Trabecular metal augments for reconstruction of acetabular bone defects in revision total hip replacement; early radiological and clinical outcomes.

Thesis

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By

Husam Mohamed Hassan Mohamed El Axir

M.B.B.Ch, M.Sc. (Orthopaedic surgery)

Faculty of medicine – Benha university

Under supervision of

Prof. Dr. Mohamed Gamal Eldin Alashhab

Professor of Orthopaedic surgery

Faculty of medicine - Benha University

Prof. Dr. Ahmed Shawkat Rizk

Professor of Orthopaedic surgery

Faculty of medicine - Benha University

Dr. Ayman Gamil Sorial

Consultant of Orthopaedic surgery

Peterborough Northwest Anglia NHS Foundation Trust

U.K.

Dr. Emad Sanad Hussein

Lecturer of Orthopaedic surgery

Faculty of medicine - Benha University

Faculty of medicine

Benha University

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طبيب \ حسام محمد حسن محمد الاكسير

توطئة للحصول على درجة الدكتوراه في جراحة العظام

تحت اشراف

ا.د. محمد جمال الدين الاشهب

أستاذ جراحة العظام

كلية الطب-جامعة بنها

ا.د. احمد شوكت رزق

أستاذ جراحة العظام

كلية الطب-جامعة بنها

د. ايمن جميل سوريال

استشاري جراحة العظام

مستشفي بيتربورو انجليا- انجلترا

د. عماد سند حسين

مدرس جراحة العظام

كلية الطب-جامعة بنها

كلية الطب-جامعة بنها

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بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا
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LIST OF CONTENTS

LIST OF ABBREVIATION

Abbreviation	Complete word
AAOS	American Academy of Orthopaedic Surgeons
AIBG	Acetabular impaction bone grafting
APC	Anti-protrusio cage
ASIS	Anterior superior iliac spine
BMI	Body mass index
BW	Body weight
CDH	Congenitally dislocated hip
CoCr	Cobalt chromium
COP	Ceramic on polyethylene
CRH	Center of rotation of the hip
CRP	C-reactive protein
DDH	Developmental dysplasia of the hip
DVT	Deep venous thrombosis
ESR	Erythrocyte sedimentation rate
FL	Tensor fasciae latae
HA	Hydroxyapatite
HB	Hemoglobin
HCLP	High cross-linked all-poly
HHS	Harris Hip Score
IBG	Impaction bone grafting
ICM	International Consensus Meeting

ID	Inner diameter
ITB	Iliotibial band
LLD	Leg-length discrepancy
MOP	Metal on polyethylene
MPa	Megapascal
OA	Osteoarthritis
OHS	Oxford hip score
OR	Operating Room
ORIF	Open reduction and internal fixation
PE	Polyethylene
PJI	Periprosthetic joint infection
PMMA	Polymethylmethacrylate
RLL	Radiolucent line
Ta	Tantalum
TAL	Transverse acetabular ligament
TCP/HA	Tricalcium phosphate-hydroxyapatite
THA	Total hip arthroplasty
TKA	Total knee arthroplasty
TM	Trabecular metal
TMA	Trabecular Metal Augments
WBC	White blood cell
([HR]Qol)	(health-related) quality of life

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The number of total hip arthroplasties (THA) performed each year is increasing according to the Agency for Healthcare Research and Quality, more than 450,000 total hip replacements are performed each year in the United States [(1)]. Similar trend has also been observed for revision hip procedures [(2)]. The reconstruction of acetabular defects in revision total hip arthroplasty (THA) can be challenging. Different strategies have been performed to achieve goals of successful revision surgery [(3)]:

- Achieving press-fit of the implant.
- bridging bony defects.
- restoration of the center of rotation of the hip.
- Avoid lateralization of the socket through excessive buildup of medial wall

In patients with small oval defects, adequate stability can be achieved using a suitable shell on its own. Jumbo components can be used to achieve stability in those with larger oval defects [(3)].

Other strategies include the use of a combination of allografts with cemented shells, rings or cages, shells with a high center of rotation, cup-cage constructs, and elliptical shells. However, insufficient primary stability and host-bone contact of < 50% can hinder osseous fixation and lead to early failure [(3)]. Drawbacks to their use, include failure due to breakage or loosening, in the case of cages and reinforcement rings and graft resorption and late failure, in the case of allograft bone used with earlier acetabular component designs [(4)].

Antiprotrusio devices and cages, along with cemented acetabular components, have been used for these situations but mid- and long-term results have not been encouraging the use of custom triflange acetabular components (CTACs; Zimmer Biomet, Warsaw, Indiana) offer another option, especially when there is an associated chronic pelvic discontinuity. However, this construct is expensive, requires approximately six weeks for manufacture, and typically does not match the preoperatively mapped defect if there is iatrogenic bone loss during removal of the existing component [(5)].

Modular trabecular metal augments can be used to treat severe acetabular defects. Several studies have published encouraging mid-term results with the use of modular porous metal augments in conjunction with a porous tantalum acetabular component for the treatment of severe acetabular bone loss [(5)].

Revision total hip arthroplasty is a complex, time consuming, and technically challenging procedure with substantially different resource requirements than primary total hip arthroplasty. Revision procedures are more difficult, more time consuming, and associated with greater liability for the surgeon. In revision procedures, operative times usually are longer and bone loss frequently necessitates bone graft, other augmentation, or both. Length of hospital stay and postoperative complication rate also may be higher. These factors combine to result in substantially greater hospital costs for revision surgery [(6)].

AIM OF THE THESIS

The aim of this prospective cohort study was to evaluate early functional and radiological outcomes in patients undergoing revision total hip arthroplasty (rTHA) with acetabular defects with using of trabecular metal augments (TMA) for reconstruction of the acetabulum.

REVIEW OF LITERATURE

RELEVANT ANATOMY AND BIOMECHANICS

The hip is the largest joint in the body. It is a perfect example of a ball-and-socket joint. Its articular surfaces are the femoral head and the horse-shoe shaped articular surface of the acetabulum, which is deepened by the fibrocartilaginous labrum. The non-articular lower part of the acetabulum, the acetabular notch, is closed off below by transverse acetabular ligament (TAL). From this notch is given off the ligamentum teres, passing to the fovea on the femoral head [7].

The Acetabulum

The acetabulum is a deep, cup-shaped, hemispherical depression, directed downward, laterally, and forward. It is formed medially by the pubis, above by the ilium, laterally and below by the ischium; a little less than two-fifths is contributed by the ilium, a little more than two-fifths by the ischium, and the remaining fifth by the pubis. It is bounded by a prominent uneven rim, which is thick and strong above, and serves for the attachment of the labrum, which contracts its orifice, and deepens the surface for articulation (Fig.1) [8].

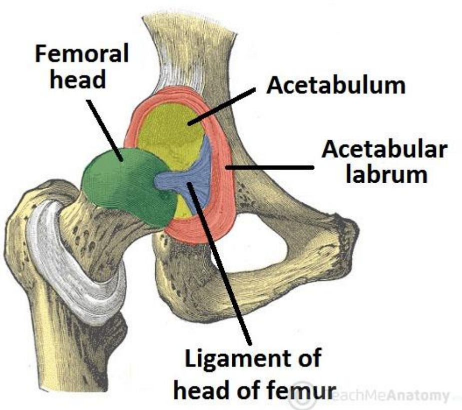

Figure 1: hip joint anatomy [9].

Letournel described the acetabulum as an inverted —Y with anterior and posterior columns (Fig. 2). The anterior column includes the pelvic brim, anterior wall, superior pubic ramus, and anterior border of the iliac wing. The posterior column includes the greater and lesser sciatic notch, posterior wall, ischial tuberosity, and most of the quadrilateral surface [10].

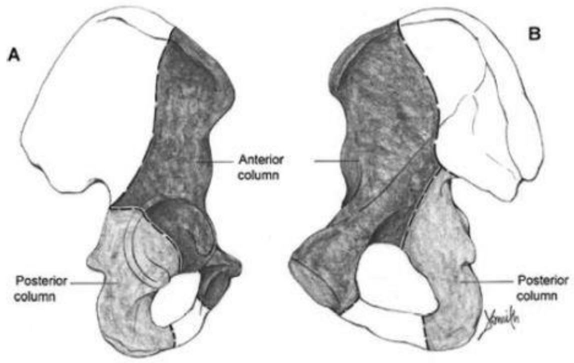

Figure 2: Delineation of the anterior and posterior columns of the acetabulum on the inner (A) and outer (B) aspects of the hipbone [10].

The acetabular surface is orientated approximately 45° caudally and 15° anteriorly. The acetabulum has a mostly circular contour in its superior margin, but it has only enough hemispherical depth to allow for 170° coverage of the femoral head [11].

Consider anatomical variations between male to female in the acetabular osteology (table 1).

	Female	Male
Abduction angle	57.1 (50.7 to 66.8)	55.5 (47.7 to 65.5)
Anteversion	24.1 (14 to 35.3)	19.3 (8.5 to 32.5)
Radius	25 mm (21.7 to 30.3)	26.7 mm (24.5 to 28.7)
Depth	0.79 mm (0.56 to 1.04)	0.85 mm (0.65 to 0.99)

Table 1: the acetabulum anatomical variation between male to female [8].

Capsular anatomy

The external fibrous layer of the capsule is attached to the acetabulum proximally, close to the margin of the acetabular rim and to the transverse acetabular ligament. It attaches to the intertrochanteric line anteriorly, the base of the femoral neck superiorly, about 1cm superomedial to the intertrochanteric crest posteriorly and on the femoral neck close to the lesser trochanter inferiorly The capsule has two major groups of fibers, longitudinal and circular [12].

Three ligaments reinforce the capsule (Fig. 3,4):

1. The iliofemoral (Y-shaped ligament of Bigelow)
2. the pubofemoral
3. the ischiofemoral [7].

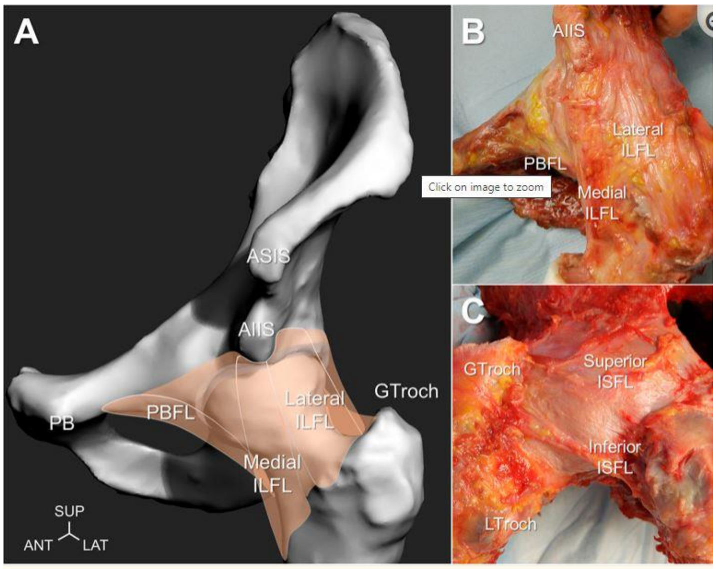

Figure 3: Anatomy of the capsular ligaments illustrated with a left-sided hip model in neutral position (**A**) and showing the anterior view of a cadaveric hip specimen in external rotation (**B**) and the posterior view of a cadaveric hip specimen in internal rotation (**C**). The lateral and medial branches of the iliofemoral ligament (ILFL), pubofemoral ligament (PBFL), superior and inferior fibers of the ischiofemoral ligament (ISFL) [13].

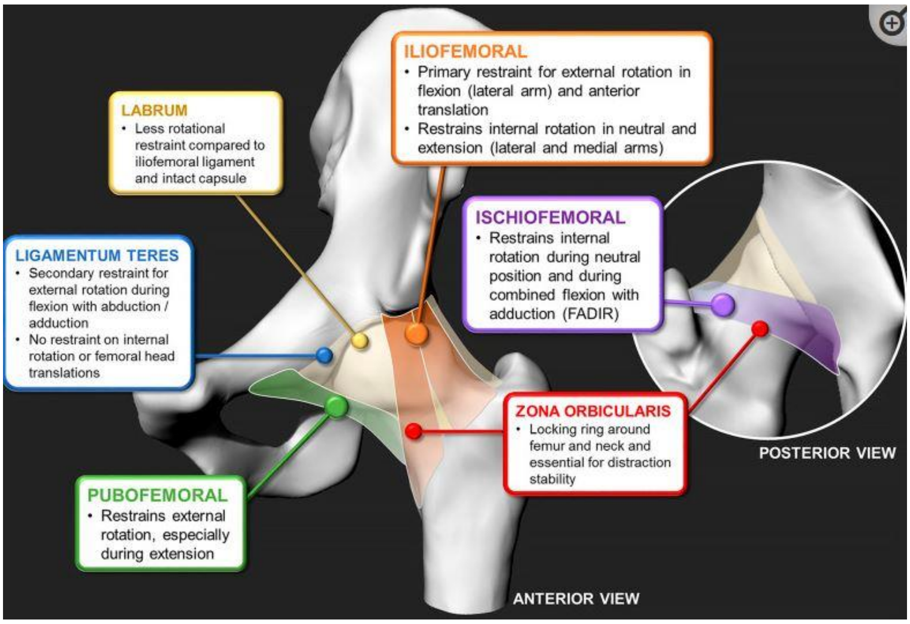

Figure 4: capsular ligament contributions to joint stability, outlining iliofemoral, ischiofemoral, and pubofemoral ligaments ,the zona orbicularis' ligamentum teres, and labrum [13].

The muscular attachments surrounding the hip are extensive with a total of 27 muscles crossing the hip joint (Fig. 5). The primary flexors are the iliacus, psoas and rectus femoris (direct and indirect heads). main extensors are the gluteus maximus. The abductors are the gluteus medius, gluteus minimus, tensor fascia lata, and iliotibial band. The external rotators are the piriformis, quadratus femoris, inferior gemellus, superior gemellus, oburator externus, and internus [14].

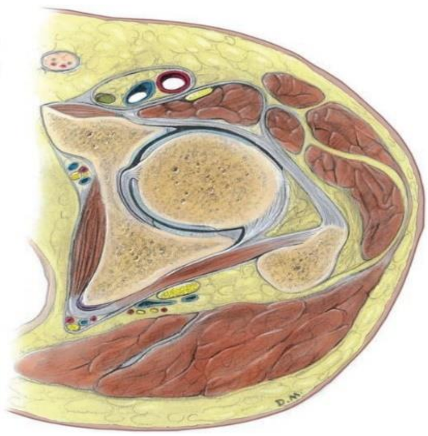

Figure 5: Transverse section at the level of hip joint [9].

Surgical Anatomy

For arthroplasty, important surgical landmarks within the acetabulum include the anterior and posterior brim, the base of the fovea, and TAL. The anterior and posterior edge can help to determine if appropriate acetabular component anteversion and flexion are present. The base of the fovea serves as a guide to the extent to which the acetabulum can be medially reamed (Fig. 6) [11].

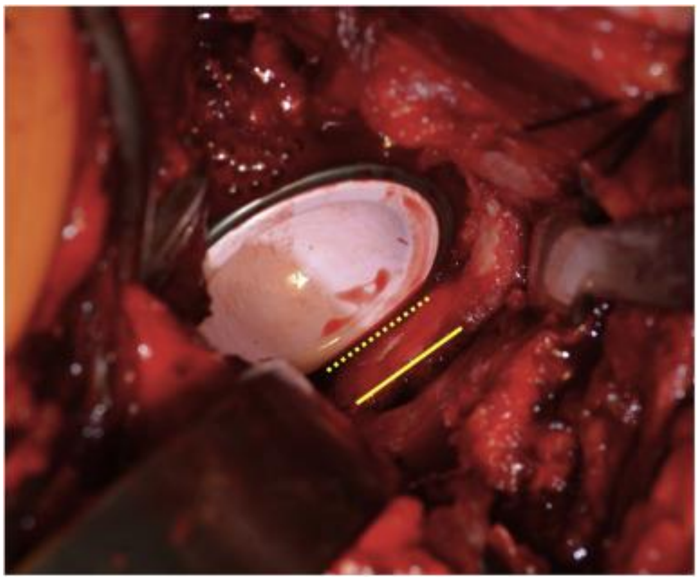

Figure 6: Intraoperative view of the transverse acetabular ligament help to identify the true acetabulum [15].

Topographic features of the ilium, ischium, and pubis as they relate to the acetabulum and its center are important for properly reconstructing the hip. The angular relationships of these bones are important for implant fixation. These relationships are even more important in implant revisions where the normal anatomy often is altered or damaged and is virtually devoid of the reference points seen in the minimally compromised, or normal, hip [16].

The Acetabular Quadrant System

The acetabular anatomy and surrounding nerves and vessels can be easily understood by using the acetabular quadrant system. Use of this system allows the surgeon to know the location of intrapelvic structures with respect to fixed points of reference within the acetabulum [11].

Four clinically useful acetabular quadrants were delineated. The quadrants are formed by drawing a line from the anterior superior iliac spine through the center of the acetabulum to the posterior fovea, forming acetabular halves. A second line is then drawn perpendicular to the first at the mid-point of the acetabulum, forming four quadrants (Fig. 7) [17].

The posterior superior and posterior inferior acetabular quadrants contain the best available bone stock and are relatively safe for the trans acetabular placement of screws. The anterior superior and anterior inferior quadrants should be avoided whenever possible, because screws placed improperly in these quadrants may endanger the external iliac artery and vein, as well as obturator nerve, artery, and vein [17].

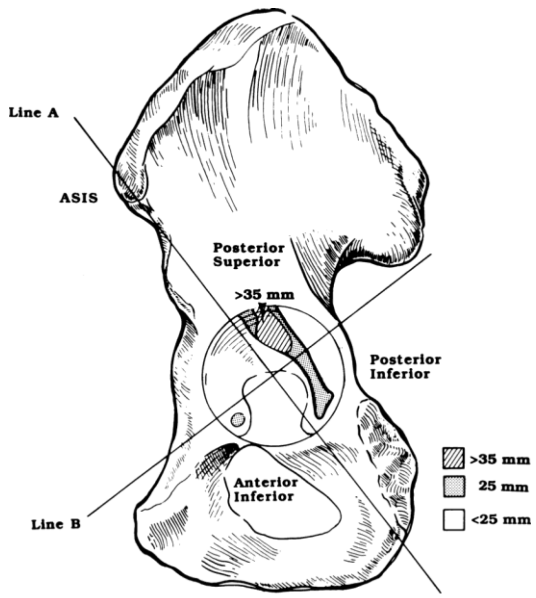

Figure 7: acetabular quadrant system for safe placement of acetabular screws [17].

Biomechanics of hip joint

The osseous acetabulum in the hip is deep and provides substantial static stability to the hip. A plane through the circumference of the acetabulum at its opening would intersect with the sagittal plane at an angle of 40 degrees opening posteriorly and with the transverse plane at an angle of 60 degrees opening laterally [18].

Kinematics

Hip motion takes place in all three planes: sagittal (flexion and extension), frontal (abduction-adduction), and transverse (internal and external rotation) [18].

In simplest terms, the hip acts as a fulcrum between body weight and the hip abductors. A dynamic equilibrium is developed with a goal of keeping the pelvis level and preventing a Trendelenburg lurch. The lever arm between the center of the femoral head and the abductor muscles is less than that between the center of the femoral head and body weight, placing the abductor muscles at a mechanical disadvantage [19].

During standing, however, body weight (BW) is supported by both hips, therefore, if the body was perfectly balanced the abductor muscles would not be required and there would be an equal force of ½BW on each hip. As it is unlikely that the body is ever perfectly balanced the joint reaction force during standing likely varies from ½ BW to 3BW, for the perfectly balanced case and single leg stance case respectively. The abductor muscles are thus very important in balance and pelvic stability, their role becoming more important as motion becomes more dynamic [20].

