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Double metal tibial blocks augmentation in total knee arthroplasty

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Abstract
Purpose Severe uncontained tibial bone defects occurring during total knee arthroplasty are challenging, and which treatment method is the best remains unknown. In this study, clinical and radiographic outcomes of double metal blocks augmentation were examined.
Methods Between 2004 and 2012, double metal blocks augmentation was carried out in 17 patients with severe asymmetric uncontained tibial bone defects. The first block was attached to the tibial tray with screws, and then the second block was cemented to the first block. Out of 17 patients, 13 (8 primary, 5 revision) were available for final follow-up at a median of 69 months (range 24–99). For clinical assessment, range of motion and Knee Society score were evaluated preoperatively and annually thereafter. At the final follow-up, Western Ontario and McMaster Universities Osteoarthritis Index, Oxford knee, Short Form-36, Lower extremity functional scale, and Lower extremity activity scale scores were evaluated. Radiographic assessment for radiolucent lines at the block–cement–bone interfaces and signs of failure was performed annually using fluoroscopy and standard radiographs.
Results Range of motion and Knee Society score were significantly improved post-operatively. Other clinical outcomes were favourable. Radiolucent lines were seen on fluoroscopy in three knees, but no sign of failure, such as loosening, collapse, or instability, was observed at the final follow-up.
Conclusions Double metal blocks augmentation is a favourable and useful method, which does not cause mechanical failure or protrusion of the prosthetic because of its modularity, to manage severe asymmetric uncontained proximal tibial bone defects >15 mm in total knee arthroplasty.
Level of evidence Case series, Level IV.

Keywords Total knee arthroplasty · Tibia · Bone defect · Metal block

Introduction

Proper management of severe bone defects is a challenge in total knee arthroplasty (TKA) [3, 10]. Most severe bone defects in primary TKA occur from severe preoperative angular deformity and commonly present as tibial bone defects [38]. Bone loss following TKA failure can occur by several factors, including implant and cement removal [45], mechanical loosening [15], wear debris-induced osteolysis [23], chronic infection [28], or delayed reimplantation of prosthesis [45]. Severe bony deficiencies can significantly influence factors such as stability, alignment, and soft tissue balancing; therefore, adequate restoration of bone stock is critical [25, 34, 37]. Reconstitution of severe bone defects, including single tibial plateau >25–40 % of the tibial support surface or >5–10 mm deep, is accepted to provide prosthetic support [13, 18, 40, 47]. Several options for the management of severe bone defects have been reported, including structural allograft, modular metal augmentation with a wedge or block, metaphyseal tantalum cones or sleeves, custom implants, or condyle-replacing hinged prosthesis [14, 39, 45]. Although several methods are available for treating bone defects, massive asymmetric uncontained

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tibial bone defects >15 mm remain difficult for surgeons. Each method has advantages and disadvantages as well as proper indications considering such defect characteristics as size, location, and type. For example, structural allograft carries risks of infection, non-union, and graft resorption. Modular metal augmentation has high availability and familiarity, but has limitations to its size and shape. Cones or sleeves are applicable to massive bone defects, but have limited indications to only cavitary defects [41].

Double rectangular metal blocks augmentation, which was previously introduced in a technical note [4], is a unique method that has the advantages of modular metal augmentation, while also overcoming the limitations of size and shape, for managing severe uncontained bone defects >15 mm. This technique can prevent protrusion of the prosthetic support, which can cause irritation to soft tissue and pain, by applying a smaller-size metal block. However, the results of this technique have not been reported, and there has been no evidence demonstrating its mechanical stability. The aim of this study was to evaluate whether double metal tibial blocks augmentation improves clinical results and provides favourable radiographic results in patients with severe asymmetric uncontained proximal tibial bone defects >15 mm after undergoing primary or revision TKA. The hypothesis was that double metal tibial blocks augmentation produces a stable and durable reconstruction and should be considered as an effective method.

