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Original Article

Management of Bone Defects in Revision Total Knee Arthroplasty

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Abstract

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Background: Bone defects remains a frequent complication of total knee arthroplasty [TKA]. The management of these defect in the revision TKA is a surgical challenge.

The aim of the work: This study aimed to evaluate the clinical and radiological outcome of the bone defects management in revision TKA [rTKA].

Patients and Methods: Thirty patients with bone defects after TKA were included. All were classically evaluated by history taking, clinical examination, laboratory and radiological workup. Then submitted to rTKA with management of bone defects by different methods. They were followed up at 6 weeks, 3 months, 6 months then yearly. The clinical outcome was measured by Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC] score, range of motion [ROM], leg raising test and clinical assessment of limb alignment. The radiological outcome by limb & component alignment. In addition, any complications were recorded.

Results: The side of surgery was mainly the right side [66.7%]. The bone defect was mainly femoral [50.0%], then tibial [40.0%] The majority of cases were Anderson class IIA [53.3%] and aseptic loosening was the major cause [56.7%]. Metal augments was the commonest treatment method [50% of cases] followed by bone graft in 16.7%. There was significant increase of postoperative ROM [100] and WOMAC score [85.9] after surgery than corresponding values before surgery [45 and 19 respectively]. Deep infection was confined to cases with cone and metal block, while deep vein thrombosis [DVT] was confined to metal block and metal augments. The postoperative WOMAC score was significantly different between management methods [the highest score was recorded with metal augments and metal blocks [90 and 90.5 respectively], while the lowest was registered with the cone [70.7].

Conclusion: The management method of bone defect had significant impact on complication type and operative time, but not on functional outcome following revision TKA.

Keywords: Total Knee Arthroplasty; Bone Defects; Pain; Revision Surgery.

INTRODUCTION

Knee arthroplasty is a surgical treatment option to restore the knee joint function and capacity through replacement of the weight-bearing surfaces of the joint. It may be partial or total knee arthroplasty. The partial option [also known as uni-compartmental arthroplasty [UKA]], used to replace only the damaged surfaces with retention of undamaged parts. The total knee arthroplasty [TKA] on the other side, replaces all three compartments of the knee joint [medial [the inside aspect of knee], lateral [the outside aspect of the knee] and patello-femoral compartments] [the joint between patella and the femur [1-4].

TKA is a reliable surgical treatment for the treatment of different knee conditions [e.g., rheumatoid arthritis, osteonecrosis or osteoarthritis]. The aim of the TKA is to relieve pain, improve functional capacity and improves the whole health-related quality of life [5, 6]. It is a highly cost-effective option. Its incidence witnessed dramatic increase in the aging populations in last decades. It is a highly successful treatment option. However, some patients remain dissatisfied with the clinical outcome. This dissatisfaction related to the development of chronic pain after TKA [7].

One the major problems after TKA is the need for revision surgery [revision total knee arthroplasty [RTKA], which was reported for a significant number of patients. The revision surgery implies replacement of the previously implanted artificial joint or prosthesis with a new alternative after the primary surgery. It is due to different causes. For example, the mechanical wear, breakage or loosening of the implant, infection, instability, mal-alignment, peri-implant fracture and persistent stiffness [6, 8]. However, the clinical and functional outcome of RTKA gained less satisfaction than the primary procedure. This attributed to the uncertainty about success rate, and high potential risk of failure. In addition, it is a challenging procedure and hard task that needs adequate exposure, extraction of old implant and insertion of new one, correction of bone loss, joint stability and soft tissue replacement to provide a stable and durable knee joint reconstruction [9, 10]

RTKA associated potential complications include bone defects [with subsequent shielding], infection, osteolysis, bone loss from lose implant or defects during implant removal [11, 12]

This study aimed to evaluate the clinical and radiological results of the management of bone defects in revision total knee arthroplasty.

PATIENTS AND METHODS

This was an interventional study of [30] patients with bone defects after TKA, who were treated with revision TKA. They were selected from the Orthopedic Surgery Department, Al-Azhar Faculty of Medicine [New Damietta]. It was completed during the duration from July 2021 to July 2024. The patients follow up ranged between 6 months and 3 years. The outcome was evaluated from the clinical and radiological points of view. We included patients with bony defects on the tibia or femur, who were submitted to revision TKR for Anderson Orthopaedic Research Institute [AORI] types I, II and III bone defects. On the other side, the exclusion criteria were 1] malignant bone defects [defects after the resection of tumors], 2] neuromuscular disorders and Charcot joints.

Preoperative assessment: In addition, to standard assessment [history [Symptoms and its analysis [pain, stiffness, instability, up-stairing, down-stairing, gait and rising from chair], clinical examination radiological and laboratory investigations, the Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC] [13] pain score was used to categorize the preoperative condition. It is one of the most common and reliable self-report pain and function scales for painful knee or hip arthritis. It is constituted of 5 domains, addressing person level activities [walking, stairclimbing, sitting, lying down, and standing]. The experienced pain on each domain is reported on a 5-point scale [from 0 [none] to 4 [the extreme].

The assessment of patient fitness for surgery was determined by the American Society of Anesthesiologists [ASA] score [14].

The local joint examination of the affected knee joint was performed with emphasis on [Skin changes, effusion and warmth, Deformity [Type, Degree, Correctable or fixed deformity, Associated deformities]. In addition, joint instability and active and passive range of motion were assessed, with patellar tracking. Furthermore, a complete neurovascular assessment of the affected limb was performed. The patient weight and height were measured and body mass index [BMI] was calculated.

The radiographic evaluation was based on standing anteroposterior [AP] and lateral X-rays to assess the implant fixation status, position and size. Knee X-rays tangential to the bone–implant interface was performed with a fluoroscopic guide to show the radiolucency lines and were required to detect the subtle loosening [15,16].

Preoperative laboratory workup included the complete blood count, blood sugar, renal and liver function tests, electrocardiography, urine analysis, erythrocyte sedimentation rate [ESR], C-reactive protein [CRP] and the cell count and culture of aspirated joint fluids. Any additional investigations [e.g., echocardiography or Doppler study] were performed according to the patient condition.