In a single leg stance, the effective center of gravity moves distally and away from the supporting leg since the non-supporting leg is now calculated as part of the body mass acting upon the weight-bearing hip (Fig. 8). This downward force exerts a turning motion around the center of the femoral head – the moment is created by the body weight, **K**, and its moment arm, **a** (distance from femur to the center of gravity). The muscles that resist this movement are offset by the combined abductor muscles, **M** [(21)]**.**

This group of muscles includes the upper fibers of the gluteus maximus, the tensor fascia lata, the gluteus medius and minimus, and the piriformis and obturator internus. The force of the abductor muscles also creates a moment around the center of the femoral head; however, this moment arm is considerably shorter than the effective lever arm of body weight. Therefore, the combined force of the abductors must be a multiple of body weight [(21)].

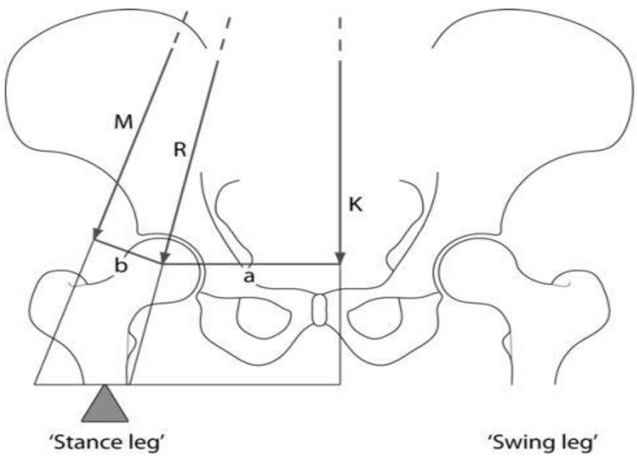

Figure 8: Free-body diagram for the calculation of the hip joint force while walking, where **K** is the body weight (minus the weight bearing leg), **M** is the abductor muscle force, and **R** is the joint reaction force [(21)].

Biomechanics of Total Hip Arthroplasty

The function of a total hip replacement is dependent upon the implant design and materials, wear and performance characteristics, short and long-term stability, surgical technique and component placement and alignment. Although the surgeon only directly controls the surgical technique, component placement and alignment, an understanding of the biomechanical performance of total hip replacement is necessary to maximize longevity and optimize function by restoring normal biomechanics and kinematics to the hip (22).

Restoration of the center of rotation of the hip joint is an important goal of THA to ensure normal gait and function. Correct use and selection of implants can restore the biomechanics of the hip with appropriate femoral offset and leg length. Modularity of the prosthetic designs offers many options for the surgeon to optimize leg length and femoral offset to match the contralateral hip side (22).

During total hip arthroplasty native global offset must be restored in order to achieve proper function of the abductor muscles and to ensure that the hip is stable. Femoral offset is defined as the perpendicular distance between the center of the femoral head and the axis of the femur. Acetabular offset has been defined as the distance between the center of the femoral head and the inner wall of the quadrilateral plate, also called true floor of the acetabulum (23).

Several methods have been described to measure offset. Femoral offset is generally measured on a standard anterior/ posterior pelvis radiograph. The global offset is the addition of the femoral and acetabular offsets (Fig. 9). Failure to accurately reconstruct the femoral and global offset may result in impingement, hip instability, polyethylene wear and trochanteric pain [23].

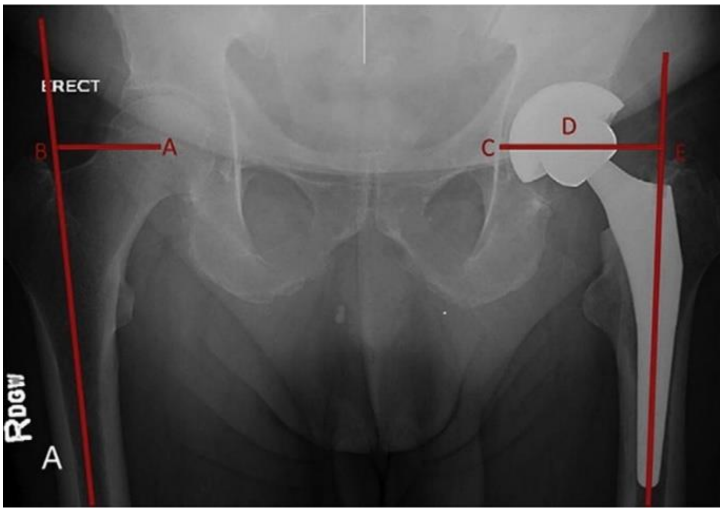

Figure 9: Radiographic measurements of the offset. BA: femoral offset. CD: acetabular offset. CDE: global offset [23].

BONE LOSS AS A CAUSE OF ACETABULAR DEFICIENCY

Deficiency of the acetabular bone stock is one of the major problems in revision total hip arthroplasty and certain primary total hip arthroplasty. It may result from numerous factors, including the following:

1. Osteolysis caused by wear, loosening, or infection.
2. Excessive bone resection at the time of previous surgery.
3. Preexisting bone deficit from acetabular fracture or dysplasia that was not corrected at the time of previous surgery.
4. Inadvertent destruction of bone during removal of a previous component or cement [(24).]

Osteolysis after total hip arthroplasty

Periprosthetic osteolysis after total hip arthroplasty now constitutes one of the most common complications and the leading reason for revision after primary replacement and also makes joint reconstruction much more difficult. Although much research work has been done both in animals and patients, the exact mechanism of osteolysis still remains unclear. However, wear particles, especially ultra-high molecular weight polyethylene (UHMWPE) has been gradually accepted to represent a major contributor to the bone loss phenomenon. Research work reveals that many different manifestations of wear are due to the complex interaction of both biological and mechanical factors [(25)].

The area of the osteolytic regions is measured on anteroposterior and lateral radiographs to arrive at a measure of lesion volume. In some cases, only 1 view is used. Although femoral lesions are viewed easily on plain radiographs, the same cannot be said for acetabular lesions. At revision, lesions behind the acetabulum usually are much larger in extent than the size predicted from viewing the preoperative radiographs [(26)].

Although osteolytic lesions are regarded as an unfavorable occurrence and are predictive of a later adverse outcome, not all lesions lead to failure. Lesions may be divided into progressive and non-progressive categories. Some lesions are stable and do not propagate, whereas others have a balloon like aspect and expand. Lesions may be localized or diffuse. Diffuse lesions may be stable or may progress along the interface. The prognosis for a lesion may be different depending on the location. Lesions behind the acetabular component are more likely to be expansive in nature, although even at this location, the lesion may not progress [(26)].

It does seem that there are different biologic processes operative for cemented and cementless implants. Cemented acetabular components tend to exhibit a linear pattern of osteolysis leading to loosening. Generally, cementless components are more likely to exhibit localized, expansile lesions with the cup remaining stable (Fig. 10). Less often, loosening of the component may precede the development of an expansile lesion (Fig. 11) [(26)].

Figure 10: Wear debris–mediated osteolytic lesion superior to well-fixed modular acetabular component [26].

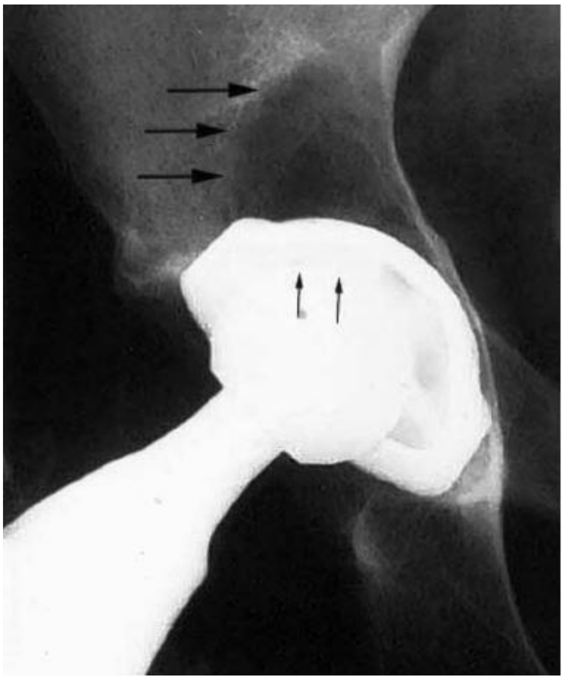

Figure 11: Wear debris–mediated osteolytic lesion superior to loose press-fit modular acetabular component [26].

Pathogenesis

Generation of particles is the first stage, wear mechanisms include adhesion, abrasion and fatigue. The production of these submicron particles in the hip is mainly secondary to abrasive wear. Joint forces and kinematics combined with the contact surface geometries and material properties determine the cyclic stresses that lead to particle generation. Though polyethylene particles are produced in a variety of sizes, studies using different methods have all demonstrated that particles resulting from wear are very small — 90% are less than 10 µm with an average diameter of 0.3–0.5 µm which is submicron. 8 The reason is that those larger than 10mm are not easily ingested by the macrophage [(25)].

Migration of particles is the second stage, the concept of effective joint space where migration of submicron polyethylene particles to all periprosthetic regions. It is not only the space within the hip capsule, but also the entire area surrounding the joint into which particles can escape and still be in contact with bone. It leads to the hypothesis that particulate debris, which often forms primarily at the prosthetic articulation, is able to penetrate the periprosthetic interface and migrate extensively. That is why lysis can occur at the tip of the femoral stem or at the dome of the acetabulum [(25)].

Cellular response to particles is the third stage, Histologic examination of tissues taken from osteolytic lesions adjacent to both loose and well-fixed implants shows that many types of cells including macrophages, fibroblasts, osteoclasts and also some bioactive products such as enzymes, cytokines and growth factors can be found. This indicates that particulate debris stimulates a foreign-body response resulting in release of bone resorption mediators. Among them, macrophages appear to play a central role in the process. Though the mechanisms of chronic inflammatory and foreign body response to wear debris and the importance of mechanical and host factors to the development of implant loosening and osteolysis are complex, phagocytosis of particulate debris by macrophages at the interface appears to be a critical step in the whole process. In general, the number of macrophages present had a direct relationship to the degree of bone resorption (Fig. 12) [25].

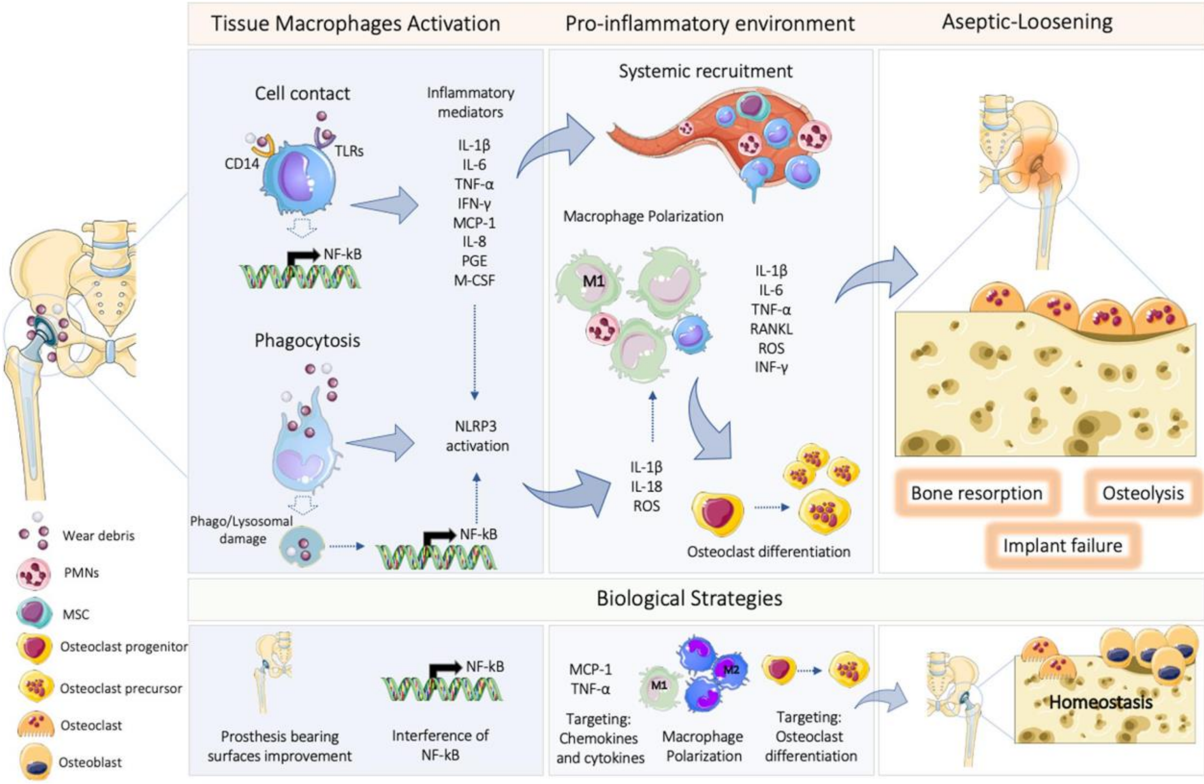

Figure 12: the biological response to wear debris [27].

Acetabular bone loss encountered at the time of revision arthroplasty can vary from mild to severe. Deficient acetabular bone stock poses a technical challenge for revision surgery because of reduced support from the anterior and posterior columns and varying degrees of medial wall and dome deficiency [28].

The loss of acetabular bone stock causes 2 major problems:

1. Difficulty obtaining adequate fixation of the acetabular component with sufficient host bone contact
2. Shift of the hip center, which then leads to difficulties in restoring limb length, normal hip mechanics, and hip joint stability [29].

During preparing for an acetabular revision surgery, management is focused around five important questions:

Can stable fixation be obtained in the remaining host bone with or without a morcellized bone graft, Are there segmental defects that necessitate structural allograft, or will a high hip center be acceptable?, Is bone loss so severe that stable cup support and fixation cannot be achieved by a simple segmental bone graft?, Is there a pelvic discontinuity that requires fixation? And What is the optimal surgical exposure to facilitate acetabular reconstruction? [30].

Detection of the osteolysis

Since implant wear and osteolysis is usually asymptomatic, it is of great importance to identify such a process as soon as possible before major complications occur secondary to progressive bone loss. One of the most reliable tools for the evaluation of wear and osteolysis is serial radiographic evaluation both in anteroposterior and lateral view [25].

Osteolysis in the femur was reported to be first identified at 12–60 months (mean 39) postoperatively. To evaluate the osteolytic lesions in the femur, we usually divided it into seven zones (Fig. 13). The size of lesion was graded according to its largest dimension — Grade1: 1–2 cm., Grade 2: 2–3 cm., Grade 3: 3–4 cm. and Grade 4: >4 cm. The lesions were classified as focal if there was only one isolated region of endosteal erosion, as multifocal if there were multiple but clearly separate regions of osteolysis, or as diffuse [25].

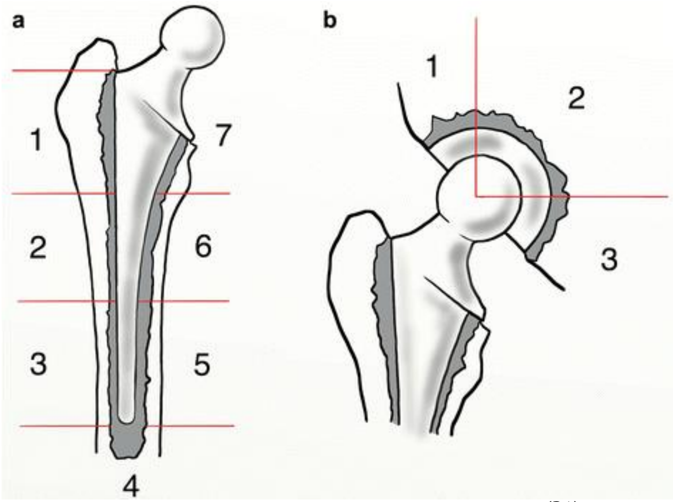

Figure 13: zones of osteolysis [31].

Polyethylene wear only becomes obvious after the femoral head penetrates into the insert and becomes eccentric. Thus, a small amount of wear is difficult to observe in its early stage. However, early diagnosis is valuable for those patients who have progressive polyethylene wear because it will give them an opportunity to be treated earlier and more effectively [25].

During preparing for an acetabular revision surgery, management is focused on: Can stable fixation be obtained in the remaining host bone with or without morsilized allograft?, are there segmental defects that necessitate structural allograft or high hip center can be acceptable?, is bone loss so severe that stable cup support and fixation cannot be achieved by a simple segmental bone graft?, is there a pelvic discontinuity?, that is the optimal surgical exposure to facilitate reconstruction?, is there any infection? And abductors function [30].

CLASSIFICATION OF ACETABULAR DEFECTS

Various classification systems have been developed to describe acetabular bone loss patterns and can be used to guide acetabular reconstruction [32].

1) Paprosky Classification

In the early 1990's, Paprosky et al. proposed an alternative method of acetabular defect classification. The Paprosky classification system e defined on the basis of the anterosuperior and posteroinferior acetabular column integrity is the system most commonly used today and has demonstrated acceptable validity. The classification system can be simplified according to the following: type 1 defects have minimal bone loss; type 2 defects have supportive columns but a distorted acetabulum; and type 3 defects demonstrate significant bone loss and have inadequate column support. Key anatomic features include integrity of the superior acetabular dome, the extent of tear drop and ischial osteolysis, and violation of the medial wall (Fig. 14 and table 2) [33].

Paprosky type I, resemble a normal acetabulum following reaming. Supportive rim, medial wall and cancellous bone stock are present. There is intact tear drop and quadrilateral plate. The ilio-ischial line is not breached and there is normal center of hip rotation. All implant apply either cemented all polyethelene or biological fixation ingrowth with uncemented shell ± screws, following filling the defect with particulate bone graft [30].

Paprosky type IIA, progressive superior bone loss. Intact rim usually found and no significant superior migration. No tear drop lysis and no medial migration. Implant is lateral to the ilio-ischial line. Fresh frozen allograft can be used to fill the defect. Uncemented cup can be used with at least 50% – 60% bone contact or cemented cup can also be used. Intraoperative assessment is important and superior mesh or structural allograft should be available as backup plan [30].

Paprosky type IIB, there is absent superior rim and the component has migrated superior-lateral. Ilio-ischial line is not breached and no tear drop lysis with intact quadrilateral plate. Proximal migration is less than 2cm. there is deferent option for reconstruction such as oblong, bilobed or large component depending on antero-posterior diameter of the acetabulum. Augmentation with a mesh superior/lateral with impaction grafting and cemented socket. Trabecular metal augment and impaction grafting with cemented or uncemented socket [30].

Paprosky type IIC, there is medial and superior migration. Ilio-ischial line is breached. There is destruction of quadrilateral plate with tear drop lysis. Reconstruction of the defect involves a structural medial wall augment. Paprosky et al even mentioned a wafer of allograft for medial wall and sealed with metal screen/ mesh in order not to be displaced medially with weight bearing [30]. Good results reported using tantalum augment for IIC, IIIA with impaction bone graft [34].

Paprosky type IIIA, there is significant superior bone loss and migration more than 2 cm. there is moderate tear drop and ischial lysis. Good operative assessment is needed to exclude pelvic discontinuity. The reconstruction is aiming to restoring hip center of rotation. Trabecular metal augment with impaction grafting and uncemented or cemented socket with screws is a good option. Trabecular metal augment has a porosity close to bone and it has excellent biological potential and healing and provide stable construct, reducing the need for massive bone graft.

