Special Article

Review Article: Management of Bone Loss in Revision Knee Arthroplasty

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The number of total knee arthroplasty (TKA) has been increasing during the past few years, as this procedure is reliable and efficacious for patients who suffered from late stage knee osteoarthritis. According to higher number this procedure on varies patient's age, there has been increasing number of younger patients. Thus, there is potential to increase incidence of revision TKA in the future. In revision TKA, one of the major problems to deal with is the bone loss, which may affect the prosthesis placement, the alignment of the limb and prosthesis longevity. Bone loss in revision TKA varies according to the degree of severity. Management options are based on the severity and the principle of bone reconstruction, which range from bone cement, autogenous graft, allograft, metal augment, and mega prosthesis. Recently, new alloys with high porosity have been introduced with satisfactory short-tem results. In this review article, the authors summarized the scientific evidences of current treatment options and outcomes of bone loss according to the degree of severity.

***Keywords**: Bone loss, Revision, Total knee arthroplasty, TKA, Porous, Augment*

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Currently, there has been increasing number of primary total knee arthroplasty (TKA) in both elderly and younger patients[1]. Furthermore, with the advance of medical technology and knowledge, the average life expectancy of human beings has been longer than that of the past decade. Thus, the incidence of revision knee arthroplasty tends to increase rapidly in the near future. Among several problems related to revision TKA, bone defect is one of the most challenging problems to deal with in this particular procedure regardless of infection[2]. In fact, bone loss occurs on both proximal tibia and distal femur, which potentially affects the stability of the knee reconstruction in revision surgery. To maintain the proper limb alignment and stable prosthetic fixation, the sufficient bone stock and stable bone implant interface must be accomplished.

Regarding bone loss management in revision TKA, several surgical options have been proposed with reports of clinical results. The present review article collects surgical options of bone loss management and clinical outcomes including the contemporary technology for severe bone loss with early results.

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Classification of bone loss

The severity of bone loss should be well evaluated preoperatively and intraoperatively. The standard radiographic study, including anteroposterior and lateral view of the knee, may not sufficient to properly evaluated the severity of the bone loss[3-5]. Additional investigations, such as radiographic study in oblique view or computerized tomography (CT) scan, are useful for preoperative evaluation of bone loss and preparation of revision total knee system and augmentation for the surgery. Several classifications of bone loss in revision TKA were proposed. According to Clatworthy and Gross[6], they simply classified bone defects as contained central forms, and uncontained peripheral forms with or without metaphyseal bone involvement, which is easy to remember. However, this classification does not provide specific management method. The most popular classification is the Anderson Orthopedic Research Institute (AORI) classification, which was described by Engh[7]. This classification specifically defined bone loss according to the site and the severity with specific management method. According to AORI classification of bone loss, the bone loss site is defined as the femur (F) and the tibia (T), independently, and the severity of bone is graded from type 1 to 3 (Table 1).

Table 1. The AORI Classification[7]

	Type 1	Type 2	Type 3
Metaphysis	Intact, minor defect (contained)	Damaged, required augmentation 2A: one condyle or plateau 2B: both condyles or plateaus (uncontained)	Deficient (uncontained)
Collateral ligament	Intact	Intact	Usually detach

Options for management of bone loss

Following the emerging of failure of primary TKA, variation of bone loss in revision surgery caused many investigators to propose several surgical options for management of this problem. In general, the key to select an appropriate surgical option for individual patient is based on two main factors. The first factor is the patient-related factor, such as age, body mass index, activity level and life expectancy. The second factor is the knee-related factor, such as the location, the size, and the character of bone loss (contained or noncontained), as well as the ligament stability.