Other preoperative measures included 1] preservation of two units of blood to be used when required, 2] preoperative hydration [one litre of Ringers solution before surgery], 3] prophylactic antibiotics [cephalosporin] starting at anesthesia time and continued for 48 hours, and prophylaxis for DVT was performed routinely by oral anticoagulation [10 mg. once daily or every 12 hours if the patient had a risk factor for DVT as varicosities or obesity].

Operative approach: All surgeries were performed under the combined epidural and spinal anesthesia without tourniquet after insertion of a urinary catheter, by the medial para-patellar approach. The surgical exposure included the old incision, with the use of the most lateral indecision [when possible] to guard against necrosis of the skin. In this approach, the sub-periosteal exposure of the medial proximal tibia, release of the deep part of medial collateral ligament were performed. In some difficult cases [n=7] the exposure was facilitated by mobilizing the extensor mechanism [i.e., removing retropatellar adhesions and subperiosteal dissection of postero-medial proximal tibia]. This permits more tibial external rotation.

Extension of the medial para-patellar arthrotomy was performed distally with tibial tubercle osteotomy in which elevation of 8 to 10 cm segment of the bone that includes the tibial tubercle and a portion of the anterior crest of the tibia, leaving the anterior compartment musculature attached to the fragment laterally for vascularity. Fixation of the osteotomy was done by cercelage wires or screws.

Tibial preparation was done after removal of spacer or previous implants. Extraction of components was a crucial step to avoid unnecessary bone loss. Specialized instruments were available [e.g., thin flexible osteotomes, micro-blades and extraction tools]. A burr and reverse curettes were used for cement removal. Great care was taken to avoid unnecessary perforation of the cortex. Minimal bone cuts were made around the femur, tibia and patella to remove fibrous tissue.

The tibial preparation included the use of intra-medullary technique in all patients. In addition to optimal exposure of the whole tibial plateau surface, as the first step in tibial preparation. Tibial cut was done by intramedullary guide through removal of any excess bone to leave a flat surface for tibial baseplate to be perpendicular to the anatomical axis of tibia and we tried to be conservative as much as possible. After cutting of the proximal tibia, the size of the tibial tray was measured provisionally. After doing the proximal tibial cut, we stopped preparation of the tibia and shift to the femur. As we have made the tibial cut, approaching the femur and performing the femoral cut was easier.

Femoral preparation: All femoral cuts were done using intramedullary alignment guide with slotted cutting jigs. In distal femur, our reference in sizing and rotation of femoral component was trans-epicondylar axis or anterior cortex of the femur. Application of jigs was done [jigs of finishing cut, PS jig, LCCK jig] for removal of any excess bone and identification of the defects [Figure 1].

Management of bone defects [according to AORIC classification] [16]: **In Type-I defects,** the metaphyseal bone was intact. Thus, managed by impaction bone graft. **In type-II defects,** there was a metaphyseal bone damage and cancellous bone loss in one femoral/tibial condyle [type IIA] or both femoral/tibial condyles [type IIB]; bone grafting or metal augmentation was needed. **In type-III defects,** the metaphyseal bone was deficient and a structural allograft or a custom-made, hinged or revision prosthesis with an extended intramedullary stem was needed. **The true joint line** was established early to determine the amount of bone loss of the proximal tibia and distal femur. One finger breadth [10 or 12 mm] below the inferior pole of the patella, 3 cm distal to the medial epicondyle or 2.5 cm distal to the lateral epicondyle and all landmarks were used in our study to determine the true joint line.

Management of femoral bone deficiency: Assessment of residual bone deficiency of the distal and posterior femoral condyles. Defects in the distal and posterior femoral condyles were managed by metal augments [Figure 2].

Management of tibial bone defects: The deficient tibial plateau was then dealt with, after the optimal tibial cut, according to the degree of deficiency, as the following:

Bone Grafts: Defects 5- 10 mm were managed by using special technique for its fixation [screws] which was used in 5 cases. The graft was taken from the bone cuts itself. Technique for Bone grafting in management of bone defects [Figure 3]. The concave, irregular defect was converted to a flat one by minimal bone removal with a saw. Bone removed from the distal femur or proximal tibia was attached to the flattened defect and secured by wires then fixed by screws [3.5 cancellous screws]. The upper tibial surface was carefully cut to create a flat surface. The junction between bone graft and tibia was filled by impacted bone graft before cementation. This aimed to prevent the extrusion of cement into the surface during final component cement fixation. The graft was fashioned to fit the defect.

Metal Augments [Figure 4]: This was done in uncontained defects 10 mm or more which were used in 15 cases. They were ½ wedges [used in 3 cases], ½ blocks [used in 2 cases] or full blocks [used in 9 cases] according to the geometry of the defect and AORIC. In cases of reconstruction of tibial defects, stemmed tibial components were used to unload the deficient metaphyseal bone [used in all cases].

The tibia was finished: Trial components were inserted for assessment of size, fitting of the prosthesis, position, equality of bone gaps and ligamentous balance. When selecting revision prosthesis, it was preferable to use the smallest amount of constraint while achieving the most stable joint possible. Signs of instability should be determined pre-operatively via clinical and radiological examination, alongside examination under anaesthesia just prior to surgery. The majority of rTKAs were performed using a posterior stabilized implant [12 cases], and posterior cruciate-retaining knees are rarely used [except for revisions of uni-compartmental arthroplasty]. If stability cannot be achieved with a posterior stabilized implant, a more constrained device, such as non-linked constrained [condylar constrained knee [CCK]] was used in 12 cases or rotating hinge [RH] designs were used in 6 cases.

Intra-operative imaging:

When indicated, it was used to: 1] determine the varus-valgus mal-position of the tibial component, 2] get idea about ligamentous imbalance after bone cuts, 3] stem offset in cases with long stem, 4] Over-sizing or under-sizing of the components.

Post-operative care: In the recovery room, the blood pressure, pulse and oxygen saturation were checked. Additional epidural dose for postoperative analgesia was taken. It was continued in the ward by continuous syringe pump system for sustained analgesia for 48 hours after surgery.

In the ward, the antibiotic and anticoagulant regimens were continued, intravenous fluids for 2 days, H2 blockers or proton pump inhibitors were given till discharge, ice was applied to reduce post-operative pain and hematoma, with blood transfusion-if required-according to hemoglobin concentrations [< 9g/dl].