Materials and methods

This retrospective study was approved by the Institutional Review Board of our hospital. The authors did not receive any financial aid from manufacturers mentioned in this study. Between 2004 and 2012, severe asymmetric uncontained tibial bone defects were managed by double metal blocks augmentation in 17 patients (17 cases) who underwent primary or revision TKA at a median age of 65 years (range 48–80 years). All operating procedures were carried out by one surgeon (CHC). Out of the 17 patients, 3 died <1 year after surgery for reasons not related to the operation, and one patient could not be followed up due to non-ambulatory status following myocardial infarction. Therefore, the remaining 13 patients (8 primary TKAs, 5 revision TKAs) were available for final follow-up at a median of 69 months (range 24–99 months). Demographic data of the patients and characteristics associated with the metal blocks are shown in Table 1.

Surgical technique

The knee joint was exposed using a medial parapatellar approach. Proper axial alignment of the tibia was confirmed by an extramedullary tibial alignment guide. Initial proximal tibial osteotomy was carried out at a depth of 10 mm from the unaffected tibial condyle. In the case of revision TKA, the proper level of proximal tibial osteotomy was set with consideration of the relationship between the patella and fibular head in order to restore the initial joint line [33]. Subsequently, the tibial bone defect was evaluated, and an appropriately sized tibial tray was selected. Matching bone resection was performed after assembling a block-cutting guide. If the tibial bone deficiency was >15 mm and the type of bony defect was uncontained, which has no bony support base after tibial bone resection, two rectangular metal blocks, 10- and 5-mm thick or 10- and 10-mm thick, were used to compensate for the bony defect. The first metal block was affixed to the tibial tray using screws, and then the second metal block was attached to the first block with polymethyl methacrylate (PMMA) cement (Fig. 1). If the metal block protruded over the natural cortical rim of the proximal tibia, downsized metal block augmentation

Table 1 Demographics of patients and characteristics of metal blocks

Characteristics of demographics and metal blocks	
Patients (no.)	13
Women (no.)	8
Men (no.)	5
Median age (±SD) (range) (years)	63 (±30) (48–80)
Median follow-up duration (±SD) (range) (months)	69 (±9) (24–99)
Diagnosis (no.)	
Primary TKA	
Primary osteoarthritis	3
Rheumatoid arthritis	3
Secondary osteoarthritis due to trauma	1
Charcot arthropathy	1
Revision TKA	
Aseptic loosening	3
Septic loosening	2
Side of double metal block (no.)	
Medial	11
Lateral	2
Width size of first and second metal block (no.)	
Same size	5
Down size	8
Height size of first and second metal block (no.)	
15 mm (10 mm block + 5 mm block)	5
20 mm (10 mm block + 10 mm block)	8
Length of tibial intramedullary stem (no.)	
80 mm	9
155 mm	4

