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CASE REPORT / CASE SERIES

A New Modular Nail Spanning System for Cement Spacer Reconstructions after Tumor Resection of the Knee

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ABSTRACT

Limb Salvage procedure is now the management of choice for most musculoskeletal malignant tumors. Thanks to advances in imaging and adjuvant modalities, limb salvage has become an oncologically safe option.

The purpose of this paper is to demonstrate the use of a new modular titanium nail spanning system designed and developed locally in the Philippines which consists of two interchangeable end-to-end interlocked IM nails in varying sizes and a sliding nail connector that can be locked in place with two set screws. Results have shown good outcomes. Several implants have been used to augment these spacers such as Kuntscher nails, Steinmann pins, plates, and other fixed-angle devices. The challenge lies in increasing the longevity of these constructs as the durability beyond 26 months has not been well established. We present two patients who underwent a knee resection arthrodesis for distal femur osteosarcoma and reconstruction using the Tumor Nail System. The largest and longest possible diameter nails were inserted: one antegrade through the tibia and the other retrograde through the femur. Once the connector was locked, the defect was filled with antibiotic-impregnated cement. Post-operative recovery was unremarkable and patients were able to do pain-free full weight bearing on their affected lower extremity. This implant's advantages include its modularity, ease of insertion, secure and robust nail connector, and circumventing contamination of the hip unlike traditionally inserted Kuntscher nails. This system is a viable option for primary knee resection-arthrodesis procedures following tumor resection. Long-term follow-up is needed to establish implant durability. Further studies can also show the potential of this implant for use as an initial spacer even in non-oncologic cases.

Keywords. limb salvage, knee fusion, knee spacer

INTRODUCTION

The application of a cement spacer following resection arthrodesis for infected knee arthroplasties has been well-known for decades, but there are few studies on its use in primary knee resection arthrodesis in tumor patients.

Primary knee resection arthrodesis with the application of a cement spacer has been a cost-effective limb salvage alternative for resource-limited countries either as a definitive treatment or as a temporary spacer while awaiting the availability of an endoprosthesis.[1] Several implants have been used to augment these spacers such as Kuntscher nails, Steinmann pins, plates, and other fixed-angle devices. The challenge lies in increasing the longevity of these constructs as the durability beyond 26 months has not been well established.[2] The purpose of this paper was to demonstrate the use of a new modular titanium nail spanning system (Tumor Nail) as a temporary spacer in two patients undergoing knee resection arthrodesis for high-grade osteosarcoma of the distal femur.

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Implant design

The implant was designed and developed locally in the Philippines. It consists of two interchangeable end-to-end interlocked solid intramedullary titanium nails with varying sizes and a sliding nail connector that can be locked into place with two set screws (Figure 1). Biomechanical testing has not yet been done. The materials used are identical to those used by the implant company for making titanium interlocking nails. The patients and responsible guardians were informed of these limitations.

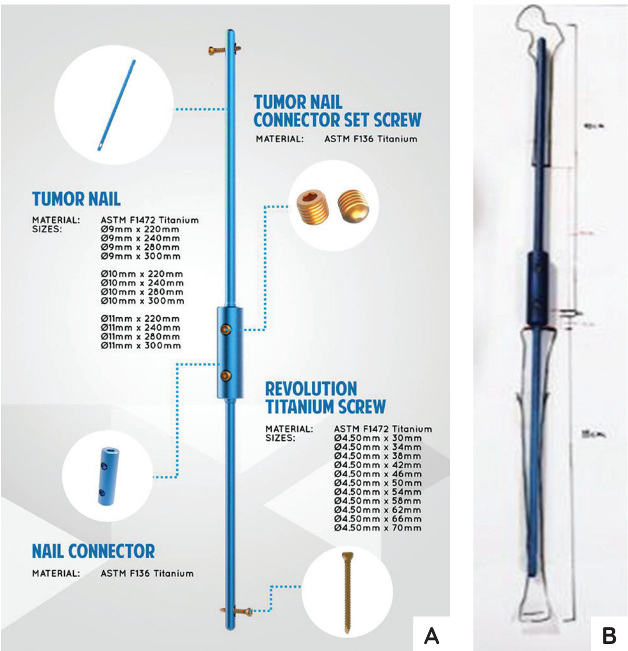

Figure 1. Implant design with the available lengths and diameters of titanium solid nails and screws **(A)**. Pre-operative templating of a tumor resection using the actual implant **(B)**.