Exercises:

1- **Strengthening muscle exercises:** static quadriceps and hamstring
exercises and straight leg raising from day one.

2- Range of motion: flexion-extension exercises both active and assisted.

3- Gait training with weight bearing as allowed by particular knee
reconstruction.

Radiology: Postoperative radiological assessment included A/P film and lateral views. The AP film was used to determine limb alignment [anatomic tibio-femoral angle], component size, position [medio-lateral] correction of tibial subluxation, cementation, defects and its management [bone graft & metal augments]. The lateral view was used to assess femoral notching, component [size, posterior tibial slope, femoral component flexion-extension], patellar position in relation to the joint line and flexion deformity

Follow up regimen: The patients were followed up at 6 weeks, 3 months, 6 months then yearly. The clinical outcome was measured by WOMAC score, ROM, leg raising test and clinical assessment of limb alignment. The radiological outcome by limb & component alignment. In addition, any complications were recorded.

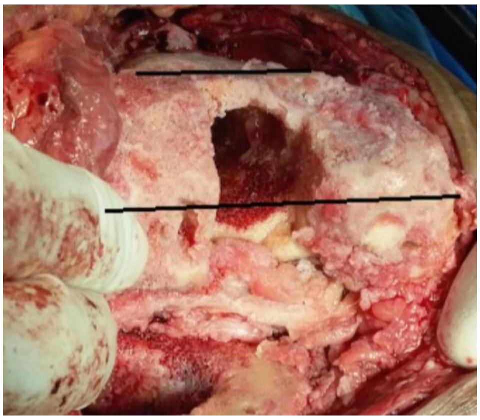

Figure [1]: Trans-epicondylar axis or anterior cortex of the femur [revision cases].

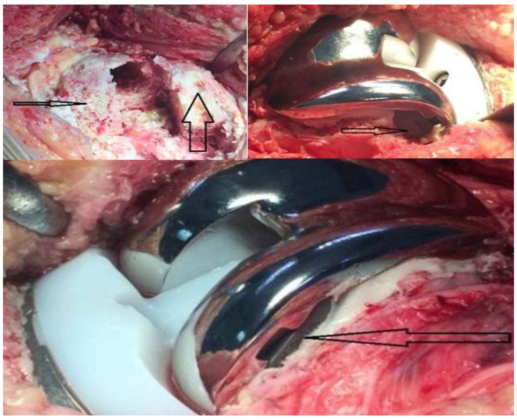

Figure [2]: Uncontained defects in the distal and posterior femoral condyles managed by metal augments.

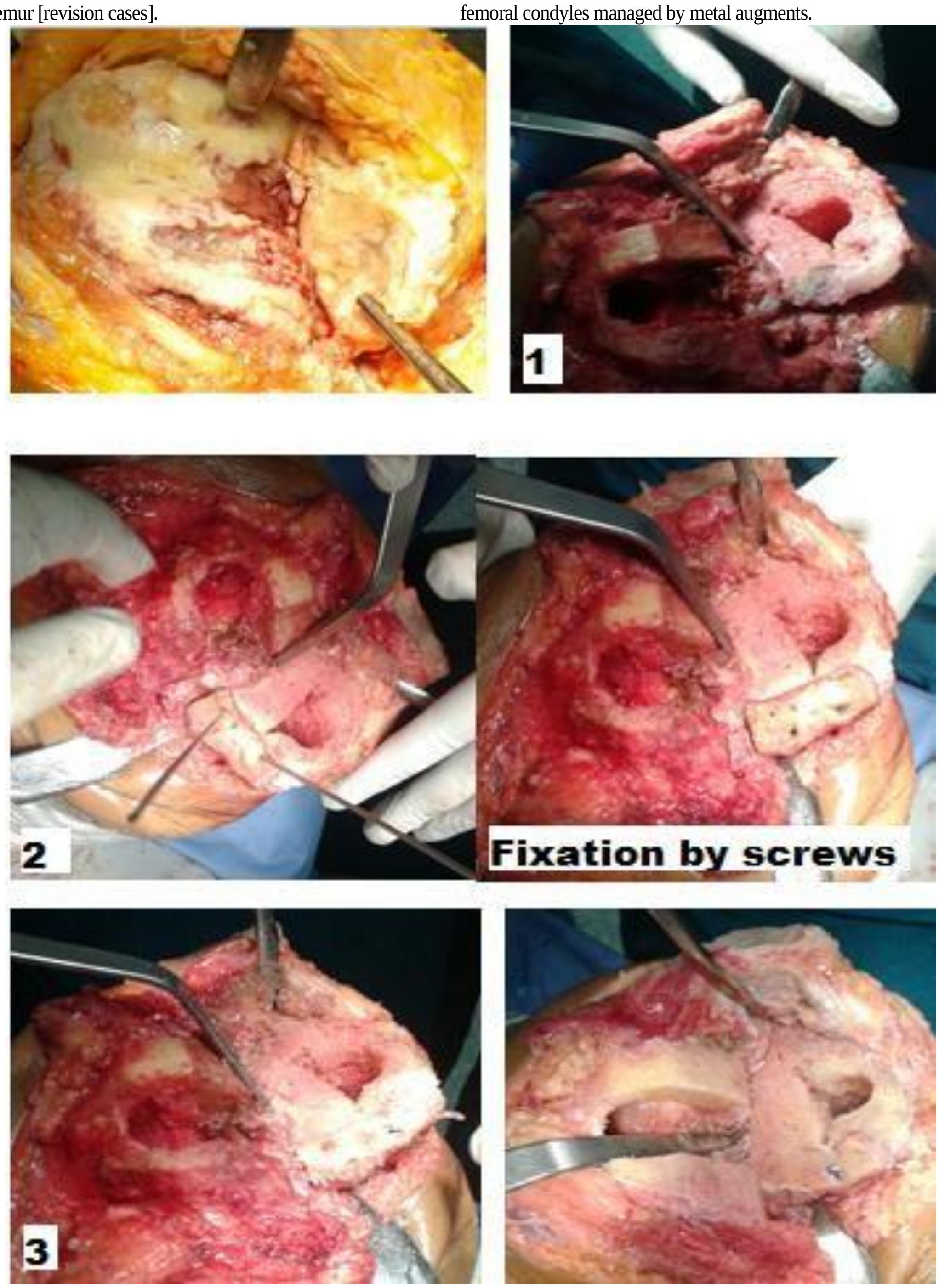

Figure [3]: Technique of bone grafting in management of the tibial defect [1, 2, 3 discussed above in technique].