Currently, several short- to long-term reports on outcomes of different surgical options for management of bone loss in revision TKA have been reported in the literature[8]. Each surgical option and its clinical outcomes are discussed as the following:

1. Polymethylmethacrylate (PMMA) with or without reinforcing screws

Using the PMMA or bone cement to fill the bone defect is the surgical option which is commonly used in both primary and revision TKA. This surgical option is simple without special preparation of the total knee systems or surgical equipments. According to the biomechanical property, the PMMA complex has an inferior load transfer for shear force compared with compression force. Thus, it is rational that applying the bone cement for filling the mild contained bone defect provides more superior outcome than that of the uncontained defect. In primary TKA, as the uncontained bone defect is the most common bone lesion, Ritter et al[9] proposed the use of PMMA with reinforcing screws in order to minimize the shearing force. Although, combined using screws and bone cement for filling the uncontained bone defect showed slightly improvement of the construction[10,11], Ritter[9] reported on 57 patients with no radiolucency between cement-bone interface in a mean 3-year follow-up. Lotke et al[12] reported satisfactory mid-term results in a series of 59 patients with the mean 7-year follow-up. In this series, 42 patients developed nonprogressive radiolucent lines, while one patient had component failure and had undergo revision TKA. Lotke concluded that the bone cement should be used when the bone defects are small and affect less than 50% of tibial plateau.

2. Bone graft

Bone grafting, regardless of autogenous graft or allograft, can restore the bone defect and increase residual bone stock[13]. Although autogenous bone graft provides inexpensive cost and simple obtaining method, the amount needed for reconstruction in revision surgery may not be adequate in moderate to severe bone loss. Thus, in revision TKA, allograft may be the preferred choice[14]. Both autogenous bone graft and allograft are commonly used in structural and morsellised preparation.

a) Autograft

The most common applicable form of autogenous bone graft is the morsellized form, which is suitable for a small contained bone defect, as this form of graft provides less morbidity at the donor site. In the study of Watanabe[15] on 30 patients with at an average 7 years of follow-up, the grafted bone united and formed good continuity with the tibial bone in all except one knees with 96% success rate. Similarly, Scuderi et al[13] reported a good result in filling a small contained bone defect with autogenous graft. Regarding clinical outcomes, Ahmed et aI[16] reported a comparable postoperative American Knee Society Score (AKSS) between 18 patients who were treated uncontained tibial defect with autogenous bone graft and 132 patients who had no bone loss.

b) Allograft

The structural allograft has more advantage on restoring a large uncontained bone defect[17,18].

Similar satisfactory mid- to long-term reports on structural allograft have been reported. Engh et al[19] showed no graft collapse or aseptic loosening associated with using structural allograft in severe tibial bone defect at a mean 8-year follow-up. Clatworthy et al[20] reported 75% success rate in using structural allograft for uncontained bone defect and 72% of allograft survivorship at ten years. Richards and associates[21] demonstrated that the clinical outcomes of patients having femoral head structural allograft (FHSA) for the management of massive bone defects during revision TKA had better clinical outcomes than those who did not have. Similarly, Bezwada[22] and Ghazavi[23] reported a favorable outcome using the structural allograft in massive bone defect.

Regarding reports on morsellised allograft, Lotke[24] reported a series of impacted morsellised allograft for intact cortical rim which had good result with no mechanical failures. The radiographic study showed that there was well graft incorporation and remodeling. Additionally, there were studies[25-27] reported good clinical outcomes of using morsellised allograft graft for filling the bone defect and the press-fit cementless long-stemmed in revision TKA.

However, disadvantages of allograft were concerned, including grafts resorbtion[28], graft fracture due to improper weight bearing, increased risk of infection and disease transmission[17,29,30].

3. Modular component (metal augment)

Following the study of Brooks et al[10] who demonstrated a comparable biomechanical study between a metal wedge and a custom-made component, the modular metal augmentation has become popular, as most contemporary total knee systems are more versatile which allow the surgeon to add the modular augment to the femoral or tibial component regardless of primary or revision knee system. Thus, this option provides the surgical ease to reconstruct the uncontained bone loss. As the metal augment does not restore bone stock, it may be appropriate option for elderly patients.

There were evidences which proved the good efficacy of metal augments in treatment of uncontained bone defect. Brand et al[31] reported no failures and no loosening of tibial components on the use of modular metal wedges to augment tibial bone stock deficiency in 22 knees with average 37-month follow-up. Similarly, studies from the Mayo Clinic reported favorable mid-term outcome using the metal augment in tibial deficiency[31,32].