Good to excellent results with this method were obtained in nearly 83% of cases (34).

Paprosky type IIIB, it is a complex condition to manage and usually referred to specialized hospital. It needs biological and biomechanical solutions. Bridging construct is needed attached to ischium and ilium combined with structural and particulate graft (30).

Type	Tear drop	HCR	Ischium	Bone loss
I	Intact	No migration	intact	mild
IIA	Intact	Mild migration <2cm	intact	Moderate
IIB	intact	<2 cm sup. – lat.	intact	Moderate
IIC	Moderate lysis	<2 cm sup. – med.	Moderate lysis	Moderate
IIIA	Moderate lysis	Sever >2 cm sup. – lat.	Moderate lysis	Sever 10-2 o'clock
IIIB	Sever lysis	Sever >2 cm sup.- med.	Sever lysis	Sever 9-5 o'clock

Table 2: Paprosky classification of acetabular bone loss (35).

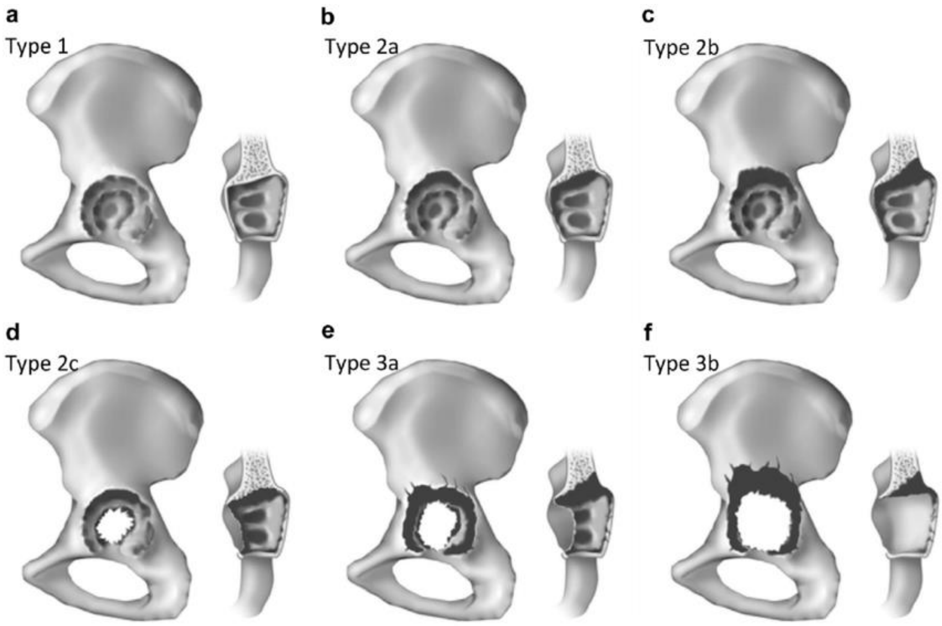

Figure 14: Paprosky classification of acetabular bone loss (36).

2) AAOS Classification

One of the first classifications was proposed by the American Academy of Orthopaedic Surgeons (AAOS) Committee on the Hip in 1989. In this system, defects were described as either segmental (complete absence) or cavitary (volumetric loss) according to defect location (superior, anterior, posterior, medial wall) (table 3) (Fig. 15). Segmental and peripheral defects can exist in combination, and pelvic discontinuity was defined as a "defect across the anterior and posterior columns with total separation of the superior from the inferior acetabulum." A final category termed "arthrodesis" was characterized not by bone loss but by failure or difficulty in identifying the location of the true acetabulum.

TYPE1 **Segmental deficiencies**	**A. Peripheral (rim defect)** ▪ Superior ▪ Anterior ▪ Posterior **B. Central (medial wall absent)**
TYPE2 **Cavitary deficiencies**	**A. Peripheral** ▪ Superior ▪ Anterior ▪ Posterior **B. Central (medial wall intact)**
Type 3	Combined deficiencies
Type 4	Pelvic discontinuity
Type 5	Arthrodesis

Table 3: AAOS classification of acetabular deficiencies [37].

It is important to distinguish the medial segmental from the medial cavitary defect. A medial segmental defect represents the complete absence of a portion of the inner medial wall or rim. A medial cavitary deficiency, however, implies excavation of the medial wall without violation of the medial rim (even in the case of protrusio) [37].

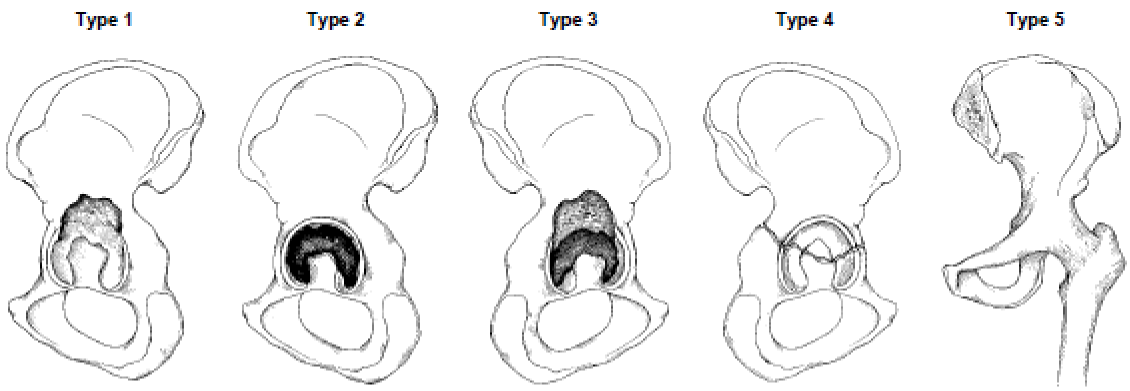

Figure 15: Classification of acetabular defects according to the American Academy of Orthopedic Surgeons Committee on the Hip. The five types are segmental (type 1), cavitary (type 2), combined segmental and cavitary (type 3), pelvic dissociation (type 4), and hip fusion (type 5) [37].

3) Gross Classification

It is a simplified system that is oriented around the requirements and specifications for bone graft in the reconstruction. (table 4) [32].

Type	Description
I	No substantial loss of bone stock
II	Contained loss of bone
III	Minor column defect: uncontained loss of bone stock involving < 50% of acetabulum
IV	Major column defect: uncontained loss of bone stock involving ≥50% of acetabulum
V	Pelvic discontinuity with uncontained loss of bone stock

Table 4: Gross classification of acetabular bone loss [32].

GOALS AND PRINCIPLES OF ACETABULAR RECONSTRUCTION

The acetabular revision surgery should aim to:

1. Achieve a stable fixation.
2. Restore the anatomic center of rotation of the hip.
3. Provide a well-contained component in the correct position.

However, severe bone loss often occurs due to osteolysis and stress shielding reducing the contact between host bone and conventional uncemented acetabular component. Excessive micromotion at this interface shown to cause bone resorption, fibrous tissue infiltration and early component loosening. After reconstructing these defects, one should attain a stable joint and avoid component impingement [38].

Management Options

In many of the acetabula the greatest volume of intact viable host bone is craniad to the normal hip center, leaving the surgeon with two options:

1. Reaming into the best available host-bone and place the component at a location that is more cranial than normal, in a position commonly called a (high hip center).
2. Attempt to restore the center of rotation of the reconstructed hip to the anatomic hip center (by fixing a bulk graft to the ilium or by using special custom components).

Hight hip center

High hip center technique is indicated in those cases where the acetabular bone destruction results in most of remaining host bone being superior to the anatomic hip center (Fig. 16) [39].

Alterations in the anatomic location of the reconstructed acetabulum will affect the forces about the hip and ultimately can affect the result of a THA in terms of function and survivorship. Changes in the hip center can have an effect on muscle function and limp by influencing the moments that the muscle must generate during walking and the length of the moment arm of each muscle. As well, increased hip loads are likely to result in premature loosening of the prosthetic joint [39].

Muscle forces and articular contact forces were determined for acetabulae that were displaced up to 30 mm in any direction from the normal acetabular location. The load on the hip joint was found to be significantly lower when the hip center was as far medial as possible, as well as somewhat inferior and anterior. The greatest loads were found when the hip center was located superiorly, laterally, and posteriorly [39].

Placement of the hip center 2 cm superior and 2 cm lateral to the anatomic hip center decreased the moment arm of the hip abductor muscles by an average of 28% and the moment generating capacity of these muscles by 38%. Neither of these parameters could be adequately restored by increasing the prosthetic neck length. On the other hand, when the hip center was moved only superiorly (2 cm), the moment arm of the abductors was only decreased by approximately 12%. The moment generating capacity of the abductors were decreased by 49%, but they could be restored to normal by simply increasing the prosthetic neck length [39].

With high hip center it is necessary to use a long prosthetic neck length or calcar replacement in order to restore the length and force generating capacity of the hip abductors. When this is done, superior relocation of the hip center without concomitant lateral displacement does not adversely affect the biomechanics of the prosthetic hip [39].

This technique has the advantages of reducing the requirement for structural bone grafts and shortening anesthetic, surgical time may be accepted as a valuable alternative and for patient with low grade infection to decrease metal components. However, some studies have demonstrated that a high hip center leads to a high rate of aseptic loosening, femoral impingement, dislocation, and leg-length discrepancy [39].

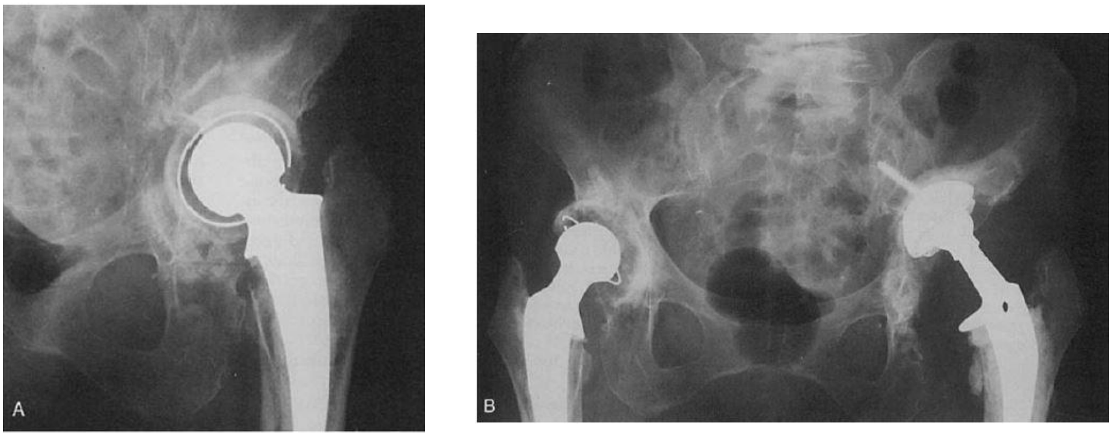

Figure 16: **A**, Preoperative radiograph of a failed cemented acetabular component with severe acetabular bone loss and fracture. **B**, Postoperative radiograph showing acetabular component placed at a high hip center [39].

Reconstruction options

The solutions during revision surgery broadly fall into one of two categories, either bypassing the deficient area, or filling the defect. Techniques to fill the defect can be divided into non-biological solutions or biological replacement, however, only biological solutions can be used for bone stock restoration. In the younger patient, restoration of bone stock is a highly desirable goal as good bone stock may be required for future surgery [40].

i.Bone Graft

Bone grafts serve a mechanical and a biologic function. Although autogenous bone is the most efficient material for both of these functions. The selection of a proper bone graft during a revision procedure is based on four main factors: the size of the defect, the location of the defect, the biology of the defect site, and whether structural support is required. The grafts can be freeze dried or fresh frozen grafts [41].

Cavitary (contained) defects can be reconstructed with cancellous morselized autograft, frozen or freeze-dried allograft, or allogeneic demineralized bone matrix. Segmental defects require bulk corticocancellous and/or cortical autografts or allografts. The ultimate incorporation of the bone graft depends on the following factors: -

a) Interaction of the graft and the host mechanical and biologic environment.

b) Host bone graft contact.

c) Stability [42].

A.Impaction bone grafting

In 1975, a new application for bone grafting was introduced for reconstruction of acetabular defects in primary total hip arthroplasty. Hastings and Parker described the combination of cemented total hip replacement and autogenous morselized cancellous grafting in intrapelvic protrusio acetabuli in rheumatoid arthritis. The graft subsequently was covered totally with a coarse mesh cup with a small rim before insertion of the cup [43].

Initially, bone grafting was performed most during complex primary hip arthroplasties, such as for dysplasia or protrusion acetabuli because of the successful early results that showed the superiority of bone graft over wire mesh or oversized cups in the prevention of progressive acetabular protrusio. Currently, revision hip arthroplasty consumes more donor bone than does primary hip replacement or any other orthopedic surgery [44].

The graft is prepared either by heads were denuded of cartilage with a handheld saw, and the mixed cortico-cancellous bone was then passed through a Noviomagus Bone Mill or by denudation of cartilage by a saw and morselization by hand utilizing a large bone nibbler. Graft chip length approximately 8–10 mm [41].

Impaction of the morselized bone graft is done by using the original technique, which involves increasing the diameter head impactor to firmly impact the graft or using the trial component (when appropriate) in the last step or reverse reaming to create a hemispherical cavity. Experienced surgeons advise against reverse reaming, which can reduce graft stability. Stability is achieved with a solid wall of strongly impacted bone grafts and without the graft moving under manual pressure [45].

Impaction grafting with cemented cups

The original technique described involved careful acetabular preparation including removal of previously implanted cement. Corticocancellous graft would then be pressed into the defect. The graft lined the native acetabulum with a layer of cancellous bone chips, which was impacted using a trial implant. Anchorage holes were created in the acetabular roof and in the graft, and the graft bed would then be covered with a metal mesh (Fig. 17) [46].

A major limitation at that time was the prolonged period of postoperative bed rest (three to six weeks), which is regarded as unacceptable in the current era of enhanced recovery. However even the originators now advocate earlier mobilization. Other disadvantages include the requirement of three or more femoral head allografts for every revision, which is expensive and resource intensive. It is a time-consuming operation and the technique itself [47].

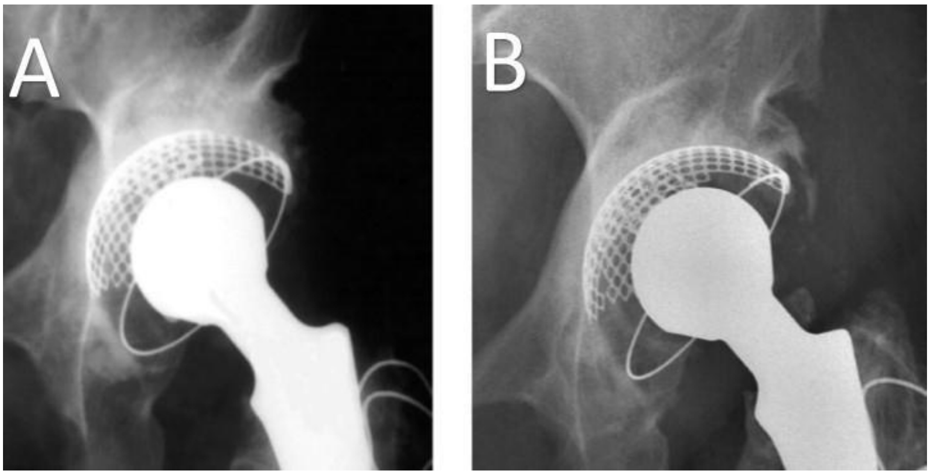

Figure 17: A) four months after revision of a failed resurfacing hip prosthesis with impaction bone grafting and a cemented acetabular component. B) 25 years after the reconstruction showing the position of the acetabular component to be unchanged. There is progressive osteolysis in zone I, but overall, the component is well fixed [46].

Impaction grafting with cementless cup

This technique has several advantages. Inserting a larger hemispherical cup is more straightforward than other revision options. An increased surface area for host bone contact increases ingrowth potential; a normal hip center location may improve abductor power and reduce impingement [43].

Cementless hemispheric acetabular components with morselized cancellous bone allografts are generally used in the setting of type 1 Paprosky contained defects with an intact rim, columns, and dome (Fig. 18). The literature recommends that at least 50% host bone contact is needed to prevent mechanical loosening between the prosthesis and native bone [48].

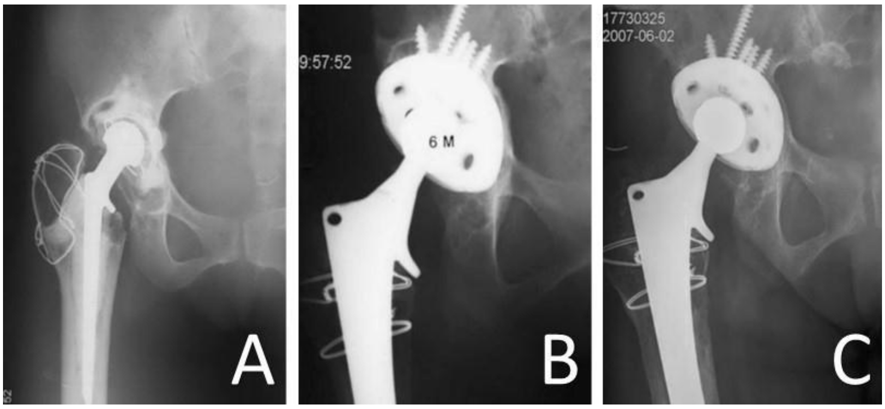

Figure 18: A: preoperative x-ray with loosening of the acetabular component. B: 6 months after acetabular cup revision with deep frozen morselized allograft and a hemispherical cementless acetabular cup. C: 144 months postoperatively, showing the incorporation and remodeling of transplanted morselized allograft, with no signs of radiolucency, and the cup was well fixed [49].

B.Structural (Bulk) graft

Structural grafts to restore acetabular bone lost in revision hip arthroplasty have been used since the 1980s. Short-term results with cemented cups were initially encouraging. Longer term follow-up of cemented acetabular components used in conjunction with structural bone grafts, however, have shown a high rate of cup loosening leading to revisions [50].

The technique of superolateral bone grafting was first described by Harris et al in 1977. They used the resected femoral head as a bulk autograft, in conjunction with implantation of a cemented acetabular component (Fig. 19) [51].

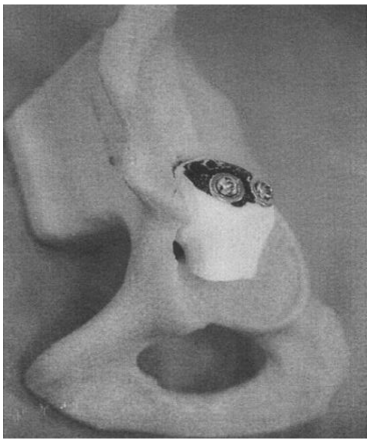

Figure 19: Shape of the bulk graft in place fixed with screws [51].

In acetabular deficiency, it seems very appropriate to use the femoral head as a bulk lateral support autograft. The strength, contour, expand-ability, and accessibility of this bone provide good reasons to prefer this technique in contrast to allografting(Fig. 20). The use of this graft also preserves the bone stock for future revisions if necessary [52].