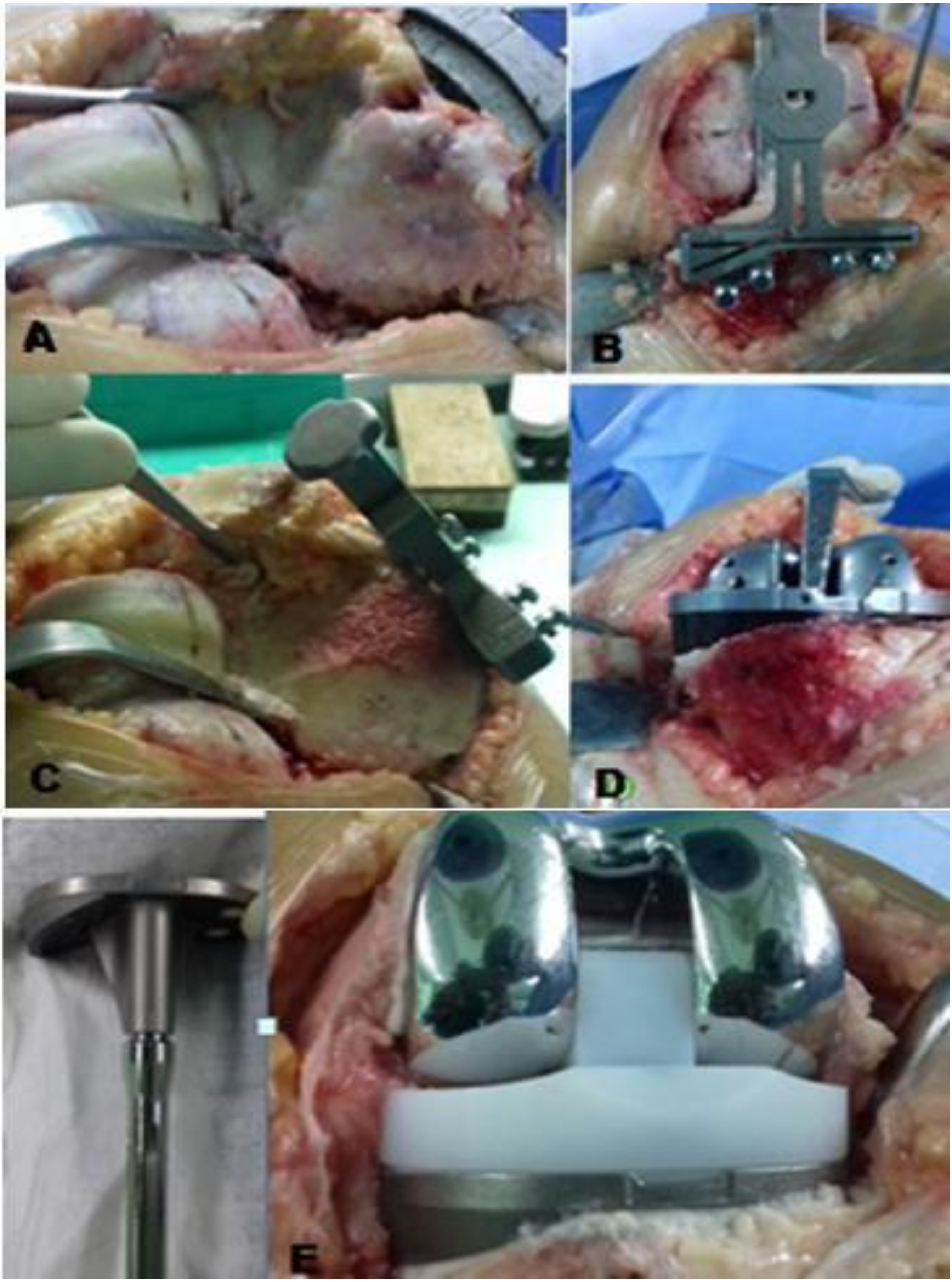

Figure [4]: Steps of management of tibial bone defects by metal augment [A. tibial defect, B. jig used for cutting wedge, C. proximal tibia after cutting the wedge, D. trial tibial component with wedge and E. actual components]

RESULTS

In the current work, the patient age ranged between 50 and 66 years. The median age was 59.6 years. The majority of patients were females [63.3%]. The mean BMI was 31.4 kg/m^2. Clinically, the side of surgery was mainly the right side [66.7%]. The bone defect was mainly femoral [50.0%], then tibial [40.0%] and only 10% had double defect in tibia and femur. The majority of cases were class IIA [53.3%] according to Anderson classification and aseptic loosening was the major cause [56.7%] [Table 1].

Metal augments was the commonest treatment method used in the current work [used in 50% of cases] followed by bone graft in 16.7% and the least was cone alone or cone with metal block [6.7% each] [Table 2].

The preoperative data were presented in table [3]. In addition, this table showed that, there was significant increase of postoperative ROM and WOMAC score after surgery than corresponding values before surgery.

Regarding association between management methods and complications, the results revealed that, deep infection was confined to cases with cone and metal block, while DVT was confined to metal block and metal augments. Otherwise no significant association between superficial infection or limited rom with management methods [Table 4].

The operative time was significantly variable between different methods of treatment. The longest time was registered with metal block and metal augments and cone and metal block [240 minutes]. The shortest time was registered with bone graft [120 minutes] [Table 5].

