki, Yohei Asano, Shiro Saito and Hiroyuki Tsuchiya

Abstract

Background: Giant cell tumor of bone (GCTB) is an intermediate tumor commonly arising from the epiphysis of the distal femur and proximal tibia. Standard GCTB treatment is joint-preserving surgery performed using thorough curettage and the filling of the cavity with allo-, auto-, polymethyl methacrylate (PMMA), or synthetic bone graft. Calcium phosphate cement (CPC) is an artificial bone substitute, which has the benefit of being able to adjust defects, consequently inducing immediate mechanical strength, and promoting biological healing. Secondary osteoarthritis may occur following GCTB treatment and may need additional surgery if severe. However, details regarding surgery for secondary osteoarthritis have not been fully elucidated. There are no reports on the use of total knee arthroplasty (TKA) for the treatment of secondary osteoarthritis following CPC packing. The insertion of an alignment rod is a standard procedure in TKA; however, it was difficult to perform in this case due to CPC. Therefore, we used a computed tomography (CT)-free navigation system to assist the distal femur cut. This study presents a knee joint secondary osteoarthritis case following CPC packing for GCTB curettage that was treated with standard TKA.

Case presentation: A 67-year-old Japanese woman, who was previously diagnosed with left distal femur GCTB and was treated by curettage and CPC packing 7 years ago, complained of severe knee pain. Left knee joint plain radiography revealed Kellgren and Lawrence (K-L) grade 4 osteoarthritis without evidence of tumor recurrence. Therefore, she was scheduled for TKA. There are no reports on the cutting of a femoral condyle surface with massive CPC with accurate alignment. Because it is difficult to insert the alignment rod intramedullary and cut the femoral condyle with CPC, we planned CT-free navigation-guided surgery for accurate bone cutting using an oscillating tip saw system to prevent CPC cracks. We performed standard TKA without complications, as planned. Postoperative X-ray showed...
Background
Giant cell tumor of bone (GCTB) is an intermediate tumor typically arising from the epiphysis of the distal femur, proximal tibia, distal radius, and proximal humerus and occasionally arising from the metaphysis [1]. Standard GCTB treatment is joint-preserving surgery by thorough curettage with adjuvant treatment and the filling of the cavity with allo-[2], auto-[3], polymethyl methacrylate (PMMA) [4–6], or synthetic bone graft [7, 8], enabling joint preservation; the local recurrence rate was reported to be up to 30%. The grading system based on the radiological tumor extension of the Campanacci grading system has been widely used to predict the local recurrence [9]. Calcium phosphate cement (CPC) is an artificial bone substitute that has the benefit of being able to adjust defects with CPC molding, inducing immediate mechanical strength, preserving the bone stock, and promoting biological healing [8, 10]. GCTB is located close to the joint; therefore, secondary osteoarthritis is a notable complication [11] that requires additional surgery if severe [12–14]. However, to date, details regarding additional surgery for severe secondary osteoarthritis have not been fully elucidated. Only two cases of standard total knee arthroplasty (TKA) for secondary osteoarthritis treatment have been reported [15, 16]. Inserting an alignment rod is a standard procedure in TKA; however, it was difficult to perform in this case due to CPC. Therefore, we used a computed tomography (CT)-free navigation system [17, 18]. There was no published report about the surface TKA guided by CT-free navigation after primary GCT surgery with CPC.

Case presentation
A 67-year-old Japanese woman (body mass index [BMI], 16.9), who was initially diagnosed with left distal femur GCTB (Fig. 1a, sup. Fig. 1) and graded as Campanacci grade II, was treated with phenol and ethanol adjuvant curettage and the filling of the cavity with CPC (Biopex®-R; Pentax Co., Tokyo, Japan) following the intraoperative pathological diagnosis of GCTB (Fig. 1b). The final diagnosis by permanent section was also confirmed as GCTB (sup. Fig. 2a). The postoperative course was uneventful; however, 5 years postoperatively, she gradually started complaining of knee pain (Fig. 1c). The pain subsequently became severe, and magnetic resonance imaging 5 years postoperatively revealed synovitis without apparent local recurrence (sup. Fig. 3). Needle biopsy confirmed chronic synovitis (sup. Fig. 2b), and knee society knee score (KSks) and knee society function score (KSfs) ameliorated from 27 and 29 to 64 and 68, respectively. The patient can walk without a cane postoperatively.