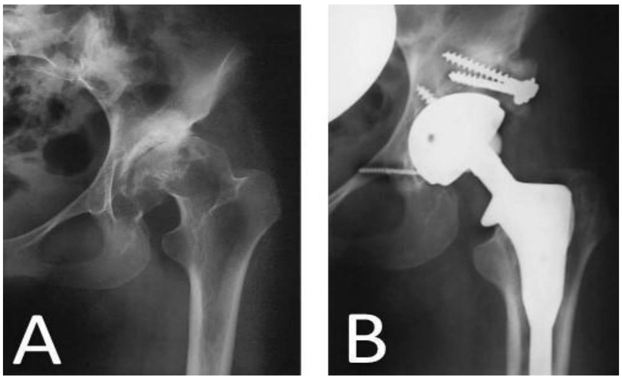

Figure 20: A: Preoperative radiograph of a patient showing neglected hip dislocation. B: Postoperative radiograph taken 10 years after surgery, showing graft union to host bone [52].

Lee et al treated 36 dysplastic hips with a cemented cup and bulk grafting. At 5-year follow-up, there was a mechanical failure rate of 6%, which increased to 39% at 10-year follow-up. They concluded that Bone graft augmentation in acetabular deficiency can produce satisfactory short- to midterm results. With longer follow-up evaluation, however, increasing rates of acetabular revision and loosening occur (53).

ii. Extra-large uncemented hemispherical acetabular components

The advantage of using a jumbo porous cup is that it has a larger surface area allowing for greater contact with host bone in order to allow biological attachment, which is required for long-term fixation. Several studies have reported success with the use of jumbo cups (54).

Extra-large sockets provide several advantages over standard-sized implants in the revision setting. First, they maximize surface contact between the porous- coated prosthesis and the host bone and increase the area of the pelvis over which forces are dissipated. Second, extra-large implants fill many bone defects, thereby reducing the need for bone grafting. Finally, extra-large sockets tend to normalize the center of rotation of the hip, which may restore soft-tissue tension and reduce impingement between the femur and the pelvis (Fig. 21) (55).

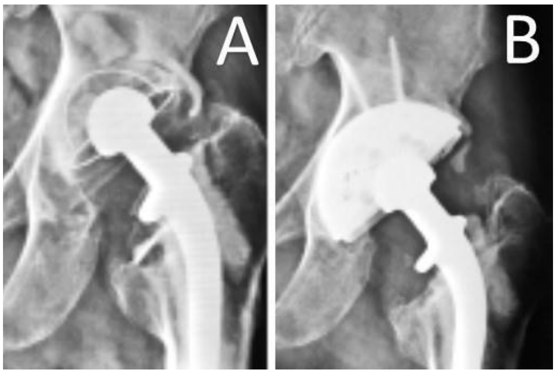

Figure 21: Revision of failed acetabular socket with jumbo cup. A: preoperative and B: post -operative x-ray (55).

iii. Bilobed Acetabular Components

An important problem in revision arthroplasty is that when we try to convert an oblong defect to a hemisphere to insert an uncemented hemispheric component, usually of extra-large size, the required reaming can damage the bone stock of the anterior and posterior columns of the acetabulum. An alternative option of reconstruction that avoids large allografts or excessive reaming is the use of porous-coated oblong acetabular implants (Fig. 22) [56].

Isolated superolateral acetabular rim defects with intact anterior and posterior walls can also be treated with a bilobed cup which is a hemispheric cup with a partial hemispheric extension. It can better match the superolateral acetabular defect and can theoretically conserve the bone that reaming of the anterior and posterior walls to insert a jumbo uncemented acetabular shell would otherwise sacrifice [57].

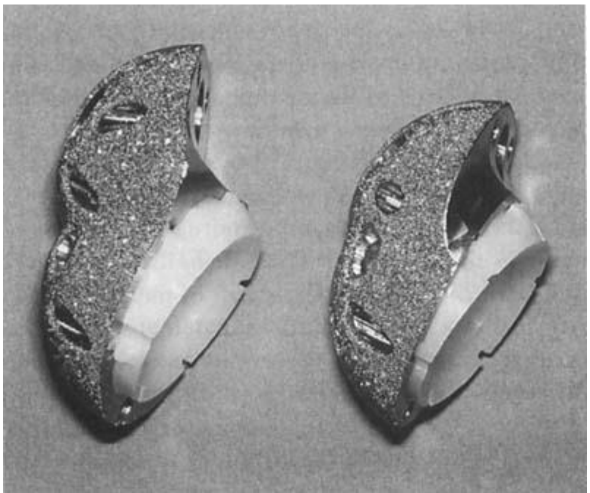

Figure 22: Bilobed oblong cup [58].

Similarly, these prostheses may be applicable in primary arthroplasty for arthritis secondary to high dislocation in developmental dysplasia of the hip. The superolateral bone defect is filled with the superior lobe of the implant, providing more bone contact. In comparison with a jumbo hemispheric cup, one disadvantage may be that it can be technically more difficult to orientate the version of a bilobed cup thus making stability more difficult to obtain. Nevertheless, for selected indications acceptable mid-term results have been demonstrated [57].

iv. Acetabular Reinforcement Rings

Acetabular reinforcement ring is one of the possible ways to deal with the difficulty in acetabular reconstruction in the presence of bone deficiency. There are two types of acetabular reinforcement ring (Fig. 23):

1. The **Ganz** ring is an acetabular reinforcement ring with a hook. This ring can help to restore the hip center by anchoring the hook at the acetabular notch, which usually remains constant even when there is severe bony destruction.
2. Without the hook (**Müller** ring), the stability relies on the contact with the host pelvic bone cranially, posteriorly and inferomedially [59].

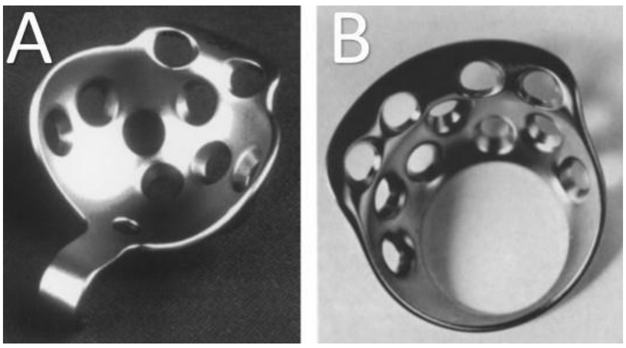

Figure 23: A: Ganz reinforcement ring. B: Muller ring [60].

Acetabular reinforcement rings are smaller and typically easier to implant than are acetabular cages. The experience with use of the Müller ring for revision surgery has been disappointing, whereas favorable results have been reported after use of the Ganz reinforcement ring for reconstruction of deficient dysplastic acetabula. The designer of the Ganz ring reported mid-term to long-term results of the use of this implant in acetabular revision surgery. The superior flange of the Ganz reinforcement ring is short, and wide exposure of the supra-acetabular part of the ilium is not required. The ring is fixed against the area of the best bone stock with screws, which allows optimal positioning, coverage, and cement fixation of the polyethylene cup [60].

v. Ilioischial Cages

The anti-protrusio cage (APC) was originally designed by Bürch in 1974 and modified by Schneider in 1975 to address the problem of protrusio acetabula (Fig. 24). The aim was to bridge areas of bone loss, allow grafting and bone augmentation in areas of protected stress, and give support for the socket. The APC is a titanium support ring that is fixed to the host ilium with screws and to the ischium with a fixation fin or keel. A polyethylene socket is then cemented into the ring, and cancellous bone graft is used to fill bone defects contained by the ring [61].

Figure 24: The Bürch- Schneider anti-protrusio cage (APC) [62].

Because there is no bone ingrowth into the cages, they have reported failure rates defined as aseptic loosening and cage migration ranging from 0% to 25% at midterm because of hardware failure of the screws or flanges. Screws may eventually break, whereas the ischial flanges can either break or loosen, leading to cage migration. Management of failed acetabular cage reconstruction (reinforcement rings or antiprotrusion cages) may require a repeated attempt at cage reconstruction (63).

vi. The Medial Protrusio Technique

Medialization provides an option in which uncemented acetabular cups can be used (Fig. 25). Dorr et al. suggested that the rate of medial protrusion of the cup is defined as the percentage of the cup beyond the ilioischial line (64). However, the exact threshold of medial protrusion has yet to be determined; for example, <45% [10], <50% [9], or ≥60% [3] have been proposed as threshold values (65).

Hartofilakidis et al. recommended that medialisation of 41% to 59% may offer a sound biomechanical environment with optimal coverage for the construct (65). This was the same recommendation of Kim et al Who recommed protrusio should be within 50%-60% (66).

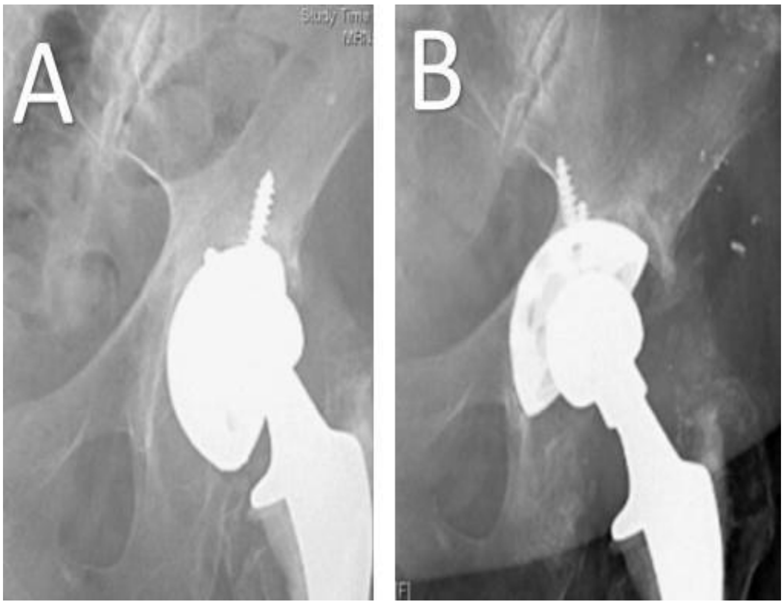

Figure 25: (A) A preoperative radiograph demonstrates a malpositioned cup with evidence of loosening clinically. (B) A postoperative x-ray after revision shows a medialized component beyond Kohler's line with adequate bone coverage (29).

Fabi et al reported on the drawbacks of this technique. Medialization of acetabular cups possesses its own potentially devastating complications because intrapelvic structures are at risk. The major complications associated with over-reaming are intrapelvic vessel complications, urogenital tract complications, nervous system complications, and intrapelvic mass formation [(29)].

vii. Implants for Pelvic Discontinuity

Pelvic discontinuity associated with bone loss is a challenging condition encountered at the time of acetabular revision. It has been defined as an uncommon condition occurring in association with total hip replacement when the hemipelvis is separated superiorly and inferiorly by loss of host bone or fracture through the acetabular columns. Pelvic discontinuity can often be detected pre operatively on plain radiography, but radio-opaque implants can obscure the condition, therefore, an intra-operative examination of the hemipelvis for discontinuity is advised [(67)].

The following implants can be used:

1) Custom triflange implants

Triflange implants are custom-made, porous coated titanium alloy components considered a final therapeutic salvage option in patients with pelvic discontinuity and/or prior radiation to pelvis. A triflange construct is designed from pelvis CT scans with metal subtraction software converted into a three-dimensional (3D) representation of the patient's hemipelvis. The implant manufacture generates individualized implants from the respective imaging (Fig. 26) [(48)].

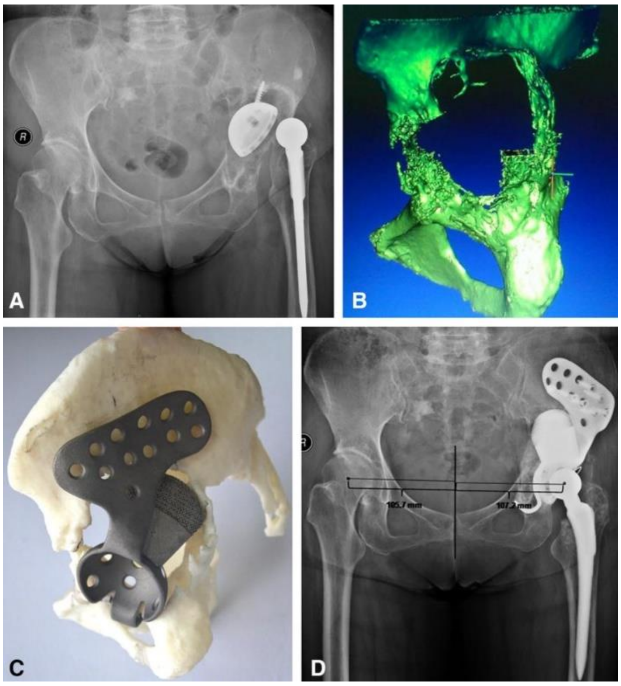

Figure 26: (A) An AP radiograph shows prosthetic cup loosening with severe acetabular osteolysis 14 years postoperatively in a 70- year-old woman. (B) A CT based three-dimensional (3-D) reconstruction of the patient's acetabulum is shown. (C) An individualized custom cage with an artificial iliac wing, 3-D printed support augment, and obturator hook was constructed. (D) A postoperative AP radiograph shows excellent restoration of the rotational center of the hip [68].

2) Cup-cage construct

The cup-cage construct has emerged as a viable option to treat the difficulties. This construct consists of a TM cup typically secured with screws with an ilioischial cage cemented within the cup. The cage provides initial stability to the cup by shielding it from mechanical forces allowing bone to grow within the porous TM cup and biologic fixation to take place, giving the entire construct its long-term stability (Fig. 27) [69].

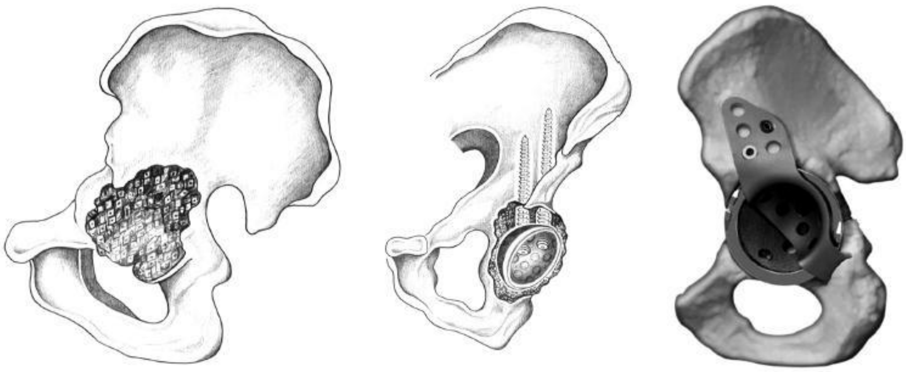

Figure 27: Diagram of the technique used showing a) the acetabular defect packed with morsellised bone graft, b) fixation of the trabecular metal acetabular component and c) the final construct [67].

3) Acetabular distraction with porous cup

The acetabular distraction technique is another novel approach for managing pelvic discontinuities. the basis of acetabular distraction is to address nonunion of fracture lines using distraction to expand the defect and create elastic recoil forces to compress the porous metal construct. Intraoperatively, a Cobb elevator is used to delineate the fracture line and debridement of the granulation tissue and reaming is performed to define bone suitable for fixation using augmentation (Fig. 28) [48].

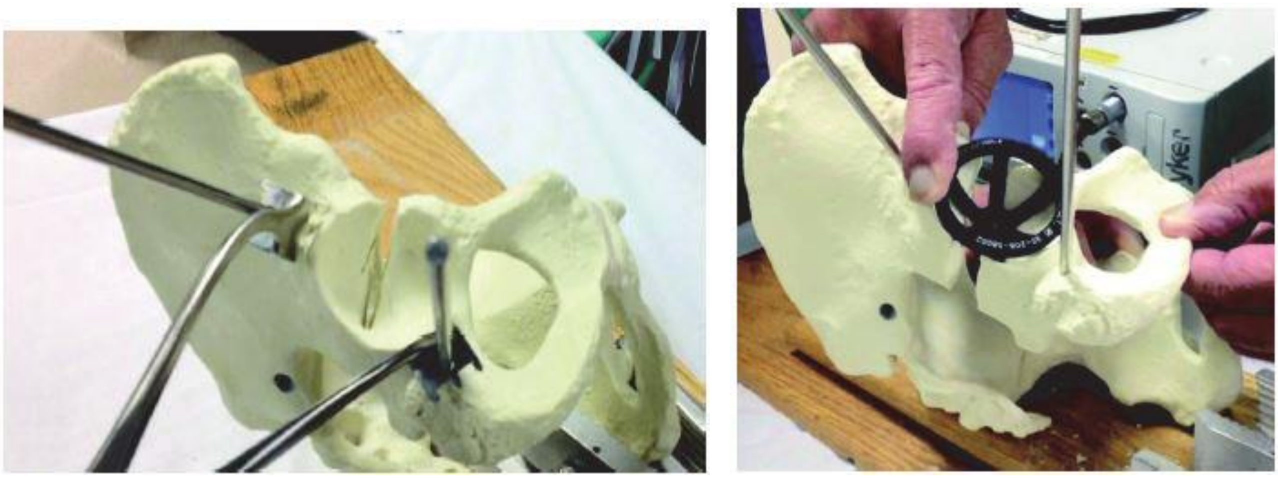

Figure 28: acetabular distraction technique [48].

viii. Trabecular metal cups

TM acetabular components come both with modular liners and as revision shells into which a cemented cup is implanted. Traditionally, the use of an uncemented cup has required greater than 50% of host bone contact. However, some authors have described the use of trabecular metal with less than 50% bone contact and have found that its use has decreased the requirement for the use of reconstruction cages. The porous nature of this material also allows additional screw holes to be burred through a revision component in whatever position is required to gain fixation (57).

TM constructs are designed to maximize the degree of biologic fixation and unlike other implants that use a porous coating, the structure of the entire TM construct is a porous architecture. The TM components have the following advantages:

1. The elastic modulus of TM is more like subchondral bone than other implant materials to improve load-directed bone remodeling. This finding also helps to minimize stress shielding adjacent to the cup.
2. The high coefficient of friction improves stability of the cup and is superior to other materials in the presence of poor bone stock.
3. The highly porous trabecular configuration is conducive to bone formation, allowing rapid and extensive bone ingrowth (Fig. 29).
4. The ability to manufacture metallic augments of different sizes and shapes to compensate for different-sized bone defects.
5. The augment is stable after bone ingrowth occurs and acts as a structural support without risk of resorption (70).

Figure 29: Implant removal due to infection. The surface almost covered by bone [71].

Flecher et al. carried out a study to determine whether the use of tantalum implants could provide stable reconstruction for any type of acetabular revision. They investigated 72 hips (71 patients) implanted with tantalum cups, some with augments, and morselized graft material. The mean follow-up was 4 years. The radiographic analysis found no radiolucent lines after 1 year and up to the last follow-up. None of the patients required revision for acetabular loosening. Three hips were revised for instability. They summarized that tantalum implants provide a stable primary cementless fixation without compromising the center of rotation and without necessarily requiring a structural graft. A single implant range can therefore be used for any type and severity of bone loss and for all types of acetabular reconstruction [72].

TRABECULAR METAL AUGMENTS

Figure 30: TM augments [73].

Trabecular metal augments have been used for several decades for treatment of bone deficiency during revision knee arthroplasty. An acetabular reconstructive technique has been developed with the use of modular metal augments using a novel biomaterial of porous tantalum (Trabecular Metal). These porous metal acetabular augments were manufactured to be used similarly to structural bone allograft techniques to achieve simultaneously biologic fixation, provide coverage and mechanical support for an uncemented hemispheric acetabular cup [73].

Different sizes and shapes of these acetabular augments accommodate the various acetabular bony defects encountered in addition to the various sizes of hemispheric acetabular components [74].

Indeed, cemented components can be implanted beneath these augments once rim support has been established. As the lack of host structural support worsens, consideration can be given to the use of multiple augments of different shapes in combination with a porous metal hemispherical shell. In certain situations, this can be combined with additional initial structural support using a cage plate to protect the reconstruction, pending bony ingrowth [28].