On the other side, the pre- and post-operative ROM did not significantly different between different methods of treatment [Table 6]. However, the preoperative WOMAC score was not different between different methods of treatment. But, the postoperative WOMAC score was significantly different between management methods [the highest score was recorded with metal augments and metal blocks [90 and 90.5 respectively], while the lowest was registered with the cone [70.7] [Table 7]

Table [1]: Demographic and clinical data of study population

		Median
Age [Years]	Median [IQR]	59.5 [55-63.25]
	Range	50-66
Sex	Male	19 [63.3%]
	Female	11[36.7%]
Weight [kg]	Mean	87.9
	Range	73-105
Height [m]	Mean	1.67
	Range	1.55-1.78
BMI [kg/m^2]	Mean	31.4
Side [n,%]	Right	20[66.7%]
	Left	10 [33.3%]
Site of bone defect [n,%]	Tibial	12[40.0%]
	Femoral	15 [50.0%]
	Both	3[10.0%]
Anderson Classification [n,%]	I	5[16.7%]
	IIA	16[53.3%]
	IIB	5[16.7%]
	III	4 [13.3%]
Causes [n,%]	Aseptic loosening	17 [56.7%]
	Periprosthetic fracture	4 [13.3%]
	Septic loosening	9 [30.0%]

Table [2]: Management Methods

Method	N	%
Metal Block and Metal Augments	**3**	**10**
Bone graft	**5**	**16.7**
Cone	**2**	**6.7**
Cone and Metal Block	**2**	**6.7**
Metal Augments	**15**	**50**
Metal Block	**3**	**10**

Table [3]: Perioperative data

		Median	IQR
ROM	Preoperative	45	45-62.5
	Postoperative	100*	90-122.5
Operative time [min]	Median Range	180 120 - 240	150- 180
WOMAC	Preoperative	19	18.3-23.4
	Postoperative	85.9*	75.1-90.3
Postoperative complications [n,%]	Superficial Infection	7 [23.3%]	
	Deep Infection	2 [6.7%]	
	DVT	3 [10.0%]	
	Limited ROM	13 [43.3%]	

* significant increase in postoperative values compared to corresponding preoperative data.

Table [4]: Association between complication frequency and management methods

	Superficial infection [n=7]		Deep infection [n=2]		DVT [n=3]		Limited ROM [n=13]	
	N	%	N	%	N	%	N	%
Metal Block and Metal Augments	0	0	0	0	3	100	1	7.7
Bone graft	1	14.3	0	0	0	0	0	0
Cone	1	14.3	0	0	0	0	2	15.4
Cone and metal Block	0	0	2	100	0	0	2	15.4
Metal Augments	4	57.1	0	0	0	0	7	53.8
Metal Block	1	14.3	0	0	0	0	1	7.7
P value	0.7		0.001*		0.001*		0.09	

***** significant

Table [5]: Comparison of operative time in different method of management

	Operative Time		P value
	Median	IQR	
Metal Block and Metal Augments	240	240-240	**0.001***
Bone graft	120	120-120	
Cone	180	180-180	
Cone and Metal Block	240	240-240	
Metal Augments	180	180-180	
Metal Block	180	180-180	

* significant

Table [6]: Association between Pre- and post-Operative ROM with methods of management

	Pre-Operative ROM		Postoperative ROM	
	Median	IQR	Median	IQR
Metal Block and Metal Augments	45	30-45	90	90-130
Bone graft	60	60-60	110	100-120
Cone	45	45-45	90	90-90
Cone and Metal Block	53	45-60	90	90-90
Metal Augments	45	0-90	110	90-130
Metal Block	60	45-100	110	90-140
P value	0.48		0.49	

Table [7]: Comparison of between Pre- and post-Operative WOMAC score with methods of management

	Pre-Operative WOMAC score		Postoperative WOMAC score	
	Median	IQR	Median	IQR
Metal Block and Metal Augments	19	19-19	74.6	70.6-89.6
Bone graft	20.5	20.5-20.5	86.5	80.5-90.2
Cone	18.6	18.3-18.9	70.7	70.2-71.2
Cone and Metal Block	23	20-26	74.3	74.3-74.3
Metal Augments	18.9	17-25.2	90	77.3-90.6
Metal Block	18.3	18.2-23.2	90.5	71.2-91.5
P value	0.74		0.040*	

Case presentation

No [1] was a female patient, 57 years old with past history of total knee replacement on the left knee, 3 years ago and problems in wound healing. The complaint was pain in the left knee with inability to walk with varus deformity on the left side and pain was present at rest and walking. The preoperative X-ray showed loosening and osteolysis around prosthesis was not available, as the patient presented after removal and spacer. The ESR levels were 15 with negative CRP. The patient was treated by two stage revision knee replacement [the first stage was performed outside]. Tibial bone defect type III was managed by tibial cone and RHK was used and tibial tubercle osteotomy was performed. Postoperative complication was in the form of superficial infection and limitation of ROM [figures 5 to 8].

The second case [figures 9 to 12] was a male patient, 50 years old with past history of TKA on the left knee, 11 years ago. He complained of pain in the left knee mainly on walking and deformity on the left side. The plain X-ray showed loosening and osteolysis of prosthesis. The laboratory investigation showed slight elevation of ESR, negative CRP and knee aspirate revealed aseptic loosening. Patient was treated by one stage revision knee replacement on the left knee and bone defect was femoral bone defect AORIC IIB which was managed by 3 femoral metal augment [1 medial & 1 lateral distal femoral augments & 1 posterior lateral femoral augment] and use of tibial and femoral stems and PS implant was used**.**

Figure [5]: Preoperative x ray & CT showing knee cement spacer with tibial defect type-III

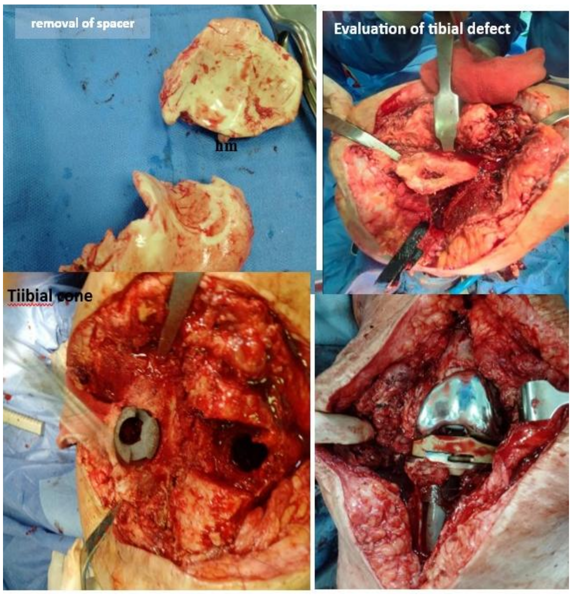

Figure [6]: Intraoperative assessment of the defect & reconstruction by cone and RHK prosthesis.