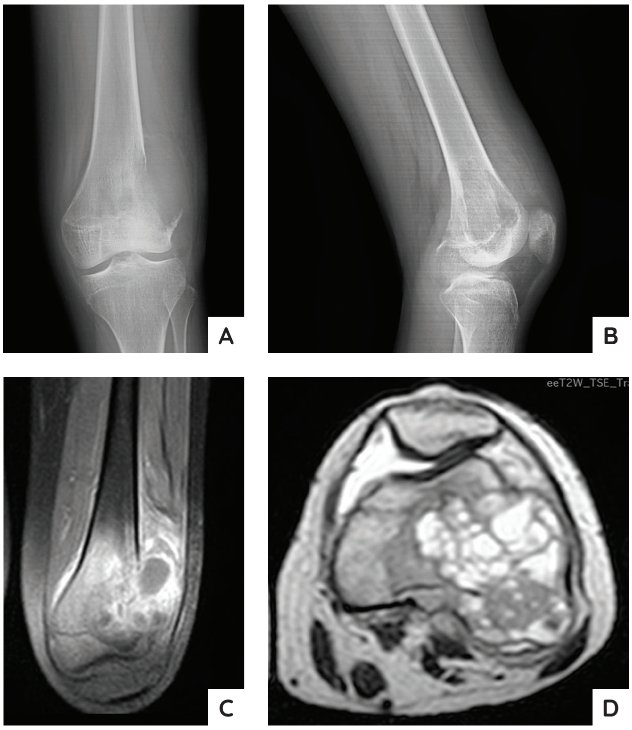

Figure 2. Initial AP **(A)** and lateral **(B)** radiographs show an aggressive lytic lesion of the distal femur with a cortical break and soft tissue mass on the lateral aspect. Initial MRI sequences before treatment. T1W FS contrast-enhanced coronal cut **(C)** and T2W TSE axial cut **(D)**.

CASE 1: EXTRA-ARTICULAR KNEE RESECTION

A 16-year-old girl presented with a three-month history of a painful left knee mass. Biopsy and curettage of the distal femur lesion were done by a private surgeon one month prior. Radiographs and MRI images are shown (Figure 2) revealing a permeative lytic lesion in the lateral aspect of the distal femur extending into the knee joint area but sparing the neurovascular bundle posteriorly. Histopathology revealed a high-grade osteosarcoma; hence, the patient underwent neoadjuvant chemotherapy with Ifosfamide, MESNA, Cisplatin, and Adriamycin for three cycles. Figure 3 shows the MRI images after neoadjuvant chemotherapy.

A direct lateral approach was done encompassing the previous biopsy site with a 2 cm margin (Figure 4). We proceeded with an extra-articular resection of the knee which involved performing a careful patellar osteotomy under fluoroscopic guidance. Femoral osteotomy was done with a 3 cm margin from the tumor while the tibial cut was positioned approximately