Conclusion: There was no report about the surface TKA guided by CT-free navigation after primary GCT surgery with CPC. We believe that this case report will help in planning salvage surgery for secondary osteoarthritis after CPC packing.

Keywords: GCTB, CPC, CT-free navigation, TKA

Fig. 1 Preoperative radiogram images. Preoperative plain radiograms of the left knee joint showed an osteolytic lesion with scalloping (a). A postoperative plain radiogram showed that the cavity was filled with calcium phosphate cement (b). A plain radiogram after 5 years showed a K-L grade 3 joint space narrowing (c). A plain radiogram after 6 years showed the progressive joint space narrowing; the narrowing by the time of this radiogram was graded as K-L grade 4 (lateral tibiofemoral) and grade 2 (medial tibiofemoral) osteoarthritis (d). A CT imaging showed K-L grade 4 patellofemoral osteoarthritis.
plain radiogram 6 years postoperatively showed K-L grade 4 (lateral tibiofemoral and patellofemoral) and grade 2 (medial tibiofemoral) osteoarthritis (Fig. 1d, e) [19, 20]. Moreover, the patient complained of a restricted knee range of motion (−20 to 130 degrees); however, she did not show lateral instability. Knee Society Knee Score (KSKS) and Knee Society Function Score (KSFS) were 27 and 29, respectively [21]. Preoperative radiogram showed K-L grade 1 osteoarthritis that progressed during the last 6 years, without major risk factors, including high BMI (>30) and injury, other than the female sex and older age (>65 years old) [22, 23]. Therefore, we diagnosed the case as secondary osteoarthritis. Standard TKA was initially planned; however, cutting the femoral surface using an intramedullary alignment nail was seemingly difficult due to considerable amounts of CPC. Furthermore, we were concerned about the risk of CPC cracks during femoral surface cutting using a standard bone saw. Therefore, we planned to use a CT-free navigation system (Navigation: Stryker Navigation Cart System: Stryker Orthopaedics, Mahwah, NJ, USA, Software: Stryker Knee Navigation Ver2.0: Stryker Orthopaedics, Mahwah, NJ, USA), which enables accurate bone cutting without an intramedullary alignment rod. Preoperative planning was performed using a 3D-templating software (ZedView, ZedKnee; LEXI Co., Ltd., Tokyo, Japan) to determine the size and position of the implant (Fig. 2). Intraoperatively, the knee joint was approached via a midline skin incision, and the suprapatellar pouch was filled with the proliferative synovial tissue. CPC and degenerative joint surface were exposed (Fig. 3a) following synovial tissue resection, which was histologically diagnosed as chronic synovitis (sup. Fig. 2c); two truckers were set on the femur and tibia. According to a previous report, we set the mechanical axes of both the femur and tibia as an anatomical index for the image-free navigation system [24]. First, in the femur, we registered at the center of the femoral head, lateral and medial epicondyles of the femur, surface of the medial and lateral condyle, Whiteside line, and knee center. Next, in the tibia, we registered at the anterior-posterior axis, lateral and medial malleolus of the ankle, medial and lateral tibial articular surface, and knee center. After registration, cutting blocks were set at the distal end of the femur and proximal end of the tibia perpendicular to their bone axes. The amount of femoral osteotomy was defined as the thickness of the implant from the femur medial joint surface, and the amount of tibial osteotomy was determined using the fibula head height. A total of 9 mm of the distal medial condyle was cut using abductor rotation, as determined by the surgical epicondylar axis (SEA). The anterior and posterior surfaces were cut via a cutting block using a Stryker Precision® blade and a Stryker Precision System 6 saw (Stryker Instruments) according to the anterior surface, which enabled the cutting of CPC without cracks. Subsequently, the tibial cutting guide was mounted using the support of navigation (Fig. 3b). After the tibial surface was cut, the implant trial was placed, and the flexion and extension gap were assessed. Finally, the component (Triathlon CR [Stryker]) was implanted with cement;
4-, 3-, and 9-mm inserts were used for the femur, tibia, and CS, respectively (Fig. 3c). The patella was resurfacing. A postoperative radiogram showed the precise alignment of the component (Fig. 4a, b) and mechanical axis, which was cited at the center of the knee joint (Fig. 4c). The postoperative course was uneventful without any adverse event. Four years later, radiogram showed good alignment and no loosening of the component (Fig. 5). The knee range of motion was 0 to 95 degrees. KSKS and KSFS ameliorated to 64 and 68, respectively.
Discussion and conclusions
This case demonstrates that standard TKA combined with CT-free navigation assistance can treat knee joint secondary osteoarthritis following CPC packing for GCTB treatment. CPC packing in the initial surgery was performed to preserve the bone stock with the biological interface and long-lasting stability; therefore, the authors planned to keep the bone stock without CPC damage. The challenge, in this case, was that the large amount of CPC packed in the distal part of the femur prevents the insertion of the intramedullary rod. To accurately cut the femoral condyle, we used a CT-guided navigation system. Moreover, a standard bone saw has the risk of causing CPC cracks [25, 26]. Therefore, we used an oscillating tip saw system [27] instead and successfully cut the surface without cracks.