4. Porous trabecular metal and metaphyseal cone

Recently, a new biomaterial, the porous trabecular metal, has been introduced and become widely used in complex revision knee arthroplasty. Biomechanically, the porous metal, made from tantalum or titanium, has good biocompatibility. Regarding trabecular tantalum metal, it has approximately 400-micron porous diameter, high volumetric porosity (70-80%), low modulus of elasticity (3MPa), excellent corrosion resistance, and high coefficient of friction[32]. The porous tantalum is also available in several shapes which can be used in both hip and knee (Fig. 1). With specific property of high volumetric porosity, it enhances and fastens the process of bone ingrowth.

The major advantage of the porous trabecular metal is that can be used in moderate to severe bone

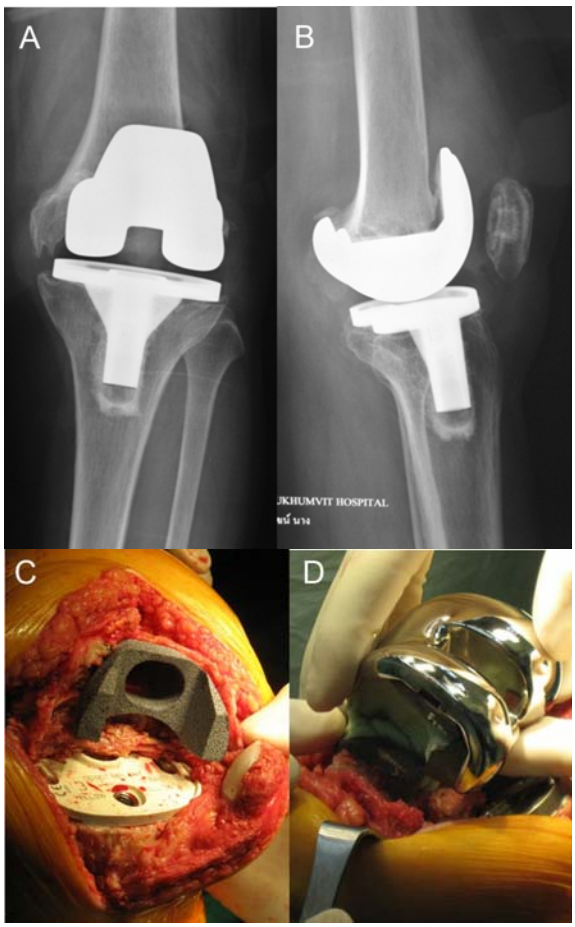

Fig. 1 A and B) demonstrating anteroposterior and lateral radiographs of loosening TKA with type 2B femoral bone loss (F2B), C and D) demonstrating the use of tantalum metaphyseal cone for distal femoral reconstruction during revision TKA

loss in order to avoid the possible complications from massive structural bone graft, which seems to be a future solution for management of bone loss in revision TKA. However, this new device does not restore bone stock which the future problem regarding bone loss in re-revision surgery may be in concern.

In a series of 16 patients, who were treated tibial bone defect with porous tantalum, with an average 31-month follow-up, the reconstructions had good function with no reoperations in 14 cases. In addition, the radiographic evaluation demonstrated stable osteointegration into the porous tantalum[33].

The metaphyseal cone is another porous metal augment which has been recommended to use in a significant metaphyseal bone loss in order to achieve structural and biomechanical restoration. It was designed to solve the problems related to bulk allograft reconstruction. According to its advantage on osteointegration property, the fixation of the metaphyseal cone to the host bone is cementless. However, the fixation of the metaphyseal cone and the prosthesis with intramedullary stem is cemented. Regarding the surgical technique, the extension of metaphyseal bone defect is evaluated. The trial the metaphyseal cone is inserted and a fine tuning inner bone shape is made for maximum contact surface between the host bone and the metaphyseal cone using a high-speed burr. With proper size of metaphyseal cone, impact it into the tibial or the femur to seat in the stable position. The noncontact surface at the periphery area should be filled up with morsellized bone graft. Then, the prosthesis with intramedullary stem is inserted and cemented with or without additional metal augment.