As long as a certain amount of contact of the implant with host bone is considered essential for long term stability of the acetabular component, a porous augment will enhance this stability through increasing the contact area. The porous augment will be supported by the host bone after ingrowth occurs, and ultimately, the acetabular implant will be supported both directly at its contact site to the host bone, and indirectly through the bony contact of the augment. This is the base of the concept of effective host bone contact, defined as the sum of the contact area of both porous implants (acetabular component and any augment) with the host bone [(74)].

Good results have been published for the use of tantalum porous metal implants for large acetabular defects although yet only with short term follow-up. Abolghasemian et al had published their results using TM implants for segmental defects of the acetabulum and have found a survival rate of 91.1% at five years when aseptic loosening was used as an endpoint. They found that in all, but two of 34 cases reviewed, all augments were found to be osteo-integrated. They found the use of an augment improved the location of their hip center of rotation and support the use of augments in combination with TM shells in the bone-deficient acetabulum but accept that there are some disadvantages to the use of augments in their study, as they do not restore bone stock for any subsequent revision [(70)].

Biomechanics of Trabecular Metal

Mechanical Properties

The mechanical properties of Ta[73] are compared with those of cancellous and cortical bone, titanium, cobalt chromium (CoCr), and stainless-steel alloys in (table 5). The modulus of elasticity for Ta is like that of subchondral bone, yet the yield and ultimate strength are significantly greater. Its fatigue properties and endurance limits were also greater than those of cancellous bone, freeze-dried bone fragments, ceramic granules, or composite calcium salt pastes. As a bone graft substitute, Ta affords sufficient support of physiologic loads while bone ingrowth occurs, and it was found to be superior in this regard to either cancellous or cortical bone [(75)].

Mechanical Property	TM Tantalum	Cancellous Bone	Cortical Bone	Titanium	Cobalt Chromium	Stainless Steel
Modulus of elasticity (GPa)	2.5-3.9	6.8	13-17	106-115	210	230
Ultimate strength	50-110	10.4	48	780-1050	430-1028	480-860
Yield strength	35-51	5.1	N/A	860	827	170-690
Compressive strength	50-70	N/A	131-205	N/A	N/A	N/A
Tensile strength	63	N/A	53	N/A	N/A	N/A
Bending strength	110	N/A	N/A	N/A	N/A	N/A
Static torsional strength	40-60	N/A	N/A	N/A	N/A	N/A
Endurance limit (10 million cycles in 4-point bending)	18-20	N/A	N/A	N/A	N/A	N/A

Table 5: Mechanical properties of tarbecular metal compared other materials. GPa = gigapascal, MPa = megapascal, N/A = not available, TM = Trabecular Metal [(75)].

Porous Ta^{73} structures used for orthopedic implants maintain a porosity of 75% to 85%, compared to 30% to 35% for sintered CoCr beads and 40% to 50% for titanium fiber metal mesh. In addition, the overall rigidity of porous Ta was similar to that of the human fibula [(75)].

Biocompatibility

Tantalum is relatively inert in vivo and is used in many medical applications. The oxide formed on the surface of tantalum implants in vivo has been reported to remain stable over a wide range of actual and potential pH ranges [35].

Bioactivity

For tantalum to mechanically bond to bone, a bone-like apatite layer must first form on the metal surface. This occurs when porous Ta is pretreated with dilute NaOH, which then can be stabilized on the metallic surface by heat treatment (300°C) [75].

Bone Ingrowth

Using a transcortical canine model, Bobyn et al implanted porous tantalum cylinders with subsequent histologic and mechanical testing at interval follow-up. In samples that had an average pore size of 430 μm, new bone was found occupying 42% of the pores at 4 weeks, 63% at 16 weeks, and 80% at 1 year. Histologic examination revealed increasing regions of bone-implant contact with time as well as evidence of haversian remodeling within the pores [76].

Mechanical testing of Ta[73] demonstrated significantly higher shear fixation strength at 4 weeks, than that of sintered CoCr beads and several other porous metals. This increase in shear strength was attributed to the greater porosity of the tantalum cylinders, leading to a higher volume of bone occupying the pores for any given percentage filled. It was concluded that porous tantalum is an effective scaffold for relatively complete incorporation, with new bone by 16 weeks and little change after 1 year [76].

Types

1. **TM Wedge Augments**

   Augments sized from 50 to 70mm in 10, 15, 20, and 30mm thicknesses.

Figure 31: Wedge type trabecular metal augment [70].

2. **TM Buttress Augments**

Figure 32: Buttress type trabecular metal augment [70].

- Addresses extensive superior segmental defects (Paprosky Type IIIA)
- Alternative to allograft, without potential for bone resorption or disease transmission
- Designed to provide a technically simpler procedure, compared to using structural allograft
- Host bone is conserved while implant size, position, and orientation are determined by the defect.

- Allows head center to be restored for optimization of patient kinematics
- Available in straight superior and posterior/anterior column configurations
- Sizing allows use with TM revision shells of any size.

3. TM Restrictors

Used to rebuild medial wall [77].

Figure 33: Restrictor type trabecular metal augment [77].

4. TM Shim Augments

Placed between buttress augment flange and host bone to optimize the fit of the buttress device against the iliac bone [77].

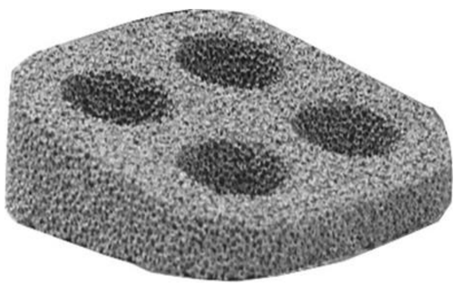

Figure 34: Shim type trabecular metal augment [70].

Intra-operative possibilities with TM augments

The augment can be placed in any position or orientation to improve the initial stability of the construct, but there are some common situations:

1. Firstly, a minor or major column defect that is surrounded by an intact rim of acetabular bone within 30 mm of the outer perimeter of the trial acetabular cup, which is the maximum thickness of augments normally available. One or two conventional augments can be used in a wedge ‘configuration or oblong cup position to fill a similarly shaped defect (Fig. 35) [74].

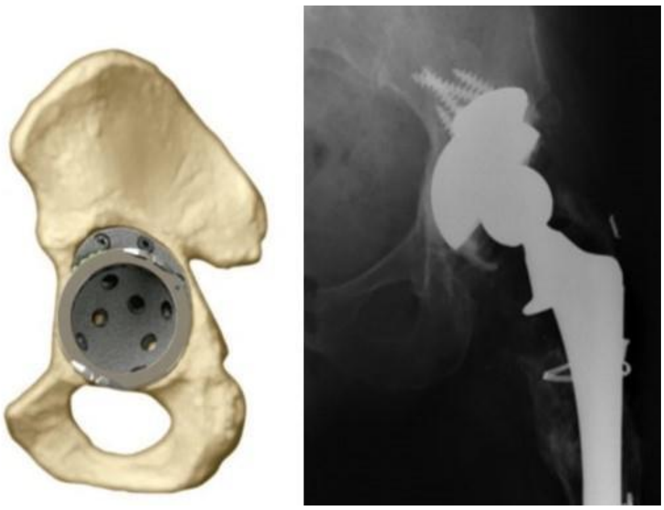

Figure 35: Oblong cup position. Algorithmic and postoperative X-ray [74].

2. Secondly, a severe contained medial defect is faced with an intact but thin peripheral rim which would not be sufficiently supportive for a cementless cup. A conventional augment could be inserted into the defect as a foundation to provide medial support to the overlying acetabular shell, footing position. (Fig. 36) [74].

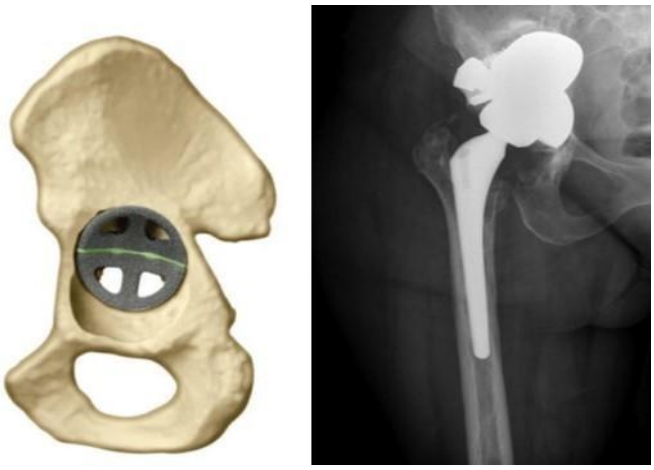

Figure 36: Footing position. Algorithmic and postoperative X-ray [74].

3. Thirdly, when a minor column defect is present with no bony rim available within 30 mm of the trial cup but with a supportive bony bed, a conventional augment can be used in the opposite way of the wedge configuration. This flying buttress configuration is assumed to be supportive to the cup as only a moderate amount of shear force on the augment is expected with a minor column defect (Fig. 37) [74].

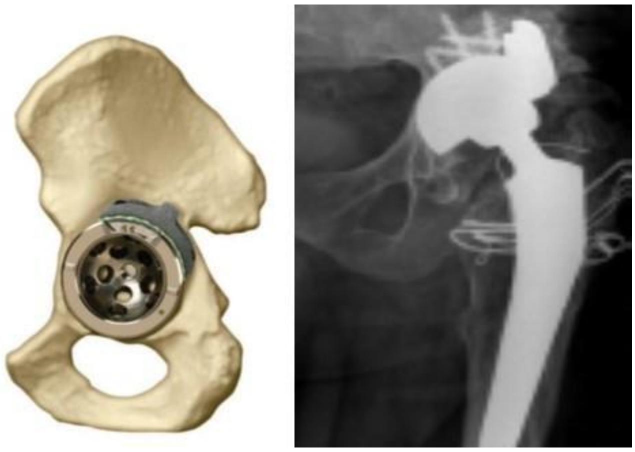

Figure 37: Flying buttress position. Algorithmic and postoperative X-ray [74].

4. Finally, a major column defect is associated with lack of bony rim within 30 mm of the trial cup. Buttress augments in this situation aim to maximize the bone contact area and stability of the construct as whole.

a. In case of a straight superior defect, a straight buttress (figure of seven) augment is desirable.

b. When the defect is mainly in the anterior or posterior part of the trial acetabular component, an anterior or a posterior column buttress augment is preferable.

c. If a gap persists between the flat part of the augment and the ilium, a shim augment can be used (Fig. 38) [74].

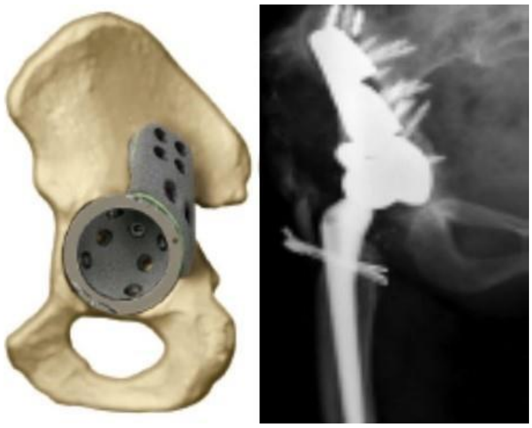

Figure 38: Buttress augments for column defects. Algorithmic and postoperative X-ray [74].

The use of more than one augment in a single reconstruction may be required, especially when a major column defect is to be addressed using wedge rather than buttress augments; they can be placed in wedge configuration, either side by side or at opposing poles of the acetabulum, based on the location of the bone defect [74].

In 2007, Gehrke et al began using tantalum augments in combination with impaction allografting and the use of an all polyethylene cemented acetabular component, instead of a tantalum cup, as an alternative to the use of structural allografts for more severe acetabular defects that were uncontained. Forty-six patients undergoing cup revision with a tantalum augment and allografting were clinically (HHS) and radiographically reviewed. Postoperative images were assessed for osteointegration, bone-remodeling and recreation of the native hip center. They found that the combination of tantalum augmentation with impaction allografting is a promising technique to manage severe uncontained acetabular defects [78].

TM versus bulk graft

The ingrowth properties of TM are superior to bone graft in revision surgery. Although allograft can reabsorb over time and leads to eventual component instability, TM maintains its structure and stability over time. The honeycomb architecture of TM allows the surgeon to drill through the acetabular shells to allow screw placement without weakening component strength. This superior stability makes TM superior to structural allografts in revision surgery [79].

TM versus impaction graft

Rowan et al compared clinical and radiological outcomes of acetabular impaction bone grafting (AIBG) and porous TM implantation in acetabular defect reconstruction. They proposed that restoration of bone stock is desirable in the younger patient undergoing revision hip arthroplasty. This benefit of AIBG must be offset against the difficulties associated with its use [80].

AIBG is technically laborious and requires significant institutional bone bank processes, funding and infrastructure. They recommended that only surgeons trained in AIBG techniques should undertake such surgeries that offer the advantage of restoring bone stock. They reported AIBG failure rate of 11% and a further 11% of patients with radiological evidence of loosening. On the basis of their experience, they stopped using AIBG reconstruction in patients with sequelae of prosthetic joint infection [80].

They proposed that AIBG should be applied to restore bone stock in the younger patient and carefully considered for patients with prior prosthetic joint infection. There was greater success with TM in higher grades of acetabular deficiency regardless of prior infection. The low rates of failure for TM are encouraging [80].

PATIENTS AND METHODS

A prospective cohort study was conducted in Benha university hospital including twenty patients undergoing revision total hip arthroplasty with acetabular defects that necessitate reconstruction.

Ethics

A written consent was obtained, and the patients were informed about the surgical procedure. All the patients were followed up for one year

The oxford hip score (OHS) [81] will be used to record the status of the hip before surgery to be able to evaluate post-operative results (Fig. 39).

Patients

Epidemiology

Number of Patients

Twenty patients were included in this study in the period between April 2019 and March 2023.

Demography

- Sex distribution

There were 12 males and 8 females in the study.

- Age distribution

Age ranged from 48 years to 70 years.

Body mass index (BMI)

Mean body mass index was from 23.1 to 37.4

Side of operation

Thirteen operations were done for the right side and the remaining seven patients had their operations for the left side.

Patient to complete. Tick (√) one box for every question

1.During the past 4 weeks **How would you describe the pain in your hip?** ☐ None ☐ Very Mild ☐ Mild ☐ Moderate ☐ Severe	7. **During the past 4 weeks** **Have you been able to put on a pair of socks, stockings or tights?** ☐ No trouble at all ☐ Very little trouble ☐ Moderate trouble ☐ Extreme trouble ☐ Impossible to do
2. During the past 4 weeks **Have you been troubled by pain from your hip in bed at night?** ☐ No nights ☐ Only 1 or 2 nights ☐ Some nights ☐ Most nights ☐ Every night	**8. During the past 4 weeks** **After a meal (sat at a table), how painful is the hip to stand up?** ☐ Not at all painful ☐ Slightly painful ☐ Moderately painful ☐ Very painful ☐ Unbearable
3.During the past 4 weeks **Have you had any sudden, severe pain- (shooting/stabbing or spasms) from the hip?** ☐ No days ☐ Only 1 or 2 days ☐ Some days ☐ Most days ☐ Every day	**9.During the past 4 weeks** **Have you had any trouble getting in and out of a car or using public transport because of your hip?** ☐ No trouble at all ☐ Very little trouble ☐ Moderate trouble ☐ Extreme trouble ☐ Impossible to do
4. During the past 4 weeks **Have you been limping when walking because of your hip?** ☐ Rarely/never ☐ Sometimes, or just at first ☐ Often, not just at first ☐ Most of the time ☐ All of the time	**10.During the past 4 weeks** **Have you had any trouble with washing and drying yourself (all over) because of your hip?** ☐ No trouble at all ☐ Very little trouble ☐ Moderate trouble ☐ Extreme trouble ☐ Impossible to do
5. **During the past 4 weeks** **How long can you walk (with or without stick) before the pain in your hip becomes severe?** ☐ No pain/more than 30mins ☐ 16-30 mins ☐ 5-15 mins ☐ Around the house only ☐ Not at all/pain severe	11. **During the past 4 weeks** **Could you do the household shopping on your own?** ☐ Yes, easily ☐ With little difficulty ☐ With moderate difficulty ☐ With extreme difficulty ☐ No, impossible
6. **During the past 4 weeks** **Have you been able to climb a flight of stairs?** ☐ Yes, easily ☐ With little difficulty ☐ With moderate difficulty ☐ With extreme difficulty ☐ No, impossible	12. **During the past 4 weeks** **How much has pain from your hip interfered with your usual work (including housework)?** ☐ Not at all ☐ A little bit ☐ Moderately ☐ Greatly ☐ Totally

Figure 39: Oxford Hip Score format [81].

Methodology

A. Preoperative evaluation

Patient selection

Inclusion criteria:

Patients who are undergoing rTHA with loose acetabular component with acetabular defects (Paprosky type II “A, B, C” and type III “A”) that necessitate reconstruction.

Exclusion criteria:

- Patient with pelvic discontinuity

Clinical evaluation

A detailed sheet will be taken for all patients including:

- Personal history including age, sex, occupation, special habits of medical importance.
- Previous surgical approach, abductors function and range of motion.
  Nineteen patients have one previous history of total hip replacement and only one patient had two previous total hip replacements were done. Fourteen patients were done through post. Approach and six patients through lat. Approach.
- Past history and medical comorbidities
  Twelve patients had no previous history of chronic medical condition, seven patients had chronic disease either (DM, HTN, Rheumatoid) and only one patient had both DM and HTN.

- Local and neurovascular assessment of the affected limb. Abductor muscle status was tested using Trendelenburg test and resisted side-lying abduction. Leg-length discrepancy was evaluated: preoperative discussion with the patient included trials that would be done to equalize the length of both limbs or at least to decrease the difference. In difficult revision cases, instability had the priority over leg length equalization.

The oxford hip scoring [81] system will be used to record the status of the hip before surgery to be able to evaluate post-operative results.

Radiological evaluation

All patients examined radiologically by:

- Anteroposterior and cross table lateral plain radiographs of the hip (Fig. 40).

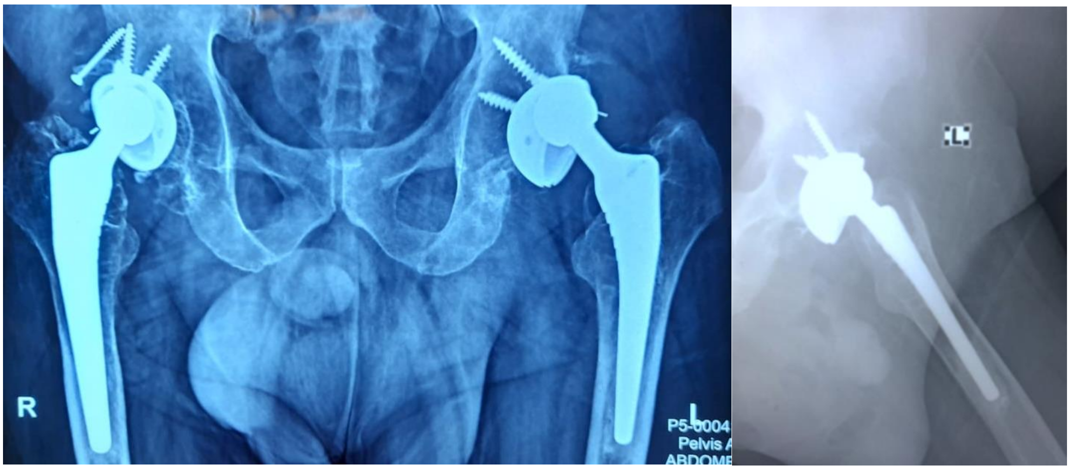

Figure 40: plain x-ray (A.P. pelvis and cross table lateral plain radiographs of the hip) showing the left failed acetabular component.