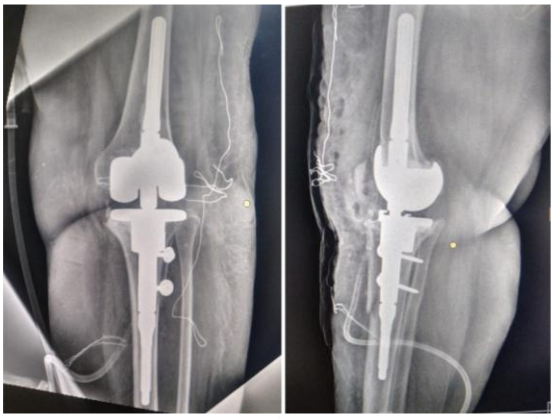

Figure [7]: Immediate postoperative x-ray of case 1 showing good alignment of tibial & femoral components**.**

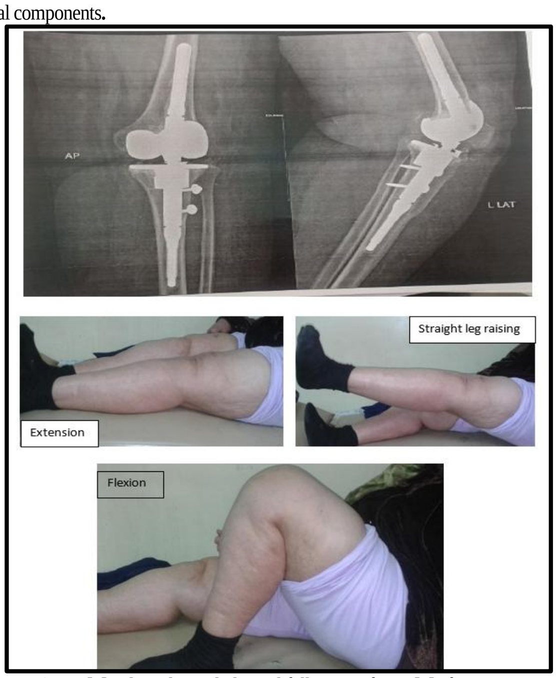

Figure [8]: Clinical & radiological follow up of case [1] after 2 years

Figure [9]: Preoperative clinical & radiological assessment of case 2

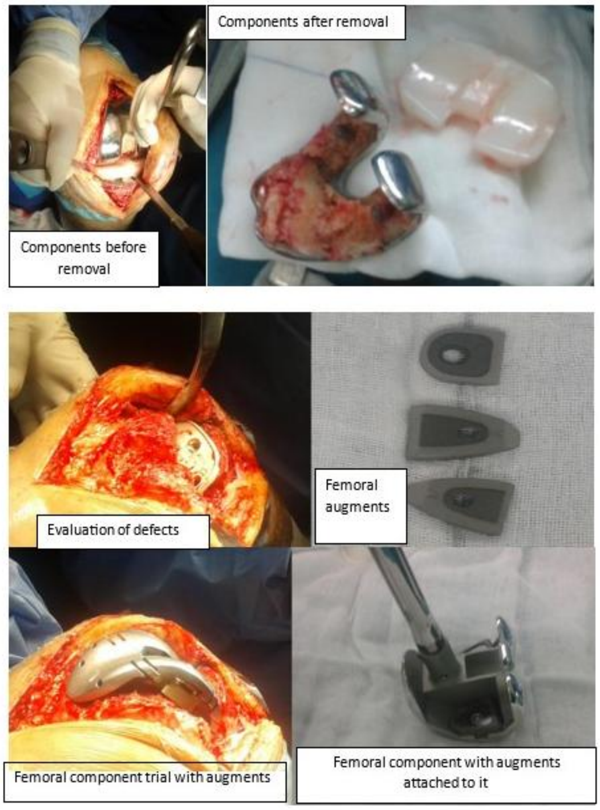

Figure [10]: Intraoperative assessment of case 2.

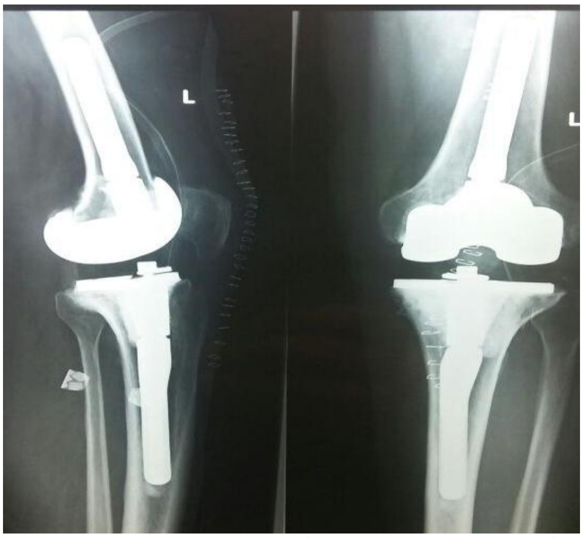

Figure [11]: Immediate postoperative x-ray of case showing good alignment of tibial & femoral components.