In this case, although GCTB was close to the joint, curettage and the filling of the cavity using biological or artificial substitutes are standard procedures. PMMA is frequently used to fill the large defect following curettage [4–6]. The mechanical strength of PMMA was reported to be >70 megapascals (mPa) [28] whereas that of CPC was 30–40 mPa [29]. Compared with PMMA, CPC has the properties of a biological interface [7] and is reported to strengthen the torsional stress of an animal long bone after filling [25]. Recent advancements in denosumab (a receptor activator of nuclear factor-κB ligand inhibitor) could induce tumor shrinkage, providing a chance to perform joint-preserving surgery instead of joint replacement [30]. Conversely, joint-preserving surgery may induce secondary osteoarthritis, with an incidence of 1.7–33% [11, 12, 14, 31]; however, details regarding salvage surgery have not been fully elucidated, suggesting that information on secondary osteoarthritis treatment is also unclear. Conti et al. reported patellofemoral joint arthroplasty as the salvage surgery for femoropatellar osteoarthritis following the initial treatment of curettage and PMMA packing for distal femoral GCTB. Monocompartmental or bicompartamental knee replacement could be applicable, depending on the degree of osteoarthritis; however, Conti et al. recommended total knee replacement.
as a stable and definitive alternative in older adult patients who have limited activities [32]. The patient, in this case, presented with K-L grade 4 (lateral tibiofemoral and patellofemoral) and grade 2 (medial tibiofemoral) osteoarthritis and was an older adult; therefore, total knee arthroplasty was performed. There are only two reports on the use of standard TKA, which preserves both lateral ligaments, to treat secondary osteoarthritis [15, 16]. Zylberberg et al. reported successful secondary osteoarthritis replacement using standard TKA and reported that the cutting of the surface and the insertion of a nail did not influence PMMA existence [15]. However, implant alignment accuracy was not fully mentioned. Lyall et al. reported the salvage of secondary osteoarthritis following an autograft using a stem augmented femoral component [16]. Different from the abovementioned two cases, the cavity after curettage, in this case, was filled with massive CPC, showing good integration with the surrounding bone. However, due to its nature, the artificial substitute was not remodeled entirely and had a risk of cracking by rough cutting or nailing. We easily suspected that there will be difficulty in the insertion of the intramedullary rod and a risk of CPC cracking by the standard bone saw or nailing. Therefore, we planned to use a CT-free navigation system that enabled the mounting of the cutting block without nail insertion. The technology of the navigation system allowed accurate bone cutting alignment, ligament balancing, and the evaluation of the symmetry of the flexion and extension gaps [17]. Several reports have confirmed that navigation-assisted TKA is more reliable in achieving precise alignment than conventional TKA using intramedullary/extramedullary alignment techniques [33–35]. We confirmed that navigation-assisted surgery was useful to perform primary TKA for secondary osteoarthritis following GCTB curettage and CPC packing. Preoperative CT-based planning was also useful for planning bone cutting and determining the implant size [36]. This case had distal femoral scalloping due to tumor extension; therefore, the filled CPC expanded anteriorly, inducing a risk of registration error. We also used the oscillating tip saw system for gentle cutting. Peters et al. reported that the oscillating tip saw system demonstrated reduced noise emission compared with the conventional saw system [37]. We considered that the low noise indicated low vibration, consequently reducing CPC crack risk. A patient-specific guide [38] or robotic surgery [39] may be promising, less invasive, and more concise.