- C.T. scan (to classify the acetabular defects) (Fig. 41).

Figure 41: C.T. pelvis (cronal and axial views showing the failed acetabular component with osteolysis).

Laboratory assessment

- CBC
- ESR, CRP
- R.B.S, HbA1C
- Urine analysis
- Urea and electrolyte

<u>Surgical technique</u>

Position

All patients were operated upon while lying in a lateral position.

Anesthesia

The choice of anesthetic technique was based on the following factors:

- Associated medication and medical conditions

- Duration and associated problems of surgery
- Preference of anesthetist and surgeon
- Patient preference
- All patients received combined spinal (subarachnoid) anesthesia, and epidural anesthesia.
- IV Tranexamic acid (15 mg/kg) was taken routinely in the OR with induction of anesthesia.
- I.V. antibiotics : Twelve patients received a double dose (2 gm) of third generation cephalosporin intravenously at the induction of anesthesia. The remaining eight patients followed the protocol for management of infected cases.

Operative steps

1. Through the posterior approach
2. Old incisions were used whenever possible. However, skin incision was modified in many occasions to allow for posterior approach or incorporate draining sinuses
3. In revision cases, incision was usually extended proximally and distally to define tissue planes more easily for release of scars and to facilitate extensile exposures when needed.
4. The sciatic nerve was routinely identified and palpated.
5. The scarred external rotators were released and reflected posteriorly with the leg flexed and internally rotated.

Technical details

1. The acetabular cup

Exposure and preparation

- Removal of failed previous acetabular component
- Debridement and removal of fibrous tissue was done.
- Preparation of the bony bed for fixation of the augments

- Intraoperative indications for using augments
  - ✓ Acetabular component uncovering of > 40%.
  - ✓ Good wall contact was found but still there was a superior acetabular defect that needs a third point for fixation to achieve primary stability.
  - ✓ Restoration of anatomic hip center of rotation when there was migration of the previous cup

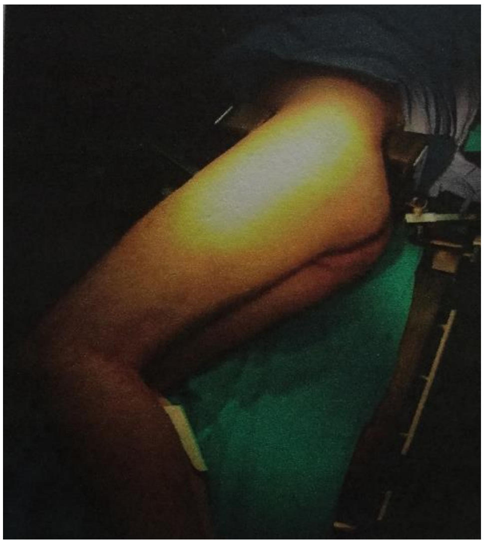

Figure 42: lat. Position of the patient.

Figure 43: Post. Hip approach (skin incision).

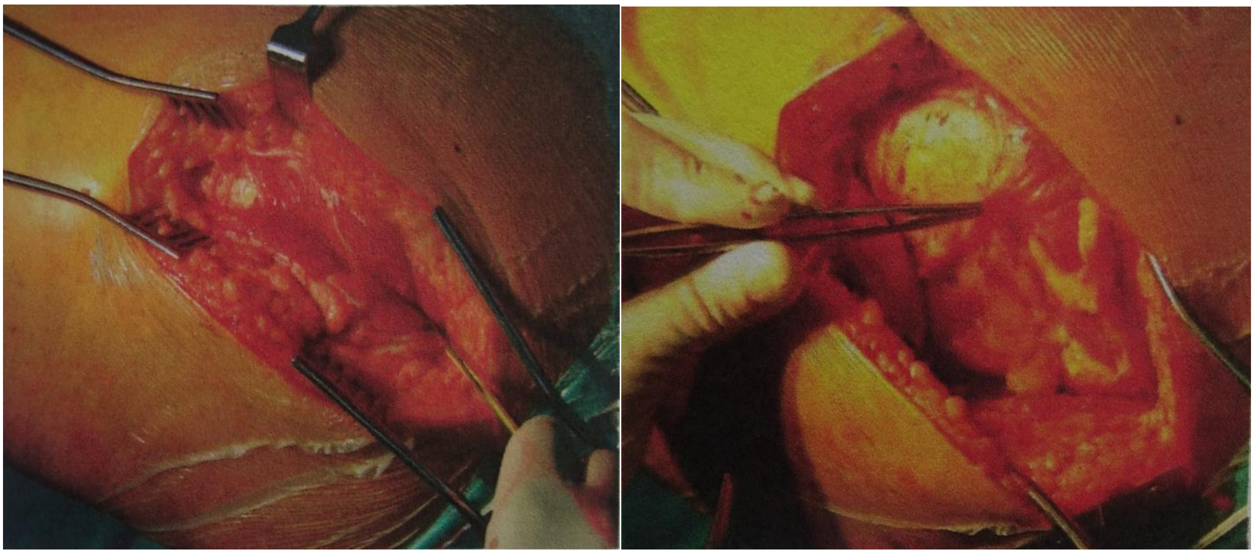

Figure 44: subcutaneous tissue dissection then splitting of the gluteus maximus.

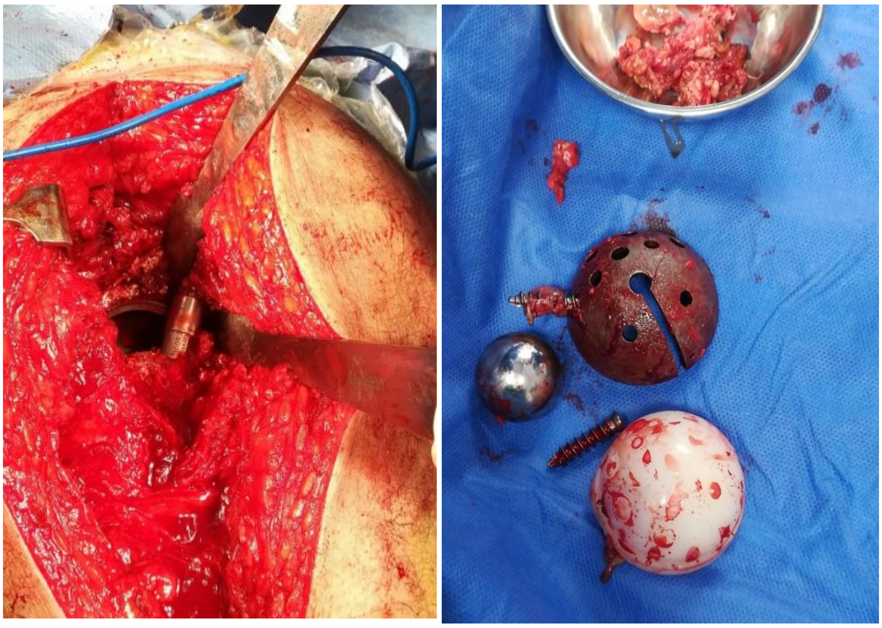

Figure 45: Failed acetabular component.

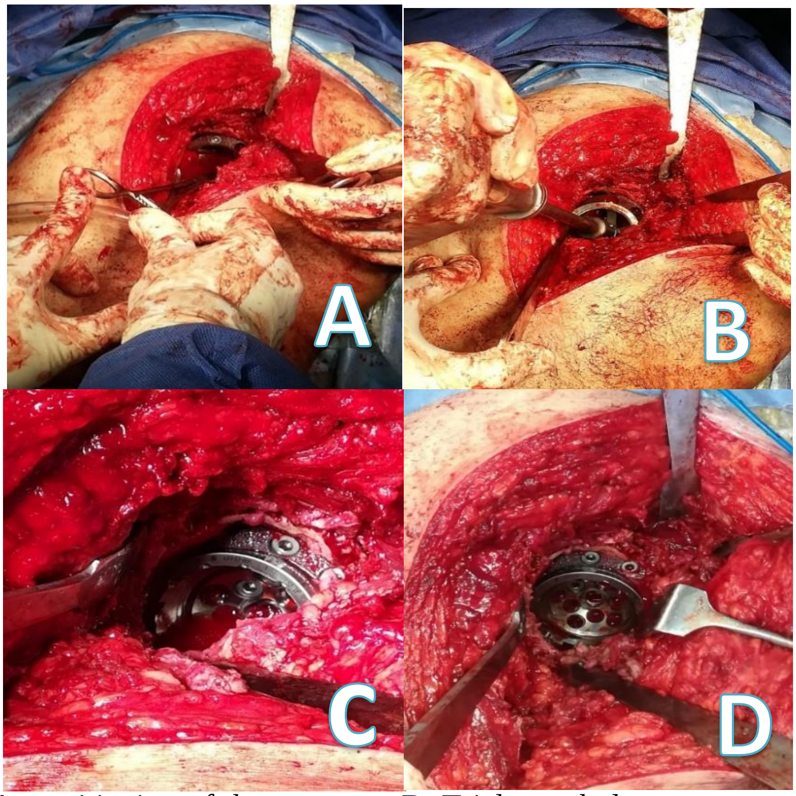

Figure 46: A: positioning of the augment, B: Trial acetabular component, C&D: the final acetabular cup with the augment.

Impaction bone grafting

It was used in five cases where the segmental defect was associated with a cavitary one (cases number 1, 3, 4, 7, 12)

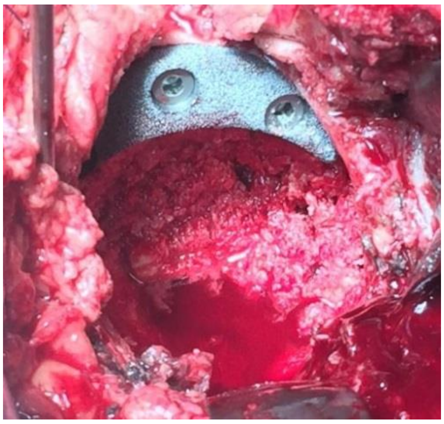

Figure 47: Impaction bone grafting, intraoperative photo.

Type of the cup.

- Cemented (Zimmer ZCA) High cross-linked all-poly cup (Longevity HCLP) was used in nine cases. seven cases had MOP bearing and 36 mm head. The other two (case 2, 9) had COP with 36 mm head.

- Cementless cup (Zimmer) was used in eleven cases. Eight of them had MOP bearing with 36 mm head and 2 cases had COP with 32 mm head and one cases had COP With 36mm head.

Closure of the wound

- Reattachment of the posterior soft tissues including short external rotators to the greater trochanter was done.
- The iliotibial band was then closed after application of suction drain
- Skin closure using skin clips

post-operative care

- Postoperative antibiotic regimen was given as ceftriaxone 2 gm infusion every 24 hours for 48 hours. In the infected cases, antibiotics were given according to the results of intra operative samples.
- Low molecular weight heparin 40 I.U. once daily started 12 hours after the surgery and maintained for one month.
- Proton pump inhibitors were given till discharge
- Hemoglobin concentration was assessed for every case at least 6 hours after the last transfused blood unit. Blood transfusion was given if HB concentration was less than 9 gm/dl.
- Static quadriceps and hamstring exercises and straight leg raising.

- The timing of postoperative partial weight bearing was variable according to the structural integrity of the acetabular reconstruction and the implant used. when trochanteric osteotomy was done, full weight bearing was postponed to 12 weeks.
- The remaining cases started full weight bearing at 6 weeks

Follow up program

Clinical evaluation

- All patients were followed up at 2 weeks, 6 weeks, 12 weeks, 6 months then annually thereafter to assess incision condition, ROM, abductors strength.
- Patients progressed to full weight bearing at the 6 weeks.

Radiological evaluation

- All patients were evaluated with anteroposterior and cross table plain X-ray immediately post-operative then at two, six, twelve weeks, six months then annually.

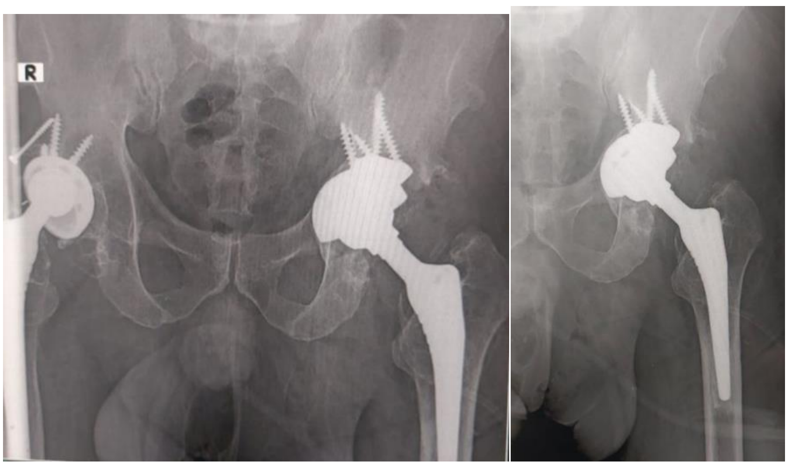

Figure 48: post-operative x-ray showing the TMA and the revised acetabular component.

- The Moore classification describes radiographic signs suggestive of osseointegration in uncemented shells. This system was modified by Gross et al to assess the probability of osseointegration. This modified classification considers augments to be unstable if (1) >3 mm migration compared with the early postoperative radiograph; (2) a radiolucent line at the augment-bone interface; (3) radiolucent lines around all screws; or (4) screw fracture [70, 82]. The hip center of rotation (HCOR) after the operation is compared to that preoperatively. This is measured relative to the inter-teardrop line and, when available, the contralateral native HCOR.

Functional outcomes will be measured with oxford hip score (OHS).

Statistical methods

The collected data will be presented as suitable tables and illustrated as suitable figures. Quantitative data will be summarized as mean ± SD and qualitative data as frequency and percentage. Analysis of data will be by aid of software package of Datatab using suitable statistical tests.

RESULTS

This prospective study started on April 2019 and included 20 hips that needed acetabular reconstruction during revision hip arthroplasty. The mean follow up duration was 16 months (rang from 12-24 months).

I. Patient demography

1. Gender

The table shows the difference between male and female regarding improvement in OHS grading.

Gender	Male	Female	P value (Chi- square Test)
Fair	0	1	0.276
Good	4	4	
Excellent	8	3	
Total	12	8	

P value >0.05 = NS = non-significant

Table 6: OHS grading results according to gender

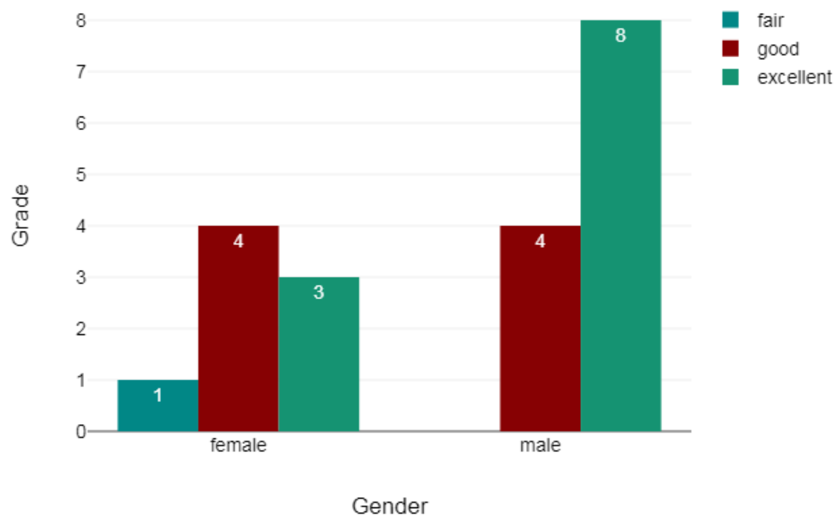

Figure 49: OHS grading results according to gender

2. **Age**

The table shows the results of OHS grading according to the age of the patients

Age	**Age <60**	**Age ≥60**	**P value (Chi- square test)**
Fair	0	1	0.492
Good	2	6	
Excellent	5	6	
Total	7	13	

P value >0.05 = NS = non-significant

Table 7: OHS grading results according to age

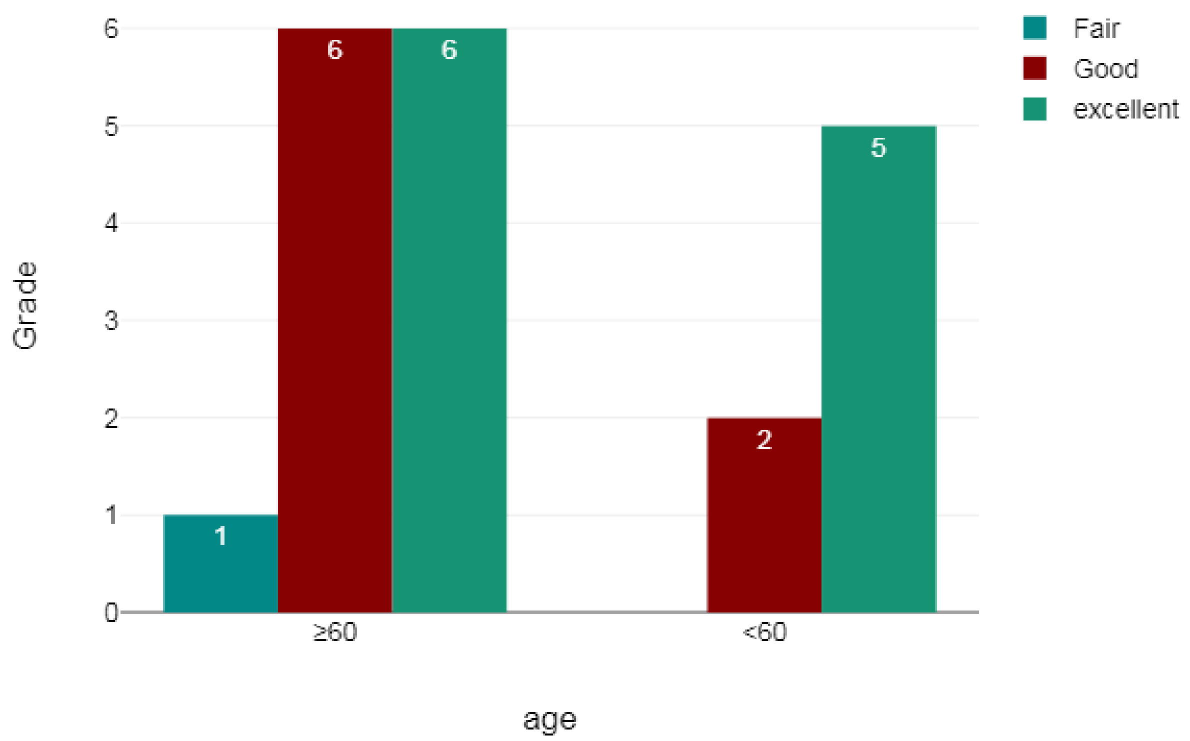

Figure 50: OHS grading results according to age

3. BMI

The table shows the results of OHS grade depending on the BMI

BMI	BMI < 30	BMI > 30	P value (Chi- square test)
Fair	0	3	0.004
Good	0	8	
Excellent	8	1	
Total	8	12	