Even though the reports are still in the short-term clinical outcomes, a series of Howard et al[34] demonstrated 24 revision TKAs with tantalum cone were followed at an average of 35 months, the average Knee Society clinical score improved from 55 points, preoperatively, to 81 points, postoperatively. Similarly, Meneghini et al[35] reported good short-term results of using porous tantalum metaphyseal cone for severe bone loss in 15 revision TKAs at an average of 34 month-follow-up without evidence of loosening or migration. Lachiewicz et al[36] reported a retrospective review of 27 revision knee arthroplasties with tantalum metaphyseal cone at a mean follow-up of 39 months, the mean Knee Society pain score improved from 40 points, preoperatively, to 79 points, postoperatively. However, the mid- to long-term results of using this new biomaterial are needed to confirm its efficacy.

5. Mega-prostheses, Custom-made prostheses, Rotating-hinge prostheses

In a large bone defect, custom-made or rotating-hinge prostheses may be required. Bistolfi et al[37] and Utting et al[38] reported acceptable outcomes of custom-made or rotating-hinge prosthesis in revision total knee arthroplasty with severe ligament instability and bone loss. . Deehan et al[39] reviewed a series of 72 salvaged knee procedures using a Kinematic rotating hinge prosthesis and reported the survival analysis of best-case 10-year implant survival of 90%. while Pour et al[40] reported the rate of prosthetic survival was 79.6% at one year and 68.2% at five years in 44 revision TKA with rotating hinge prostheses. Barrack at al[41] and Hossain at al[42] reported the comparable outcomes to condylar revision knee prostheses, it is much more expensive than that of standard prosthesis. In addition, it takes a certain time to manufacture. Thus, it should be considered as an option when other type of knee systems is not feasible. Additionally, Pour [40] suggested that it should be used in an elderly patients.

Selection of option for management of bone loss

Although there are several successful options for management of bone loss in revision TKA, each treatment option should be considered based on the characteristic of bone loss, surgeon's expertise and the availability of bone graft and complex options of TKA system at the surgeon's institution.

In many revision TKA scenarios, a preliminary preoperative evaluation for bone loss enhances the surgeon to prepare for bone graft or more complex options of TKA system. Then, a final evaluation of bone loss is made intraoperatively after removal of the prosthesis. Using a thin saw blade for breaking the cement-prosthesis interface and remove the bone cement with direct visualization may minimize bone loss. With the use of structural allograft, the surgeon should aware of proper weight bearing before the graft incorporates. Qiu and associates[43] summarized a useful treatment options as shown in Table 2. In addition, the authors summarized the overall results, advantages and disadvantages of each treatment option related to the time of follow-up in Table 3 and Table 4.

Conclusion

Bone loss is a common problem found in revision TKA which several options for management have been proposed. Regarding mild to moderate bone loss, treatment options have been well developed. However, the treatment options for massive bone loss

Table 2. Summarized treatment options for management of bone loss[43]

Defect	Treatment options
Contained	
<5 mm	Cement
5-10 mm	Cement + Screw
>10 mm	Impaction morselised allografting, structural allografting
Mild uncontained	
<5 mm	Cement
5-10 mm	Cement + Screw
<50% femoral condyle or tibial plateau	Impaction allograft bone, metal augment
Moderate uncontained	
>5 mm and >50% femoral condyle or tibial plateau, intact ligament	Metal augment, structural allografting, Modular prosthesis
Severe uncontained	
Lateral ligament involved	Metal augment, structural allografting, Megaprosthesis, tantalum augment

Table 3. Result of each treatment options

Study	Year	Mean Follow-up	N	Outcome
Cement with or without screw				
Ritter MA[9]	1986	36 months	57	No revision
Lotke et al[12]	1991	85.2 months	59	No revision
Morselized bone graft (impaction)				
Bradley GW[27]	2000	33 months	19	Revision 1 case (5.26%)
Lotke et al[24]	2006	45.6 months	42	Revision 6 cases (14%)
Ahmed et al[16]	2008	120 months	11	No revision
Hanna et al[26]	2011	87.6 months	56	Revision 5 cases (9%)
Structural allograft				
Ghazavi et al[23]	1997	50 months	28	Revision 7 cases (25%)
Clatworthy et al[20]	2001	96.9 months	29	Revision 12 cases (23%)
Engh and Ammeen[19]	2007	60 months	49	Revision 4 cases (8.16%)
Bauman et al[17]	2009	90 months	70	Revision 16 cases (22.8%)
Modular component (metal augment)				
Brand et al[31]	1989	37 months	20	No revision
Patel et al[44]	2004	84 months	79	Revision 6 cases (7.59%)
Porous trabecular metal and metaphyseal cone				
Meneghini et al[35]	2008	34 months	15	No revision
Long and Scuderi[33]	2009	31 months	16	Revision 2 cases (12.5%)
Howard et al[34]	2011	35 months	24	No revision
Lachiewicz et al[36]	2012	39.3 months	27	Revision 4 cases (14.8%)
Mega-prostheses, Custom-made prostheses, Rotating-hinge prostheses				
Pour et al[40]	2007	50.4 months	44	Revision 8 cases (18.18%)
Bistolfi et al[37]	2012	60.3 months	26	Revision 2 cases (7.69%)