TKA Total knee arthroplasty

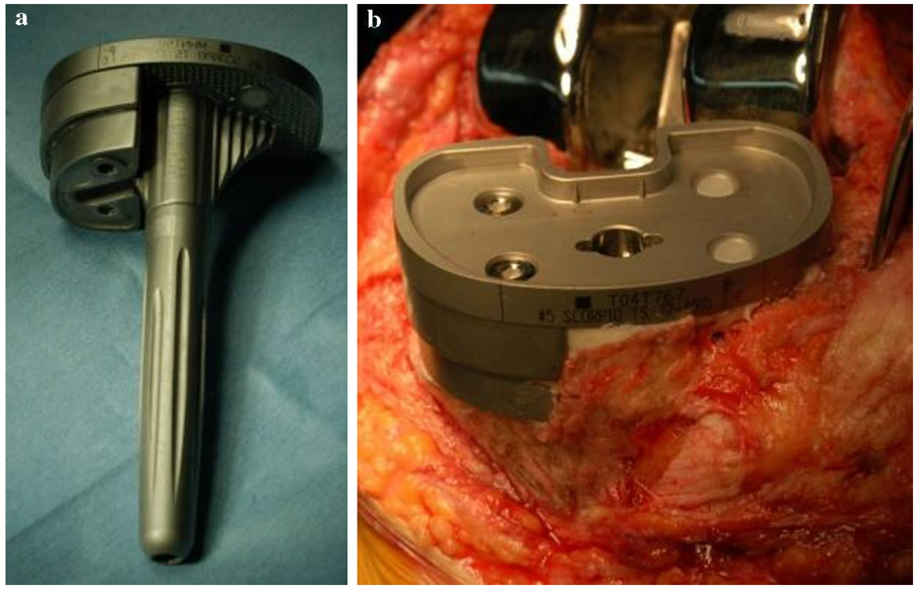

Fig. 1 Real photograph showing double metal blocks assembled to tibial tray with intramedullary stem (**a**). The first metal block being affixed to the tibial tray using screws, and second down sized metal block being assembled to first metal block with polymethyl methacrylate (PMMA) cements (**b**). The downsized metal block of width being used to maintain the cortical shape, in case of second metal block protruding over the tibial cortical rim (**b**)

was performed to maintain the natural tibial cortical shape (Fig. 1). The long intramedullary stem assembled to the tibial component was fixed in all cases using a diaphyseal dangling stem and cementation in the tibial tray and metaphysis. The size of the stem was determined by considering the length, depth, and width of the tibia, and whether the stem was fitted to or contacted the medullary canal. The implant used in this study was Scorpio TS prosthesis (Stryker Orthopedics, Mahwah, NJ, USA).

Outcome evaluations

For clinical assessment, range of motion (ROM) of the knee joint and Knee Society score (KSS; knee score, function score) [26] were evaluated preoperatively and annually thereafter. In addition, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score [7], Oxford Knee Score (OKS) [20, 35], Short Form-36 (SF-36) score [46], Lower extremity functional scale (LEFS) score [8], and Lower extremity activity scale (LEAS) score [43] were recorded at the final follow-up. Preoperative values of ROM and KSS were compared with the final values.

For radiographic assessment, standard anteroposterior (AP), posteroanterior (PA), and long-leg standing radiographs were obtained preoperatively at 3, 6, and 12 months post-operatively, and annually thereafter. Initial femorotibial anatomic alignment was compared with final anatomic alignment. Radiographic images involving component position, presence of radiolucent lines (RLLs) >1 mm in width, and osteolysis at the block–cement–bone interfaces were examined by one author (KSC) unrelated to the surgeons and procedures in this study using the Knee Society Roentgenographic evaluation system [21] with consultation to a single experienced musculoskeletal radiologist. Furthermore, supine AP and lateral fluoroscopic images, focused on the femoral and tibial components separately, were obtained annually to ensure clear views of the block–cement–bone interfaces. All radiographic measurements were documented three times with an interval of 2 weeks using a picture archiving and communication systems (Infinitti; Marotech, Seoul, Korea); the averages of the measurements were used for analysis.

Statistical analysis

The Wilcoxon signed rank test was used to compare the difference in values between preoperative and final follow-up results of ROM of the knee joint, femorotibial anatomic alignment, and KSS. The level of significance was set at $p < 0.05$. Statistical analysis was performed using SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA). The sample size required to detect differences was calculated from the absolute difference knee score of KSS between preoperative and final results. Alpha was set at 0.05, and power was set at 0.80. If the null hypothesis was set at 45, a minimum sample size of eight cases was required based on the difference between initial and final values of 64.0 ± 16.6. The present study involved 13 cases, so the overall power of the study was 0.953.

Results

Median ROM improved significantly from $110° \pm 26°$ preoperatively to $125° \pm 15°$ at the final follow-up ($p = 0.019$). All final clinical outcomes were favourable; in particular, final KSS improved significantly ($p = 0.001$; Table 2). To clarify midterm outcomes with a minimum 5-year follow-up (median, 92 months; range 60–99 months), ROM and KSS of cases improved significantly, while final results of other clinical scores were also satisfactory (Table 3).

Final anatomic alignment showed significant improvement compared with initial values ($p = 0.005$; Table 4). There was no failure, breakage, or sign of deterioration between the first and second metal blocks on radiography. On fluoroscopic images, RLLs at the block–cement–bone interfaces were observed on AP view in three knees (23 %) during the first post-operative year (zone 1, 2 cases; zones 1 and 2, 1 case). One patient (2.5 mm, zone 1) progressed at 5 years post-operatively, but no further progression existed at the final 92-month follow-up (Fig. 2). One case with RLLs on AP view demonstrated RLLs (2.0 mm, zone 1) on lateral view at 5 years post-operatively; however, progression was limited to 4 mm at the final 98-month follow-up. All RLLs did not cause any failure, component loosening, or instability.