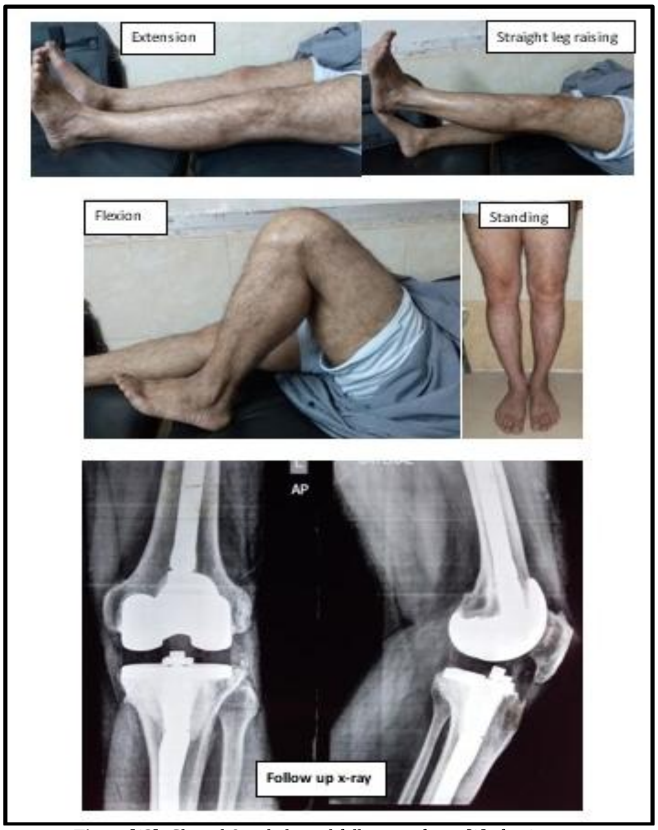

Figure [12]: Clinical & radiological follow up of case [2] after 2 years.

DISCUSSION

Revision surgery of TKA are challenging, and associated with many complications. Bone defects is a major complication of revision TKA. This can be due to stress shielding, infection, osteolysis, traumatic bone loss generated from a loose implant or iatrogenic loss during removal of the implant [17]. Bone defects due to aseptic and septic failure, or iatrogenic bone loss after removal of the primary implant, significantly endanger the stability of the implant and the final outcome of the revision surgery [18].

Metal augments were introduced for the treatment of bone defects. It seems to improve the load distribution, yielding better implant stability and fixation, and improving longevity. Nevertheless, periprosthetic infections remain the main cause for the failure of the primary procedure and the need for re-revision of TKA [19].

The main aim of this study was to evaluate the results of Management of Bone Defects in Revision Total Knee Arthroplasty clinically & radiologically. This interventional study was conducted at the Orthopedic Surgery Department, Al-Azhar faculty of Medicine [New Damietta], on 30 patients with bone defects post total knee arthroplasty treated with revision total knee arthroplasty.

Regarding demographic data, the current study showed that the patients age ranged from 50 to 66 with median age of 59.6 years. And most of the participants were female 63.3%. When compared to men, women had a higher risk of knee osteoarthritis [OA] and greater severity. In addition, the associated hormonal effects on cartilage, the thinner cartilage of the knee, increased loss of the articular cartilage, advancing cartilage defects, and a higher preoperative body mass index [>27 kg/m^2] all result in greater progression of knee OA in women [20]. Osteoporosis and osteoarthritis commonly coexist in women after their menopause. The decrease in bone density and increase in bone resorption in postmenopausal females with osteoporosis may consequently affect the surgical outcome of total knee arthroplasty [21].

In concordance with the current study **Rosso *et al.*** [18] revealed that most of patients underwent revision TKA were females [60.8%] with average age of 71.5 year.

In the current study most of defects were in the left side, about 50% were in the femoral bone, over 53.3% were class IIA and 56.7% were due to aseptic loosening. Revision total knee arthroplasty is associated with higher risk of bone defects that can be due to stress shielding, infection, osteolysis, traumatic bone loss generated from a loose implant or iatrogenic loss during implant removal [22, 23].

In agreement with the current study **Rosso *et al.*** [18] showed that the most frequent cause of failed revision TKA was aseptic loosening [41.5%] followed by septic loosening [30.2%], instability and the so-called mystery knees [9.4% each], stiffness [7.6%], and extensor mechanism insufficiency [1.9%]. Also, **Postler *et al.*** [24] showed that the most frequent reason for revision TKA was infection [36.1%] followed by aseptic loosening [21.9%] and periprosthetic fracture [13.7%].

Many authors described the available treatment options fir bone losses in revision TKA include cement, impaction bone grafting, traditional metal augments, structural allograft, metal cones, or sleeves [25, 26]. In the present study metal augment was the most frequent method [50%] while cone and cone and metal block were the least frequent [6.7%] for each. Metal augments have been developed for knee revision surgery for the management of segmental bone defects. Augments provide several advantages [e.g., extensive modularity, quick and easy use with decreased surgical time, great availability, and fewer complications] [27].

According to the recent review article by **Aggarwal *et al.*** [28], metal augmentation is one of the most commonly used techniques to tackle bone loss. These augments are available in wedge and rectangular shapes. Several biomechanical studies have indicated that rectangular blocks are superior to wedges since they could directly transmit torsional load to the bone reducing cement mantle strains between the base plate and the tibial plateau. They can be attached using cement or screws, allowing up to 20 mm of segmental bone loss to be replaced and offer immediate support with satisfactory transfer of load.

In the present study operative time was range from 120 to 240 min with median of 180 min. However, **Garbarino *et al.*** [29] showed that the mean operative time for revision TKA was 148±61 min and ranged from 30 to 497 min, the study also showed that revision TKA is a complex procedure, often requiring increased operative times compared to primary TKA. The results from this study indicate that less time spent in the operating room can lead to shorter LOS for revision.

As well, **Peterson *et al.*** [30] showed that the mean operative time of 8081 revision TKA procedures was 149 minutes which was significantly longer than primary TKA [94 minutes]. Also, **Chen *et al.*** [31] showed that an increase in operative time was associated with postoperative complications in revision total knee arthroplasty. On adjusted multivariate analysis, each additional 15 minutes of operative time increased the likelihood of wound complications, postoperative blood transfusion, and extended hospital stay.

As regards outcome scores, the current study showed that preoperative ROM was 45 while post-operative was 100 and WOMAC score preoperative was 19 while post-operative was 85.9, indicating significant improvement in functional outcome of patients with bone loss in revision surgery. **Jabbal *et al.*** [32] showed that methods for managing bone loss have traditionally been cement augmentation, impaction bone grafting, bulk structural bone graft and stemmed implants with metal augments. No single technique was found to be superior in functional outcome.

In concordance with the current study **Rosso *et al.*** [18] showed that among 51 patients [53 knees] with bone loss in revision TKA surgery, there was a significant improvement in all functional scores [P < 0.05]. The average post-operative range of motion was 110.5° [SD 10.7]. At the radiological evaluation, all the implants resulted well aligned, with 15.1% of nonprogressive RLL. There were 2 failures, with a cumulative survivorship of 92.1% at the last follow-up [SD 5.3%].