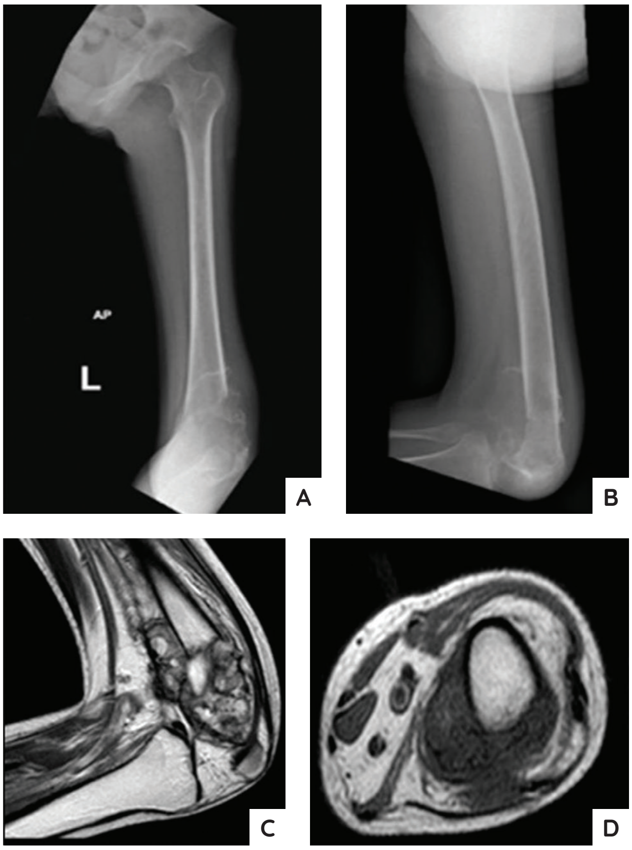

Figure 3. Imaging after neoadjuvant chemotherapy. AP **(A)** and lateral **(B)** radiographs of the femur showing radiographic response. Knee MRI sagittal **(C)** and axial **(D)** cuts show involvement of posterior femoral condyles.

12 mm below the tibial plateau thereby keeping the joint capsule intact but being proximal to the tibial tubercle to preserve the patellar tendon attachment (Figure 5).

The defect post-resection was 17 cm. Rapid frozen section for the bone osteotomy margins were negative. Reaming was done before the insertion of the nail. We planned for a 1 cm shorter lower extremity to facilitate gait clearance. Based on pre-operative templating we inserted the largest and longest possible diameter nails which was 10 x 300 mm: one antegrade through the tibia and the other retrograde through the femur. The design of the connector (8 cm in length) allowed it to slide easily between the exposed cut ends of the femur and tibia nail allowing intra-op adjustment of the modular components. Once the connector was locked into place, the defect was filled with 80 grams of antibiotic-impregnated cement molded around the implant. We were able to cover the implant using the rectus femoris together with the medial retinaculum (Figure 6). No intra-operative complications occurred. Post-operative soft tissues and radiographs are shown in Figure 7.

CASE 2: INTRA-ARTICULAR KNEE RESECTION

A 16-year-old boy presented with a six-month history of progressive pain in the left knee. Radiographs revealed an osteolytic mass at the distal femur. MRI images showed extra-articular involvement from the knee joint. A biopsy at our institution confirmed this to be a high-grade osteosarcoma hence the patient underwent neoadjuvant chemotherapy. Following a good response to the chemotherapy, the patient was then scheduled for limb salvage surgery.

A direct lateral approach to the femur was done in line with the previous biopsy site, making sure to include a 2 cm margin. An intra-articular knee resection was carried out. The femoral osteotomy was made 15 cm distal to the greater trochanter. After the removal of the tumor, a 23 cm long defect was left. We then used a 10 x 280 mm solid nail for the femur and a 9 x 300 mm solid nail for the tibia to span the defect. The defect was filled with bone cement. The construct was covered with the remaining muscle bulk (part of the rectus femoris, vastus lateralis, and part of the tensor fascia lata) (Figure 10).