Table 2 Clinical outcomes at preoperative and final follow-up

Clinical outcomes ($n = 13$) (maximum values)	Preoperative score			Final follow-up score			p value[f]
	Median	SD	Range	Median	SD	Range	
Range of motion (°)	110	26	55–135	125	15	90–135	0.019
Knee score of Knee Society (100)[a]	22	16	1–50	95	13	84–100	0.001
Function score of Knee Society (100)[a]	45	20	10–65	88	15	55–100	0.001
Oxford knee score (48)[a]				42	5	33–47	
PCS[c] of Short Form-36[a]				43	11	24–60	
MCS[d] of Short Form-36[a]				48	8	34–63	
Lower extremity activity scale (18)[a]				11	2	7–15	
Lower extremity function scale (80)[a]				59	12	34–75	
WOMAC[e]-pain[b] (0–20)				3	2	1–6	
WOMAC[e]-stiffness[b] (0–8)				1	1	0–4	
WOMAC[e]-physical function[b] (0–68)				11	6	4–24	

[a] More favourable results as outcomes score is higher
[b] More favourable results as outcomes score is lower
[c] Physical component summary
[d] Mental component summary
[e] Western Ontario and McMaster Universities osteoarthritis index
[f] Wilcoxon signed rank test

Table 3 Clinical outcomes at preoperative and final follow-up in minimum 5-year follow-up patients

Clinical outcomes ($n = 8$) (maximum values)	Preoperative score			Final follow-up score			p value[f]
	Median	SD	Range	Median	SD	Range	
Range of motion (°)	108	31	55–135	123	15	90–135	0.042
Knee score of Knee Society (100)[a]	32	17	1–50	95	5	84–99	0.012
Function score of Knee Society (100)[a]	45	18	25–65	90	13	60–100	0.012
Oxford knee score (48)[a]				42	5	34–47	
PCS[c] of Short Form-36[a]				46	8	36–60	
MCS[d] of Short Form-36[a]				50	9	34–63	
Lower extremity activity scale (18)[a]				11	1	11–15	
Lower extremity function scale (80)[a]				60	10	40–75	
WOMAC[e]-pain[b] (0–20)				3	2	1–6	
WOMAC[e]-stiffness[b](0–8)				1	1	0–2	
WOMAC[e]-physical function[b](0–68)				12	4	5–14	

[a] More favourable results as outcomes score is higher
[b] More favourable results as outcomes score is lower
[c] Physical component summary
[d] Mental component summary
[e] Western Ontario and McMaster Universities osteoarthritis index
[f] Wilcoxon signed rank test

Table 4 Anatomic alignment undertaken at preoperative and the final follow-up

Femorotibial anatomic alignment (varus;−, valgus;+)	Preoperative value			Final follow-up value			p value[a]
	Median	SD	Range	Median	SD	Range	
Initial varus alignment ($n = 10$)	−11	−7	−2 to −25	5	2	+2 to +6	0.005
Initial valgus alignment ($n = 3$)	21	17	+10 to +43	7	2	+5 to +8	