Also, **Algarni** [33] investigated outcomes associated with revision TKA by reviewing 52 knees that required a metaphyseal sleeve with a cementless tibial or femoral stem. The mean follow-up time was 4.1 years [range 2.0–7.5 years] with a minimum follow-up of 2 years. Following rTKA, the range of motion improved by 17° on average [p=0.19] and KSS increased by just under 28 points [p< 0.001]. Aseptic loosening survivorship and overall survivorships were 100% and 96.3%, respectively, with only one case of sustained fracture and reoperation.

As well, **Chun *et al.*** [34] assessed the mid-term to long-term clinical and radiographic results for severe bone defects of 27 patients undergoing revision TKA using a fresh frozen femoral head allograft and a standard condylar implant with a diaphyseal-engaging stem. In their study, 26 out of 27 knees were observed to have no collapse, disease transmission or stress fractures, and the mean range of motion had increased from 71º to 113º and the mean Hospital for Special Surgery knee score had improved from 46 to 83 points, providing a reliable and durable result.

In the current study we found that patients may complain from more than one complication; DVT was associated with tibial meatal block combined with femoral metal augments. Superficial infection was the most frequent complications 23.3% while 43.3% of participants complaining from Limited ROM. **Petersen *et al.*** [35] reported that patients with osteoarthritis [OA] undergoing revision TKA experienced more chronic complications after surgery. In their study, 99 OA patients were investigated after revision TKA surgery and found to have reduced function, poorer quality of life, and higher pain intensity compared to TKA patients. **Stambough *et al.*** [36] investigated a clinical study with 76 patients following revision TKA and reported that as many as one-third of patients had experienced complication or failure.

Werle *et al.* [37] suggest that metal augmentation is an acceptable technique. In their study, they used large [30 mm] metal distal femoral augments to compensate for type 3 bone defects and observed no radiographic evidence of loosening; no implants had been revised after a mean of 37 months. **Patel *et al.*** [38] treated a total of 102 revision TKA patients [type 2 defects] with metal augments and observed 92% survival at 11 years, with no significant complications, including fretting and loosening. **Quinn *et al.*** [39] showed that postoperative functional outcomes following revision total knee arthroplasty demonstrated a mean OKS of 39.25 [range, 14–48]. Mean ROM increased from 100° [range, 5°–145°] preoperatively to 112° [range, 35°–135°] at 1 year postoperatively [p < 0.001]. Interestingly, the factors associated with improved postoperative outcomes following revision total knee arthroplasty included male gender, fewer previous revision total knee arthroplasty procedures, increased preoperative ROM, and receiving a less constrained implant.

Regarding the association between surgical method and complications, the current study found a significant difference between management methods and Deep infections [only happened in cone and metal block method] and DVT [only happened in Metal block and metal augment]. To the best of our knowledge this is the first study assessed the association between surgical method of revision TKA and complications. Several factors were associated with infection post TKA, a meta-analysis by **Chen *et al.*** [40] showed that the main factors distinctly associated with infection after TKA were BMI, diabetes mellitus, hypertension, steroid therapy, and rheumatoid arthritis. Also, **Lenguerrand *et al.*** [41] in a more recent systematic review of patient risk factors for prosthetic joint infection in TKA identified male sex, smoking, increasing body-mass index [BMI], steroid use, previous joint surgery, and comorbidities such as diabetes, rheumatoid arthritis, and depression, as notable risk factors for infection. Moreover, there is a significant risk of DVT after TKA, in multivariate logistics regression analysis **Gao *et al.*** [42] showed that preoperative HCT, anesthesia mode, and diabetes were independent risk factors for DVT in patients over 60 years old after TKA.

In the current study we found that bone graft method had a significant lower operative time while tibial metal block and femoral metal augment, cone and tibial metal block had a significant longer operative time. To the best of our knowledge this is the first study assessed the association between surgical method of revision TKA and surgical time. The above results need to be confirmed with larger studies, as operative time may be affected with several factors including surgeon factors [seniority and experience] patient related factors like perioperative complications, and complexity of the procedure.

In the current study preoperative scores [ROM and WOMAC] were non-significantly differed between different method of management. Also, there was no significant difference between different method of management as regard outcome scores [ROM and WOMAC], with a tendency to better outcome in metal augments and metal block methods. In agreement with the current study **Jabbal *et al.*** [32] showed no signal for superiority between different methods for managing bone loss including cement augmentation, impaction bone grafting, bulk structural bone graft and stemmed implants with metal augments.

However, **Quinn *et al.*** [39] showed that the factors affecting post-operative functional outcome following revision TKA included male sex [$p = 0.02$], fewer previous RTKA operations [$p = 0.001$], higher preoperative ROM [$p \leq 0.001$], and implant type [highest OKS in CR group and lowest OKS in hinge group, $p \leq 0.001$].

Patel *et al.* [38] described the results of type 2 bone defects treated with modular metal augments in 79 revision TKAs and showed that the presence of non-progressive radiolucent lines around the augment in 14 % of knees was not associated with poorer knee scores, range of movement, survival of the component, or type of insert used.

In their update systematic review and meta-analysis, **Daines BK and Dennis DA** [43] concluded that, metaphyseal sleeves and cones appear to be a favorable addition when we dealing with large, central, contained and non-contained defects. They added, the use of stem extensions is helpful in enhancement of fixation and lessening stresses to weakened condylar bone.

Conclusion: The current study showed that bone loss is a common problem found in revision total knee arthroplasty which several options for management have been proposed. In addition, accurate diagnosis of bone defects and proper selection of treatment methods are necessary to improve the survival rate and construction stability. Currently, several techniques, instrumentation, biomaterials, and implant fixation have been developed to manage bone defects. However, most of the management systems possess specific complications and unsatisfactory clinical outcomes. Novel approaches should be developed to improve the functional capacity, implant survival rates, and quality of life in a cost-efficient manner.

The current study found that management method has significant impact on complication rate and operative time, but have no significant impact on functional outcome following revision total knee arthroplasty.

The current study was limited by small sample size, being a single center study and relatively short follow up period. Further studies with larger sample size and longer follow-up are needed to confirm our results and to identify risk factors of revision TKA.

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