Neither patient developed intra- or post-operative complications. Immediately post-operatively, no immobilizer was required for either of them. Weight bearing on the post-operative leg was delayed for two weeks for both patients to allow adequate healing of retinacular repairs. Figure 12 shows both patients doing full weight bearing on the post-operative leg after six weeks (Case 1) and two weeks (Case 2). The marked delay in ambulation of our first patient was due to prolonged room isolation after contracting a Burkholderia

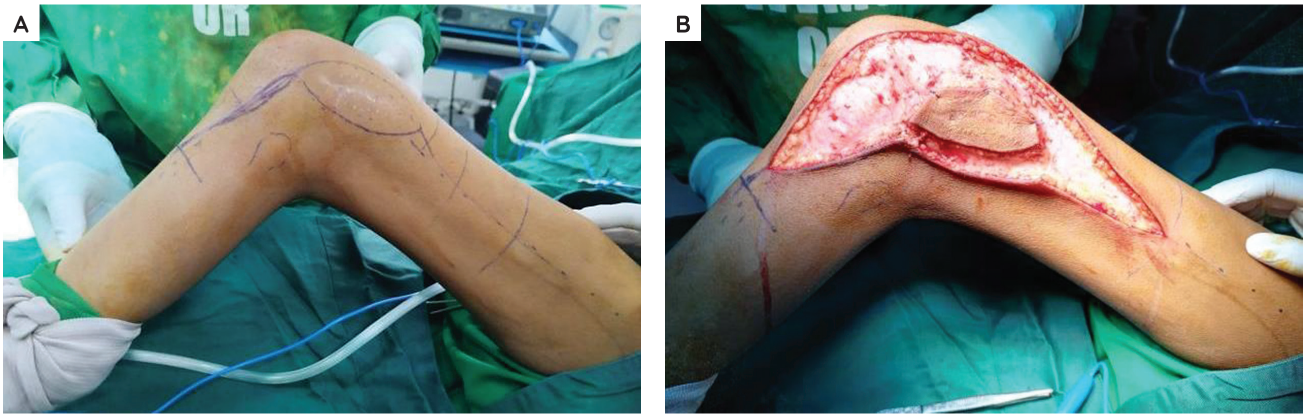

Figure 4. Incision encompassing previous biopsy site via a lateral approach **(A)**. The biopsy site was outlined and removed together with the tumor **(B)**.

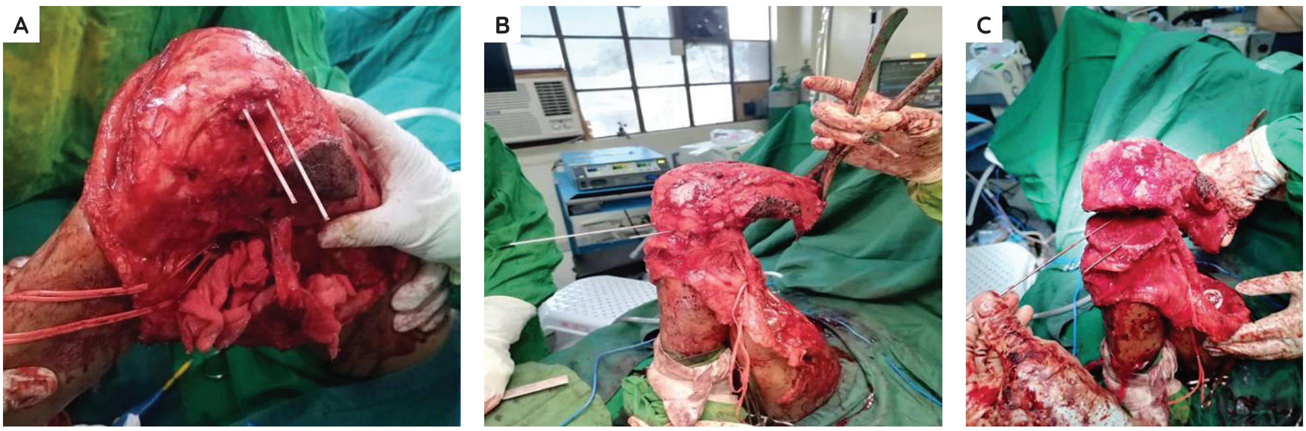

Figure 5. Extra-articular resection with patellar **(A)**, femoral **(B)**, and tibial **(C)** osteotomy.