[a] Wilcoxon signed rank test

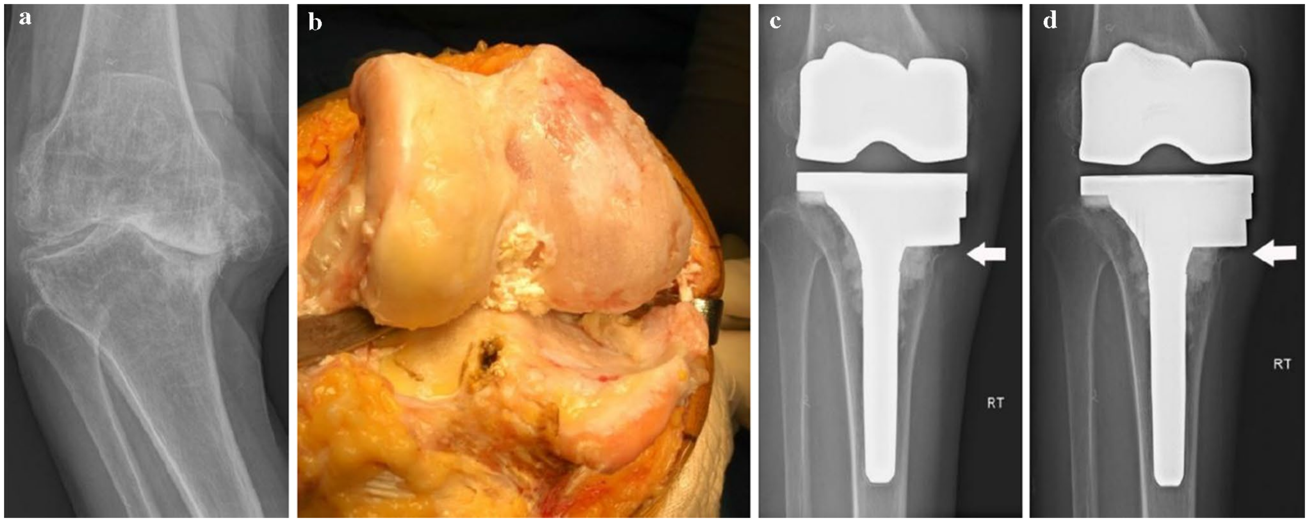

Fig. 2 Preoperative standing anteroposterior (AP) images (**a**) and intraoperative photographs after arthrotomy (**b**) showing severe uncontained proximal tibial bone defects, approximately 23 mm compared with unaffected lateral tibial condyle. AP view of fluoroscopy with medial double metal blocks (10 mm block + down sized 10 mm block) combined intramedullary stem at 60-month follow-up after primary total knee arthroplasty, demonstrating radiolucent line (*white arrow*) of 2.5 mm width bottom the block (**c**). AP view at 92-month follow-up indicating non-progressive stable radiolucent lines (*white arrow*) at same area without any radiographic failure signs and broken sign between first and second metal block (**d**)

Discussion

The most important finding of the present study was that double metal tibial blocks augmentation presented favourable clinical outcomes without any case of mechanical failure. Radiographically, there was no aseptic loosening or failure between the block–cement–bone interfaces. Only three cases showed RLLs, two of which showed progression. However, scoring by measuring the width of the RLLs [21] was not greater than a score of 4, which is probably not significant and stable. All RLLs did not cause evidence of mechanical failures. Therefore, the results of this study fully support the hypothesis that this technique produces a stable and durable reconstruction and should be considered as an effective method. The satisfactory clinical and radiographic results after a minimum 5-year follow-up demonstrate the favourable midterm durability and mechanical stability of this construct.

Management methods for severe bone defects >15 mm are limited. Structural allograft is suitable for younger patients who require further revision TKA in order to restore bone stock. Advantages of allograft include potential for biologic ingrowth and versatility [14, 16, 45]. However, allograft has concerns regarding disease transmission, as well as less osteoinductive power with regard to non-union, malunion, and late collapse [11, 22, 38]. The survival rate of allograft is not favourable: only 77.2 % at 5 years [6] and 72 % at 10 years [12]. Only surgeons with extensive experience demonstrate the best results [19]. Impaction bone graft which can be converted into contained defects by use of wire mesh may be used for uncontained defects. However, follow-up duration in previous studies has been limited to the short term. Impaction bone graft has the same disadvantages as bulk allograft [31, 32, 36].