P value >0.05 = NS = non-significant

Table 8: OHS grading results according to BMI

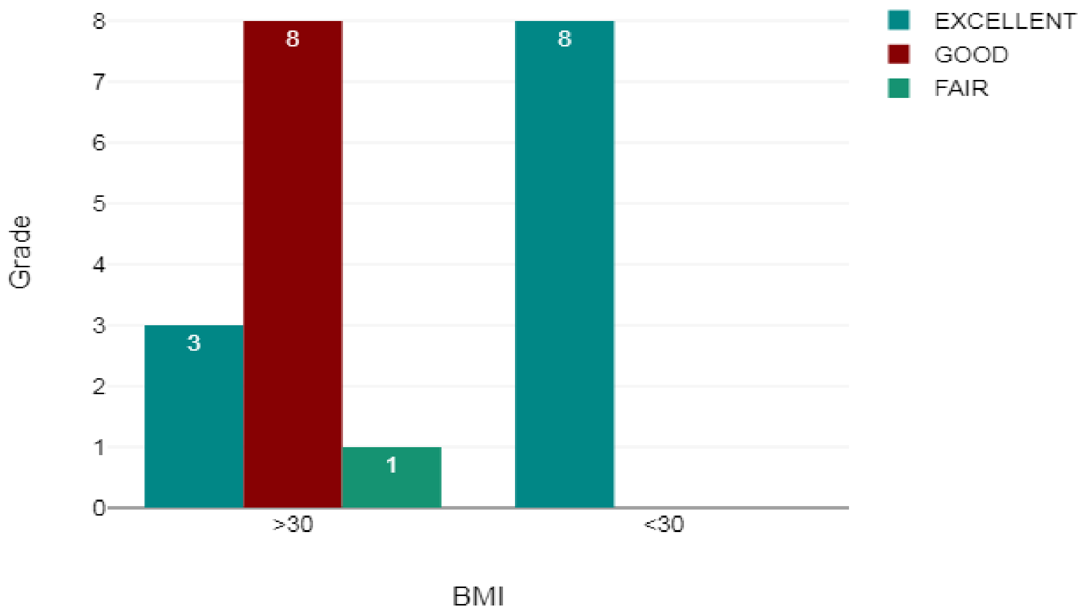

Figure 51: OHS grading results according to BMI

4. Cause of loosening

The table shows the cause of loosening in the twenty patients

Cause of loosening	No. of the patients
Aseptic loosening	18
Septic loosening	2

Table 9: causes of loosening among the patients

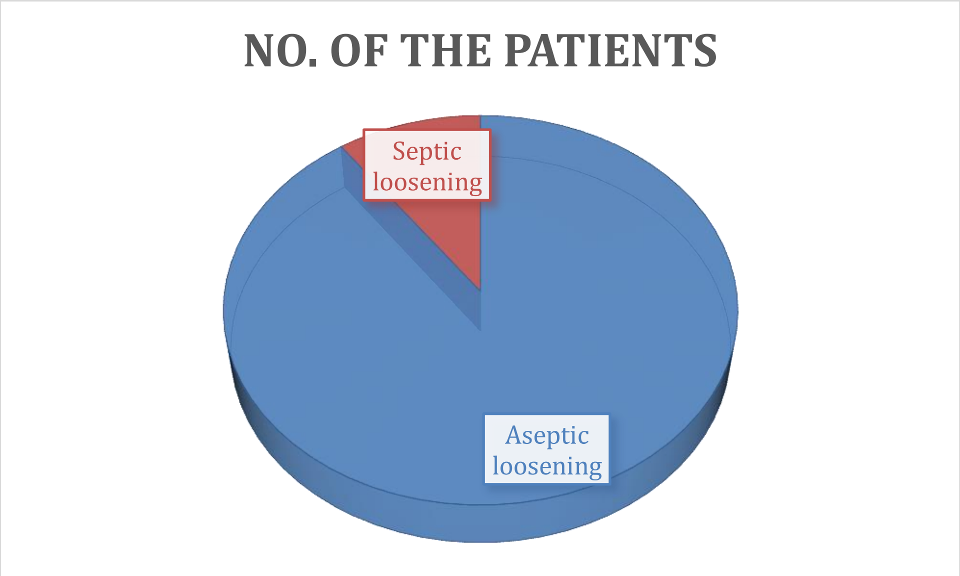

Figure 52: chart of distribution of cause of loosening among patients

II. Clinical results

Oxford hip score (OHS)

- Mean OHS at the latest follow-up visit was 38.9.
- Mean OHS increased from 12.85 preoperatively to 38.9 at latest follow up visit

OHS	Mean ± SD		t-Test	P- value
	Pre-operative	Post-operative	32.58	<.001
	12.85 ± 4.33	38.9 ± 5		

Table 10: Comparison of mean preoperative and postoperative OHS.

SD = standard deviation, P value >0.05 = NS = non-significant

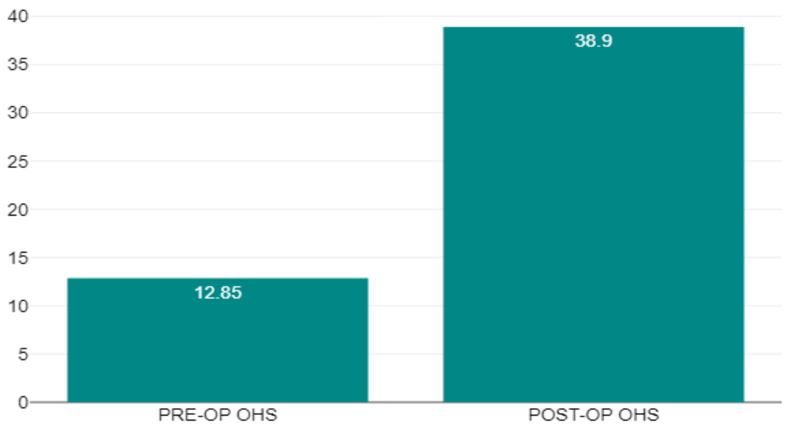

Figure 53: Comparison of mean preoperative and postoperative OHS.

Type of defect

The table shows the OHS grading post-operative according to the type of the defect

Type of the defect	Paprosky II	Paprosky III	P value (Chi- square test)
Fair	0	1	0.009
Good	11	4	
Excellent	4	0	
Total	15	5	

P value >0.05 = NS = non-significant

Table 11: OHS grading results according to type of the defect.

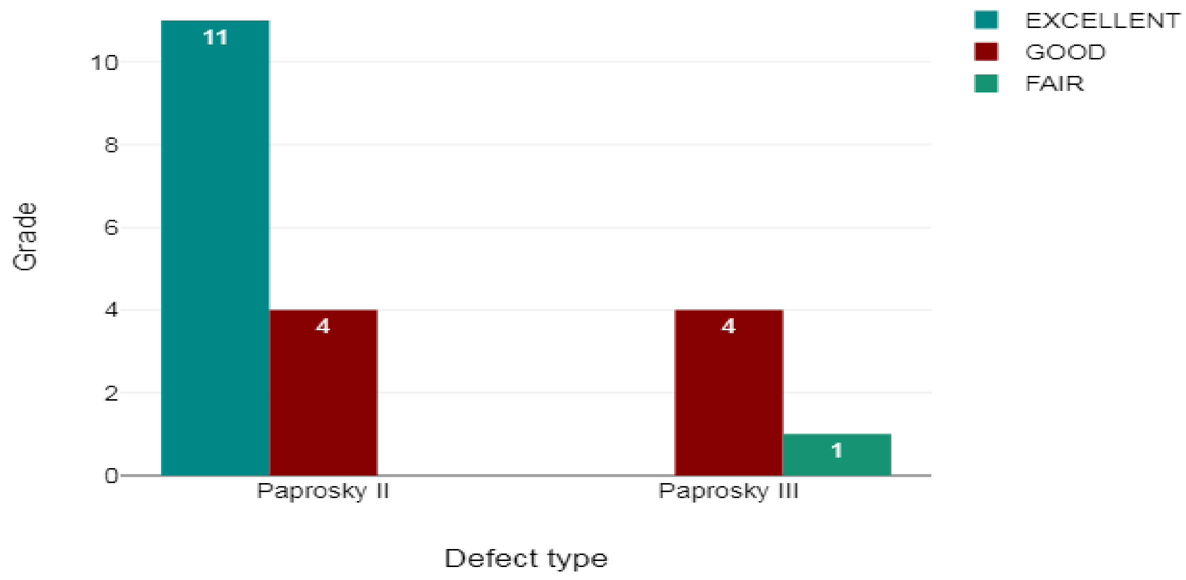

Figure 54: OHS grading results according to type of the defect

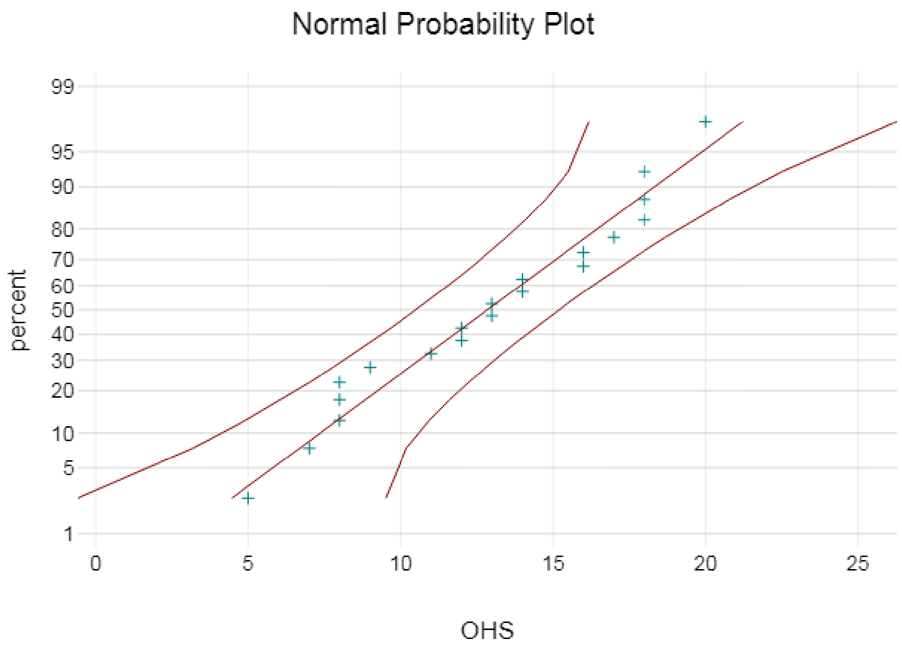

Figure 55: normal distribution of data

The table shows the deference in the improvement in OHS among the patients depending on type of the defect, presence of infection and IBG usage.

OHS improvement	Mean ± SD		Mann Whitney test (z)	P value
Type of defect	**Paprosky II**	**Paprosky III**	1.61	0.119
	65.55± 7.72	73.14± 10.03		
Presence of infection	**Infected**	**Non-infected**	0.15	0.91
	67.57± 8.71	67.26± 9.39		
IBG usage	**IBG**	**No IBG**	0.13	0.933
	67.17± 8.62	67.54± 9.08		

Table 12: Mean improvement in OHS in different groups

SD = standard deviation, P value >0.05 = NS = non-significant

Grading of OHS at last follow up visit:

OHS grade	Number of patient	Percentage (%)
Fair	1	5%
Good	8	40%
Excellent	11	45%
Toral	20	100%

Table 13: OHS grading results

Impaction bone graft

The table shows the results of usage of IBG on post-operative OHS grading.

IBG	N0 of cases	P value (Chi- square test)
Fair	0	0.834
Good	2	
Excellent	3	
Total	5	

P value >0.05 = NS = non-significant

Table 14: OHS grading results in cases with IBG.

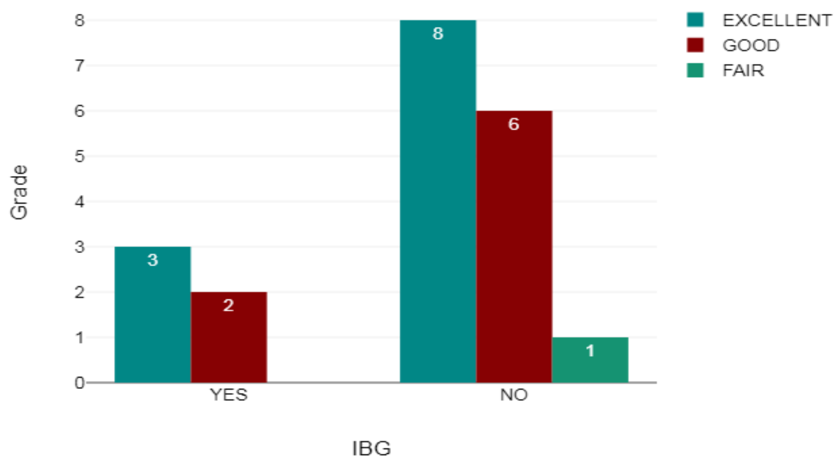

Figure 56: OHS grading results in cases with IBG.

III. Radiological results

1. Signs of unstable augment

- Radiolucent line appeared in one case (1) and it was asymptomatic. The extension of that line didn't change over 16 months of post-operative follow up. No revision was done

Figure 57: Radiolucent line in case 1

2. Signs of cup migration

- No migration of any cup was discovered in relation to the interteardrop line.
- No significant difference was found between abduction angle in the immediate postoperative period and in the most recent follow-up radiographs.

3. Bone graft

Bone/graft interface was evaluated in the three zones of DeLee and Charnley:

- No fracture of the graft
- No radiolucent lines in the interface
- No graft resorption
- Graft incorporation was confirmed by cup and augment stability without incidence of migration.

CASE PRESENTATION

Case 1

History: Female patient 48 years old, house wife, rheumatic, non-obese (BMI 27.2 kg/m2)