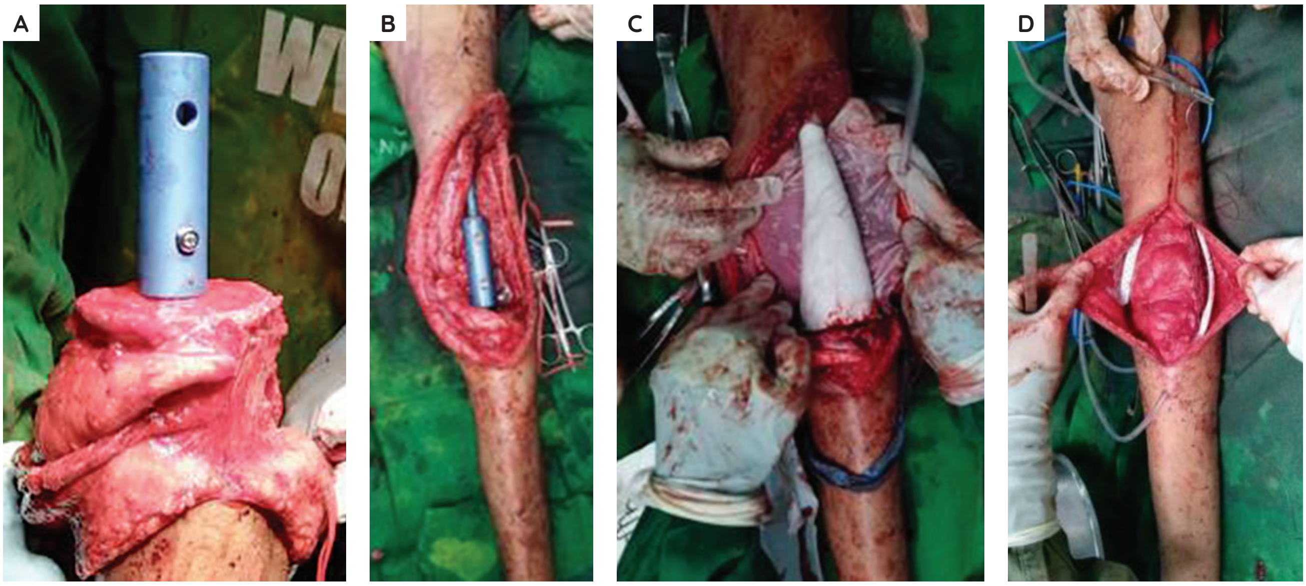

Figure 6. Intra-operative photographs. Sliding of connector through tibial nail and locking with set screw **(A)**. Defect spanned by tumor nail **(B)**. Augmentation of construct with antibiotic bone cement **(C)**. Rectus femoris with preserved medial retinaculum covering the implant **(D)**.