Table 4. Advantages and disadvantages of each treatment option

Management options	Advantage	Disadvantage
Cement with or without screw	Simple method	Risk of thermal necrosis Radiolucent Only used in small defect
Morselized bone graft (impaction)	Osteoinduction Osteoconduction Potentially provide bone stock	Not recommend in uncontained defect Graft resorption Graft collapse
Structural allograft	Physiologic material Manage large bone defect Potentially provide bone stock	Disease transmission Graft resorption Fracture Risk of infection
Modular component (metal augment)	Various shapes and sizes Biomechanical support	Stress-shielding Fretting and corrosion Potential bone loss in the long-term follow-up
Porous trabecular metal and metaphyseal cone	Biocompatibility Induce osteointegration Manage large bone defect	No long-term study Expensive Potential bone loss in the long-term follow-up?
Mega-prostheses, Custom-made prostheses, Rotating-hinge prostheses	Manage severe bone defect	Expensive

are still debatable. The new porous metal augments have become alternative option besides the structural allograft with a good short-term outcome.

Potential conflicts of interest

None.

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บทความฟื้นฟูวิชาการ: การรักษาภาวะการสูญเสียกระดูกในการผ่าตัดเปลี่ยนข้อเข่าเทียมซ้ำ

ศริษฏ์ หงษ์วิไล, อารี ตนาวลี

การผ่าตัดเปลี่ยนข้อเข่าเทียมมีจำนวนเพิ่มขึ้นอย่างรวดเร็วในช่วงหลายปีมานี้ เนื่องจากเป็นการผ่าตัดรักษาภาวะข้อเข่าเสื่อมในระยะท้ายที่ได้ผลดีและมีประสิทธิภาพ ทั้งนี้ มีความหลากหลายอายุของผู้ป่วยที่ได้รับการผ่าตัดมากขึ้น จึงมีผู้ป่วยที่อายุน้อยจำนวนเพิ่มขึ้น ดังนั้น โอกาสที่ผู้ป่วยจะได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียมซ้ำ (revision total knee arthroplasty) ในครั้งถัดไปจึงมากขึ้น ปัญหาใหญ่ที่สำคัญปัญหาหนึ่งในการผ่าตัดซ้ำ คือการรักษาภาวะการสูญเสียกระดูก (bone loss) ซึ่งมีผลกระทบต่อตำแหน่งที่ดี และความยืนยาวของการใช้งานในการใส่ข้อเทียมข้อใหม่ ภาวะการสูญเสียกระดูกมีความรุนแรงหลายระดับ ซึ่งแต่ละระดับมีแนวทางการรักษาแตกต่างกันไป ตั้งแต่การเสริมด้วยสารยึดกระดูก (bone cement) การปลูกกระดูกซึ่งนำมาจากผู้ป่วยเอง (autogenous graft) หรือจากผู้อื่น (allograft) การใช้โลหะเพื่อเป็นตัวหนุน (metal augment) การใช้ข้อเทียมที่พิเศษเฉพาะ จนถึงการใช้โลหะชนิดใหม่ที่คุณสมบัติเป็นรูพรุน (porous material)I ซึ่งให้ผลการรักษาระยะสั้นเป็นที่พอใจ บทความฟื้นฟูวิชาการนี้ ผู้นิพนธ์ได้รวบรวมแนวทางและผลการรักษาภาวะการสูญเสียกระดูกแต่ละระดับตา แนวทางหลักฐานทางวิชาการที่มีอยู่ในปัจจุบัน