Metaphyseal tantalum cones and sleeves are an alternative treatment for massive bone defects to restore metaphyseal stability [27, 45]. Tantalum surfaces present osteoblast expression for growth of native bone into the metal [9, 24]. Advantages of cones and sleeves include simplifying the surgical technique, shortening the operating time [40]. In the average 36-month follow-up results of 29 cases with trabecular cones, improved clinical outcomes and no RLLs were reported [42]. Another recent study reported similarly favourable results and no evidence of loosening [17, 29, 44]. In the 36 case of sleeves, no significant osteolysis or loosening was found at average follow-up of 38 months [5]. Other studies on sleeves have described similarly favourable results [1, 2]. However, weaknesses of the above studies include a short-term results and inclusion of only revision TKA cases. Potential concerns of them include removal difficulty, long-term durability, high cost, iatrogenic fracture during vigorous sleeve impaction, and epiphyseal stress shielding [24]. Most importantly, the primary indication of cones and sleeves is contained cavitary metaphyseal defects, meaning they are not suitable for severe asymmetric uncontained bone defects [14]. Additionally, the size of commercially available cones and sleeves is not suitable for Asian patients who commonly have much smaller tibial diameter compared with Caucasians.

Custom implants can provide the best fit for large bone defects. However, since accurate preoperative evaluation of bone loss is difficult, custom implants may not fit well. Other disadvantages include considerable time to produce, expansive costs, and a lack of reported results [47]. Condyle-replacing hinged prosthesis should be used for massive bone defects with loss of collateral ligamentous support, especially in low-demand, elderly patients. However, a potential disadvantage of hinged prosthesis is that there are few remaining reconstructive options if this method should fail [14].

Prosthetic augments are used for defects of 5–10 mm [47], or when 40 % or more of the projected implant–bone interface is unsupported by host bone [13]. Metal augments provide good load transmission to underlying bone as well as immediate support and stability [11]. They can be applied easily and quickly, allow for intraoperative custom fabrication, and require minimal bone resection [41]. Unlike allograft, there are no concerns about disease transmission, non-union, malunion, or augment collapse [14]. Lee and Choi [30] described the average 78.6-month follow-up results of 46 cases with tibial metal blocks and reported improved clinical outcomes and no radiographic failure. Considering these advantages, prosthetic metal augments were considered as suitable for severe asymmetric uncontained bone defects. Prosthetic augments are limited in size and shape, however. The Scorpio TS prosthesis used in this study has only two rectangular block size options, 5 or 10 mm. To compensate for bone defects >15 mm, a larger-size metal block was designed by attaching each block with cement. Because no screw system to attach each block has been developed, there was no choice but to use PMMA cement. The long intramedullary stem assembled to the tibial component was used not only to decrease the osseous strength of the defect base, but also to conserve the peripheral bone from stress [41].

This double blocks augmentation technique has several characteristics. First, this method is unique, simple, has no learning curve, and reduces operating time. Second, there are no concerns regarding disease transmission, bone healing, or graft resorption. Third, this technique is useful in cases of primary or revision TKA. Fourth, indications include defects with an intact cortical shell and uncontained asymmetric defects. Fifth, the double blocks augmentation technique can easily overcome the unsuitable size problem associated with cones and sleeves.

There are several limitations in this study. First, this was a retrospective study, and there was no comparative group. Second, sample size of 13 cases is small (as in most case series), and four out of 17 patients were lost to follow-up. However, the causes of loss were inevitable events in older patients. Third, the follow-up duration was not uniform, and the minimum follow-up of 24 months is short; however, the minimum 5-year follow-up cases showed a 100 % survival rate up to 99 months after surgery. In the future, a larger number of patients and longer-term follow-up results will be required to evaluate the fate of this technique.

The clinical relevance of this study is that double metal blocks augmentation is a useful method for managing severe asymmetric uncontained proximal tibial bone defects >15 mm. Second, this technique does not cause mechanical failure such as loosening, instability, or subsidence. Third, protrusion of the prosthetic support, which can cause irritation to soft tissue and pain, can be prevented by applying a smaller-size metal block, if necessary, in patients with a smaller tibia.

Conclusion

The author's preferred technique of double metal blocks augmentation—attaching double blocks to the tibial tray with the use of cement and screws—is a favourable and useful method to manage severe asymmetric uncontained proximal tibial bone defects >15–20 mm based on clinical and radiographic results at a median of 69 months after primary or revision TKA.

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