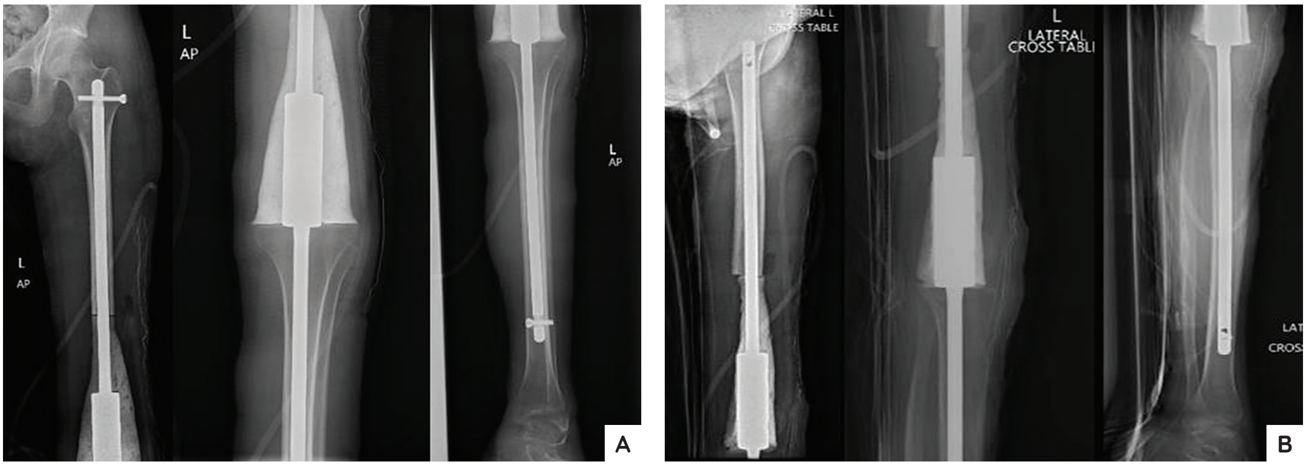

Figure 7. Post-operative AP **(A)** and lateral **(B)** radiographs of femur, knee, and leg.

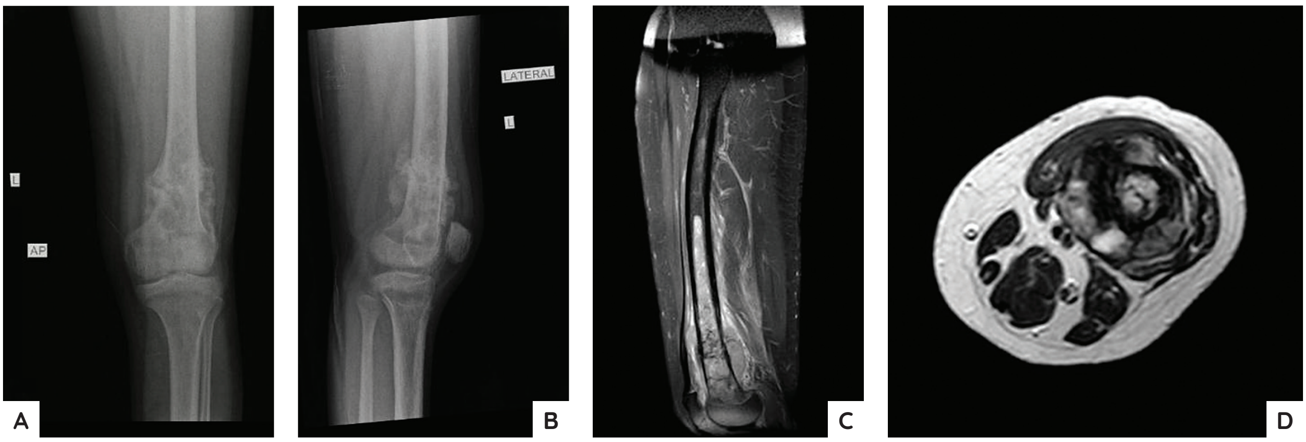

Figure 8. Initial AP **(A)** and lateral **(B)** radiographs show a lytic lesion in the distal femur with involvement of surrounding soft tissue. T1W FS contrast-enhanced sagittal cut **(C)** and T2W TSE axial cut **(D)**.

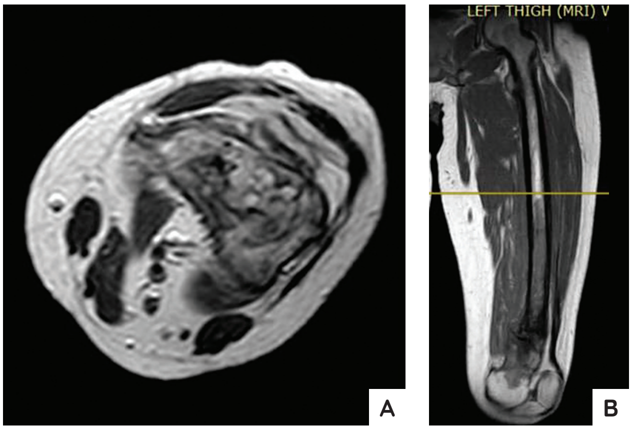

Figure 9. MRI after neoadjuvant chemotherapy. Axial cuts show no contamination of the knee joint **(A)**. Extensive intramedullary involvement proximally **(B)**.