In conclusion, we treated a case of secondary knee osteoarthritis following primary GCTB surgery with CPC using TKA assisted by a CT-free navigation system, which was not previously reported. We believe that this case report will help in planning salvage surgery for secondary osteoarthritis after CPC packing. Navigation-guided TKA leaves the bone stock intact and may offer the best result compared with other surgeries.

**Abbreviations**

GCTB: Giant cell tumor of bone; PMMA: Polymethyl methacrylate; CPC: Calcium phosphate cement; CT: Computed tomography; K-L: Kellgren and Lawrence; KSS: Knee Society Knee Score; KSF: Knee Society Function Score; TKA: Total knee arthroplasty; SEA: Surgical epicondylar axis; AP view: Anteroposterior view; aLDFA: Anatomical lateral distal femur angle; MPTA: Medial proximal tibia angle; WI: Weighted image; STIR: Short inversion time inversion recovery.

**Supplementary Information**

The online version contains supplementary material available at https://doi.org/10.1186/s12891-022-05131-0.

**Additional file 1: Sup. Fig. 1.** Preoperative magnetic resonance imaging revealed the tumor expanding anteriorly, with mixed low- and iso-intensity in T1-weighted image (WI) (a, d), and mixed iso- and high-intensity in short inversion time inversion recovery (STIR) T1-WI (b) and T2-WI (e). The gadolinium-enhanced image showed tumor enhancement (c, f). Coronal view (a, b, c), Axial view (d, e, f).

**Additional file 2: Sup. Fig. 2.** Histological analysis of the primary tumor revealed mononuclear, multinucleated cells and foam cells, which were compatible with giant cell tumor of bone (a). Biopsy specimen presented the proliferation of synovial lining cells with inflammatory cells (b). Excised synovial tissue specimen showed the proliferation of synovial lining cells, inflammatory cells, and hemosiderin deposition (hematoxylin and eosin stain; scale bar, 100 μm).

**Additional file 3: Sup. Fig. 3.** Magnetic resonance imaging after 5 years showed no tumor recurrence (coronal view: a. T1-WI, b. STIR T1-WI, c. STIR T2-WI), and joint fluid retention and synovial lesion in the suprapatellar pouch (axial view: d. T1-WI, b. STIR T1-WI, c. STIR T2-WI).

**Acknowledgements**

We would like to thank Editage (www.editage.jp) for English language editing.

**Authors’ contributions**

A.T. assisted in data collection, case analysis, the writing of the manuscript, and the performance of surgery and follow-up. T.O. assisted in performing the surgery. K.A. assisted in patient care. N.Y., T.O., K.H., S.M., K.I., T.Y., H.Y., S.M., Y.A.1, Y.A.2, S.S. and H.T. assisted in drafting and reviewing the manuscript. All authors read and approved the final version of this manuscript.

**Funding**

No funding has been received for this project.

**Availability of data and materials**

All data generated or analyzed during this study are included in this published article.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Written informed consent was obtained from the patient for the publication of this case report and any accompanying images. A copy of the written consent is available for review by the Editor of this journal.

**Additional file**

This article is part of the Topical Collection “Bone and joint surgery.”