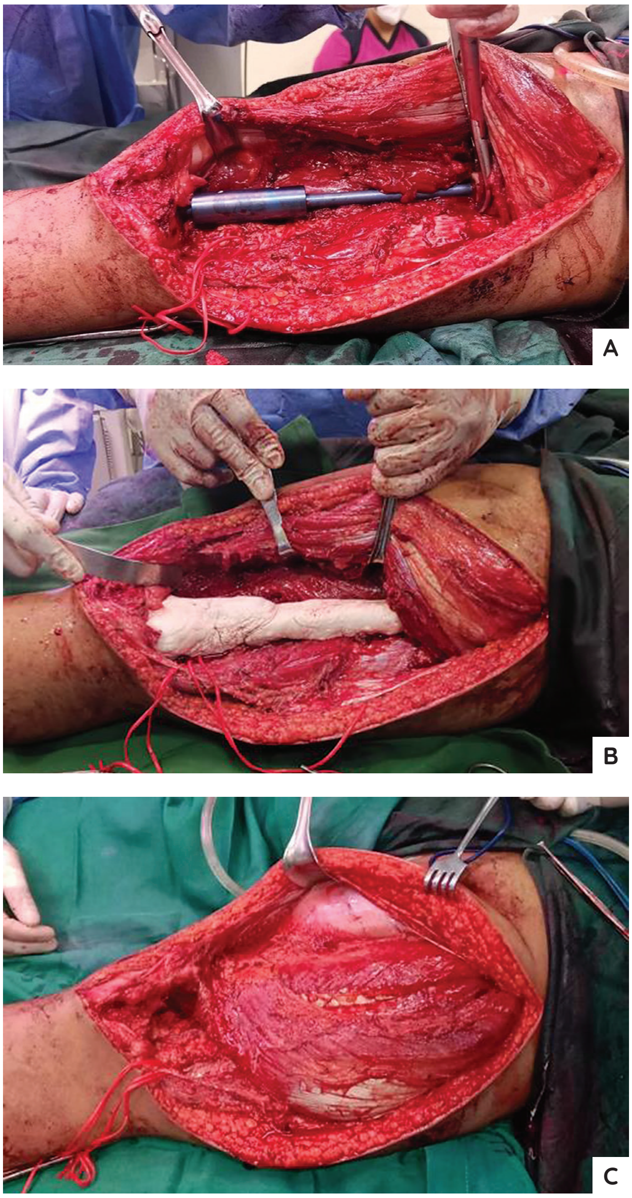

Figure 10. Intra-operative photos following placement of tumor nail to span the defect after resection **(A)**, augmentation with antibiotic-impregnated bone cement **(B)**, soft tissue coverage with remaining muscle bulk **(C)**.

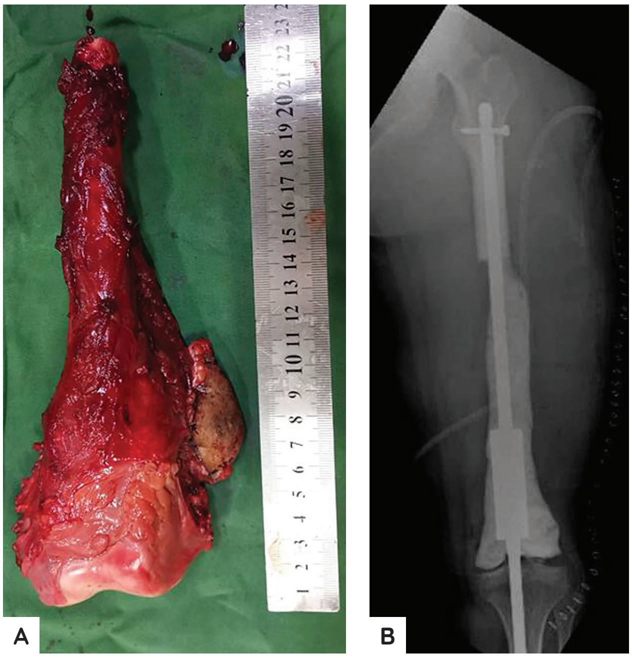

Figure 11. Twenty-three (23) cm resected distal femur with tumor and biopsy site **(A)**. Post-operative AP radiographs of the femur showing cement spacer spanning the defect **(B)**.

Figure 12. Latest clinical follow-up. Patient 1 at 12 months after surgery showing full weight bearing over left leg, side **(A)** and front **(B)** view. Patient 2 at 12 months post-surgery, side **(C)** and front **(D)** view.

infection which was not related to the operative site. Both patients were able to ambulate pain-free and independently without crutches, climb stairs, and go about their activities of daily living. Both patients also remained disease-free at seven months (Case 1) and two months (Case 2) post-operatively.

DISCUSSION

The distal femur and proximal tibia are the locations most affected by malignant bone tumors, particularly osteosarcoma.[3] The standard approach for this disease was neoadjuvant chemotherapy, surgery, which includes osteochondral allograft, allograft composite prosthesis, autograft reconstruction, and modular megaprosthesis (with the goal of a mobile knee), and then adjuvant chemotherapy.[3] However, postoperative chemotherapy was considered dangerous for wound healing and implant integration thus temporary spacers were considered to ensure completion of chemotherapy.[3] When evaluating a reconstruction technique we need to consider the ease of the procedure, its complications, functional outcome, and the durability of the construct. Besides being cost-effective compared to other grafts, cement spacers provide other advantages as well. The operating time is shorter compared to using biological constructs which require shaping to ensure optimal fit to the defect.[3] Using a cement spacer avoids donor site morbidity and avoids graft complications from adjuvant treatment modalities.[5] The rehabilitation schedule does not depend on evidence of graft incorporation or "hypertrophy" of the graft and patients are ambulant with immediate weight bearing on a stable limb.[2]

A study by Puri et al. reported on 15 patients who underwent cement spacer constructs following tumor resection, none of whom had mechanical failures. However, the mean follow-up was only 26 months. They accepted that a longer follow-up may lead to failure of the construct in some cases which prompted them to recommend the use of stacked Kuntscher nails, or combinations of a nail and a plate with adequate intramedullary length of the nail on either side.[2] In this case, the patients could ambulate at 4 weeks with no difficulty, and follow-up radiographs did not show any signs of failure.

The use of Kuntscher nails for cement spacers in knee arthrodesis typically necessitates insertion through the hip abductors, which poses a risk of contaminating the hip with tumor cells. Hence, the Tumor Nail's modularity allows interchangeable nail lengths and diameters, and insertion through the knee defect (avoiding hip contamination), while being a securely locked and durable construct.

CONCLUSION

We showcased several advantages of this implant design, including modularity, ease of insertion, a securely locked and robust nail connector, and protection of the proximal hip structures from contamination. This implant system is an acceptable option for primary knee resection-arthrodesis procedures following tumor resection, especially when tumor endoprostheses are not available.

Although one patient acquired a Burkholderia infection, this case was determined by Infectious Disease Unit to be a contaminant in IV fluids and antiseptic formulas, therefore, it was difficult to pinpoint the exact moment of infection, precluding the classification of the case as a post-op complication.

However, the post-operative recovery was unremarkable and both patients were able to do full weight-bearing on their affected lower extremity, long-term follow-up will be needed to establish implant durability. Further studies can also show the potential of this implant for use as an initial spacer even in Masquelet procedures and infected knee arthroplasties.

ETHICAL CONSIDERATION

Patients' consent was obtained before submission of the manuscript.

STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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