Diagnosis: aseptic loosening of the acetabular component

Type of defect: Paprosky: 2B, AAOS: 2A

Operative details: revision of acetabular component with cemented cup

Clinical evaluation

The preoperative OHS was 18

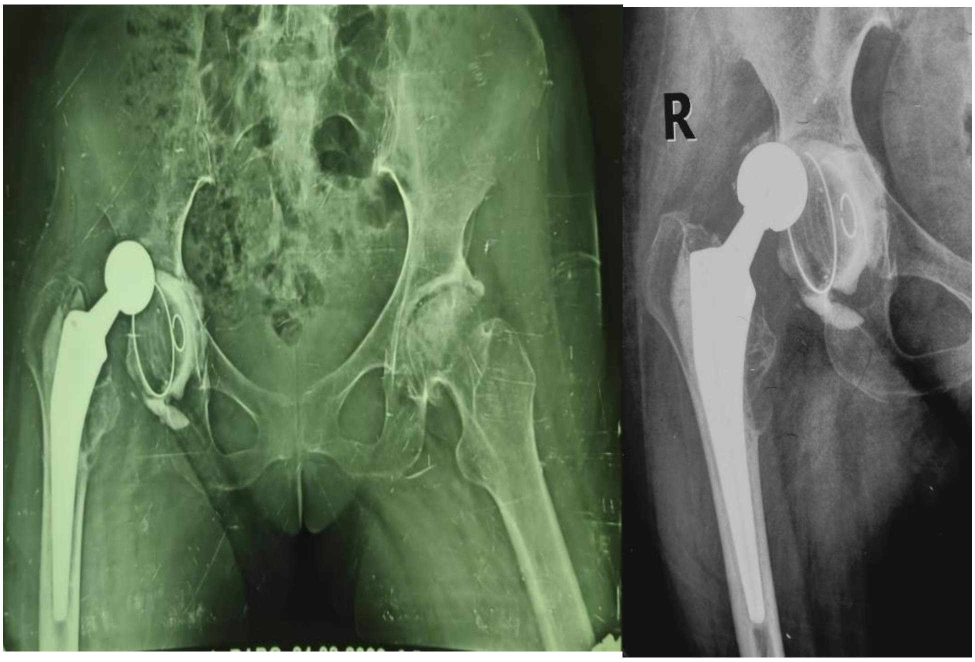

Figure 58: pre-operative x-ray

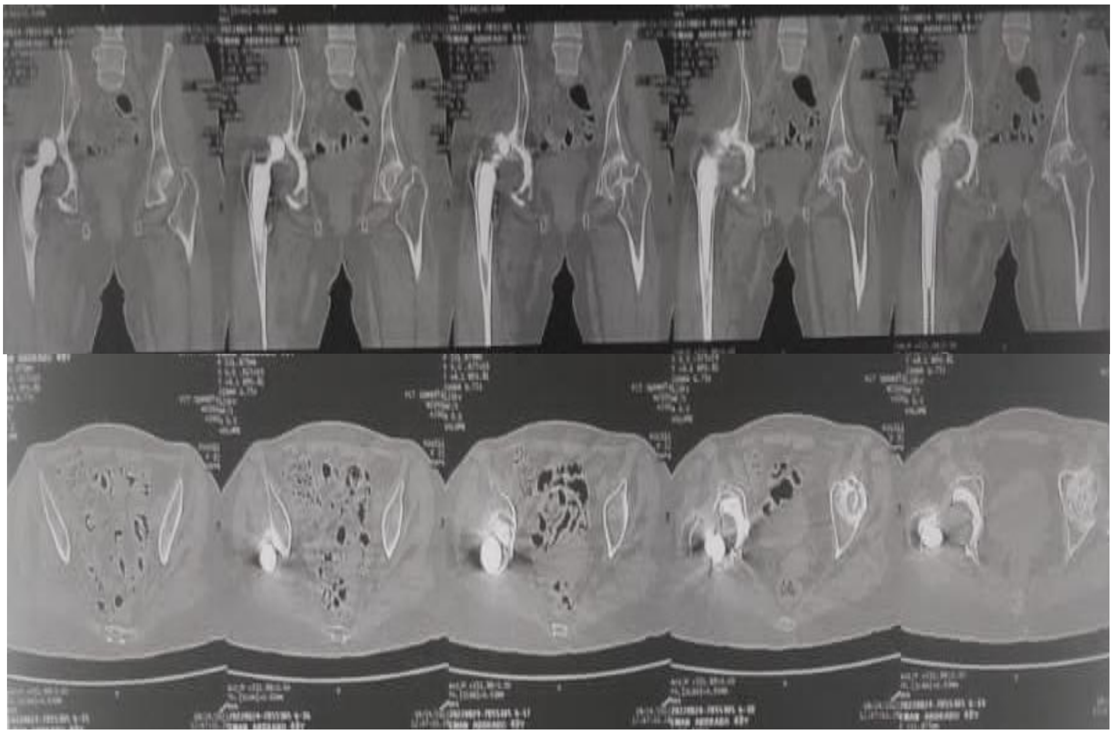

Figure 59: pre-operative C.T

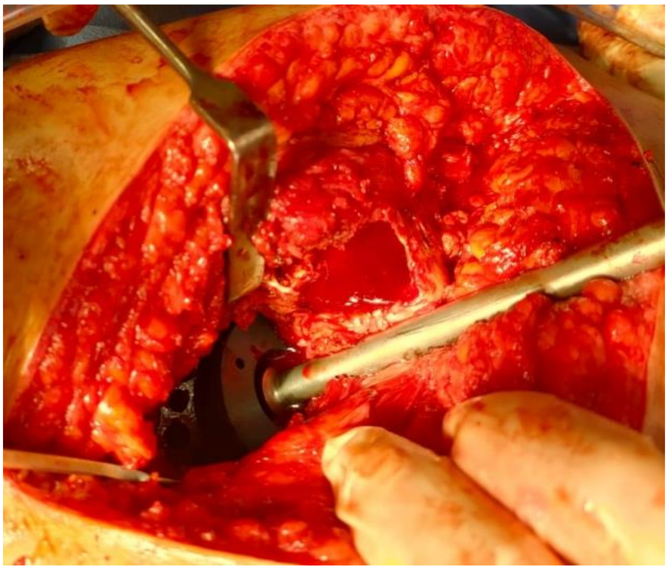

Figure 60: intra-operative photo for trial augment and trial cup

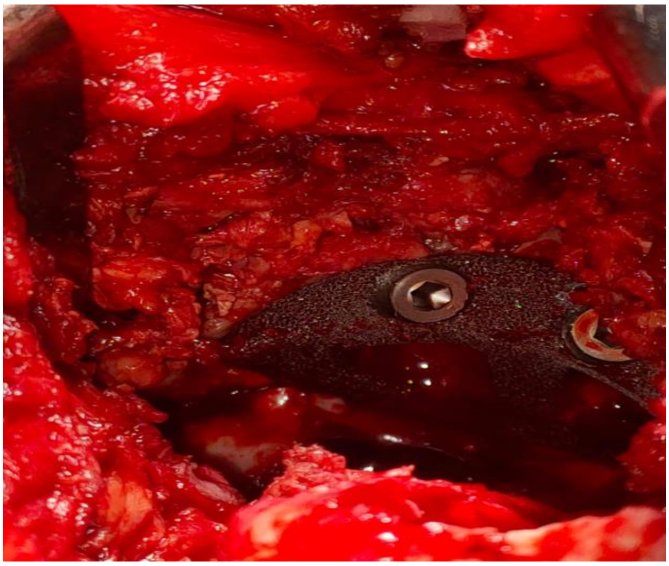

Figure 61: intra-operative photo for the augment

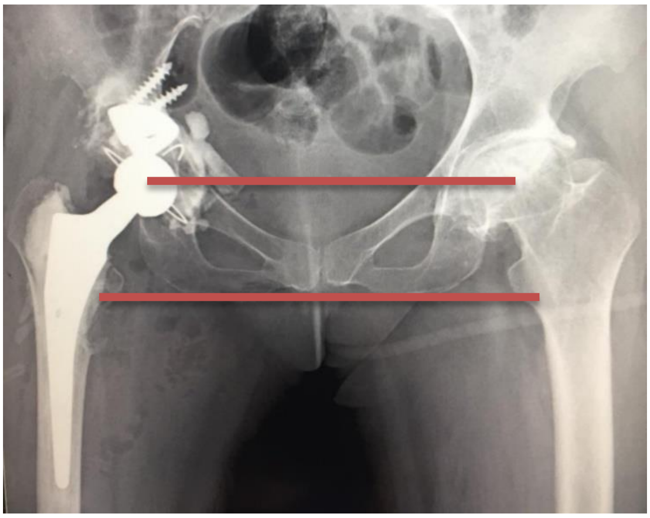

Figure 62: post-operative x-ray

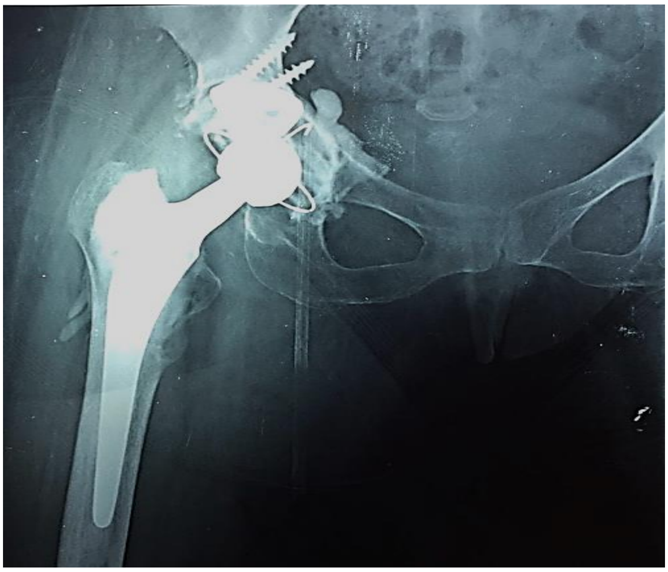

Figure 63: follow up x-ray after 6 weeks

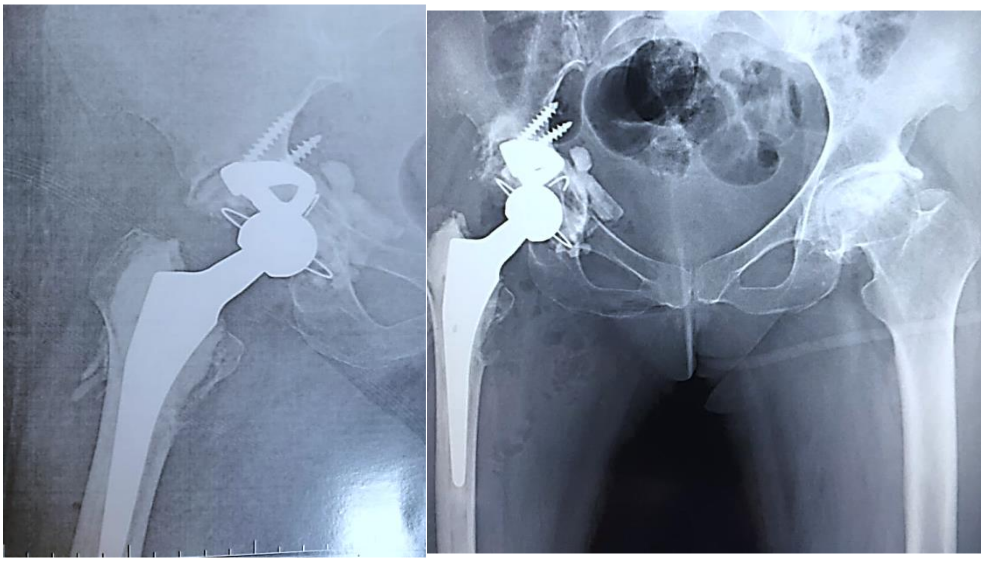

Figure 64: follow up x-ray after 3 months

Figure 65: follow up x-ray after 6 months

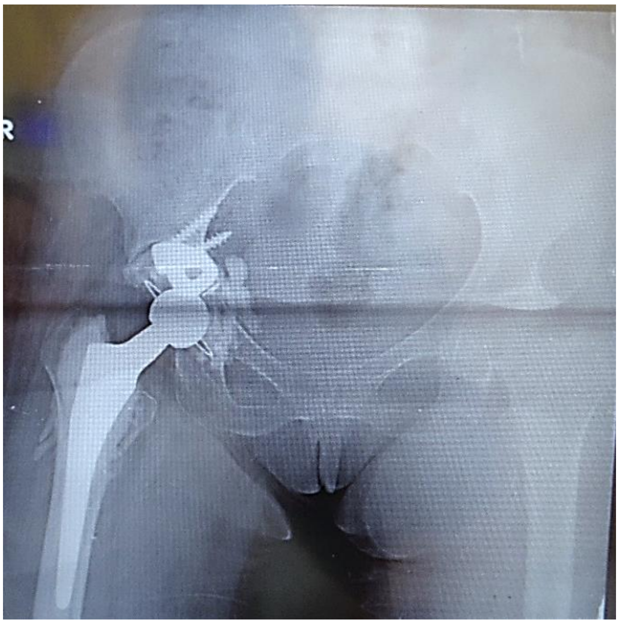

Figure 66: follow up x-ray after 12 months

Figure 67: clinical photos for the patient (A: standing without aids, B,C: hip abduction).

The patient at the final follow up has a good range of motion and the postoperative OHS is 43.

Case 2

History: Female patient 64 years old, house wife, no past medical history, obese (BMI 32.7 kg/m2)

Diagnosis: aseptic loosening of the acetabular component

Type of defect: Paprosky: 2C, AAOS: 2A

Operative details: revision of acetabular component with cemented dual mobility cup

Clinical evaluation

The preoperative OHS was 18

Complications

Sciatic nerve affection in the form of foot drop for which NCV was done and showed neurotmesis and till the last follow up still not recovered

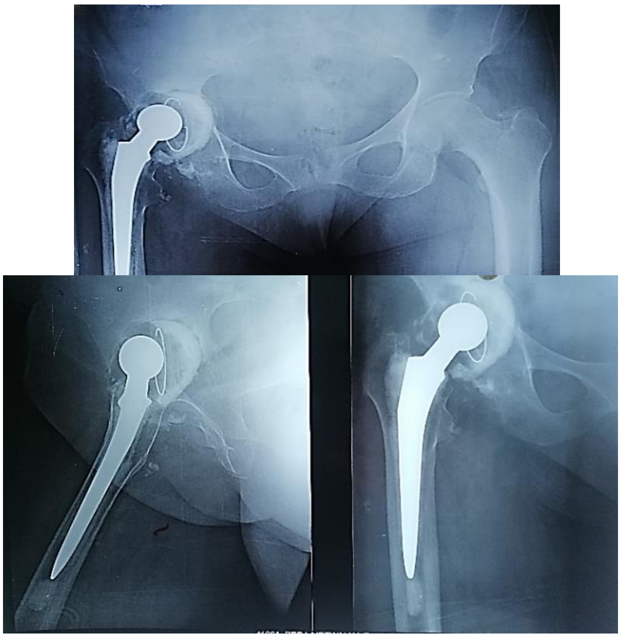

Figure 68: pre-operative x-ray

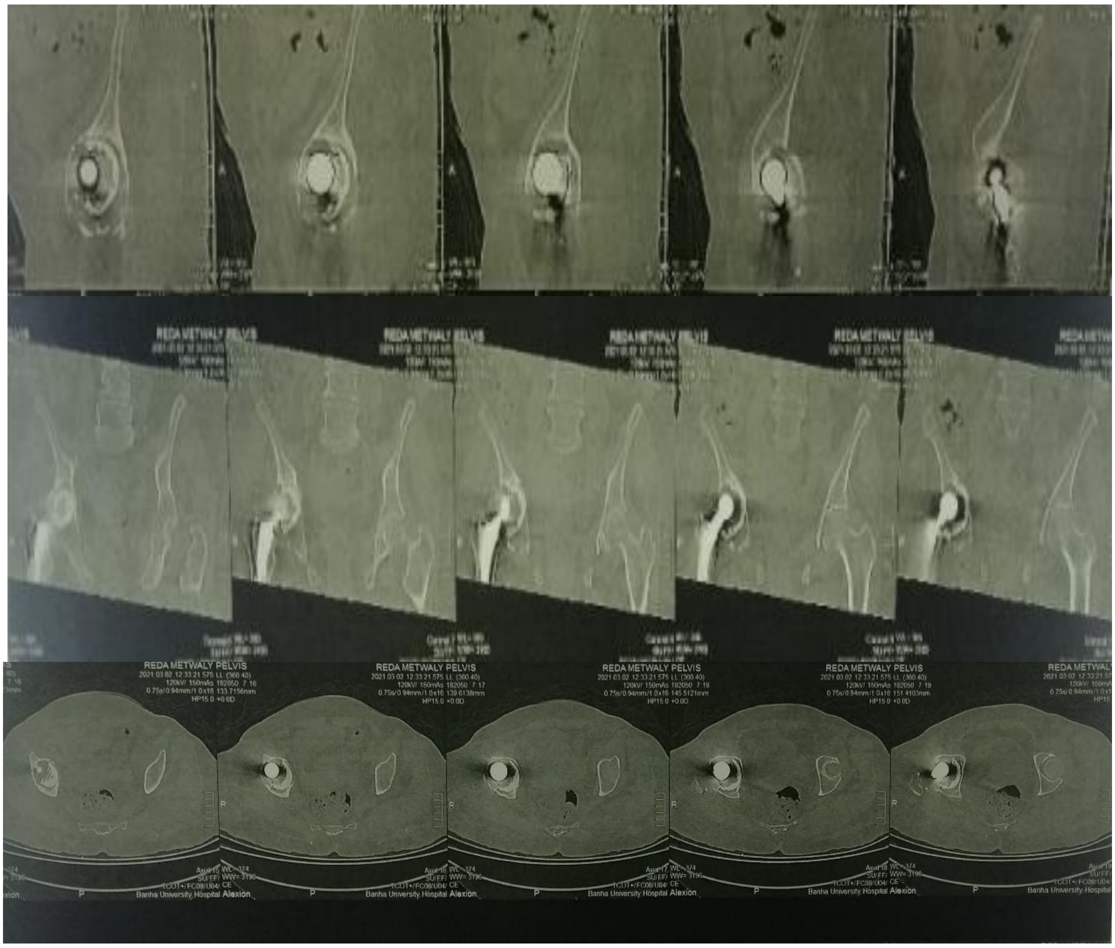

Figure 69: pre-operative C.T

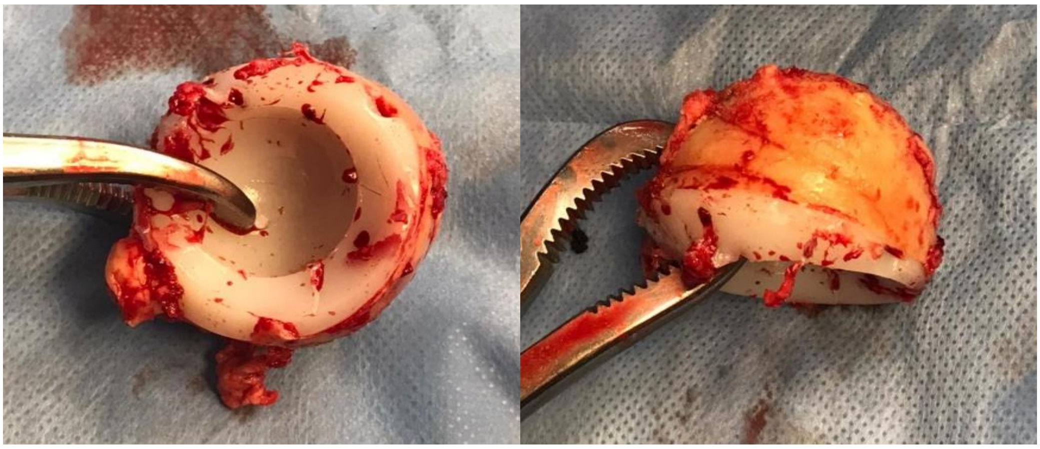

Figure 70: removed polyethylene cup

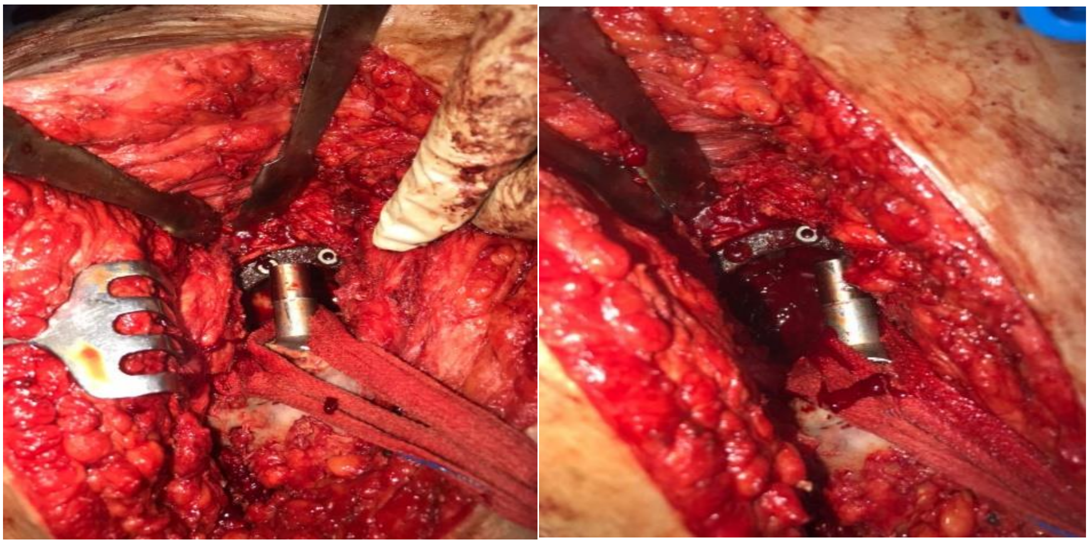

Figure 71: intra-operative photo after augment insertion

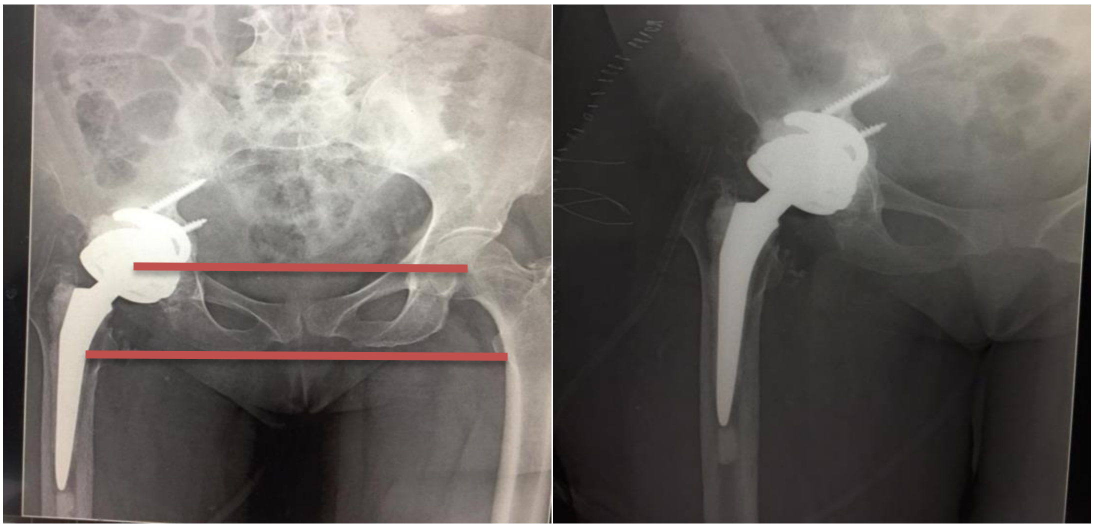

Figure 72: post- operative x-ray

Figure 73: follow up x-ray after 3 months

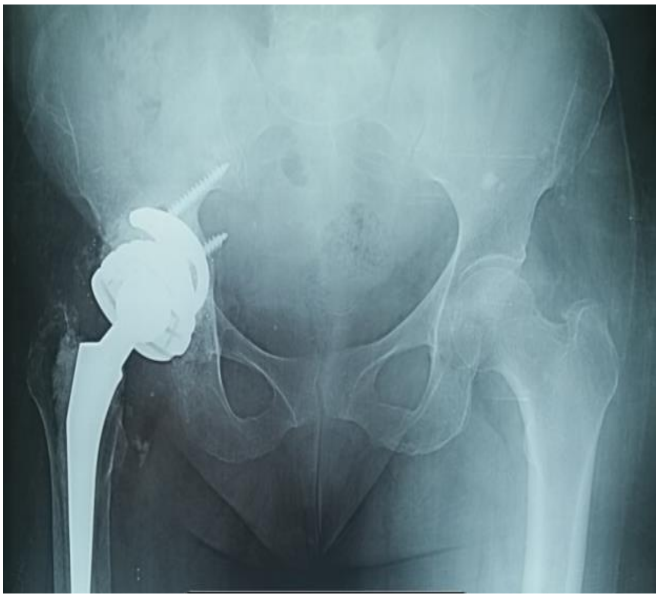

Figure 74: follow up x-ray after 6 months

Figure 75: follow up x-ray after 14 months

The postoperative OHS is 40.

Case 3

History: male patient 59 years old, worker, no past medical history, obese (BMI 30 kg/m2)

Diagnosis: aseptic loosening of the acetabular component

Type of defect: Paprosky: 2B and AAOS: 1A

Operative details: revision of acetabular component with cementless cup

Clinical evaluation:

The preoperative OHS was 8

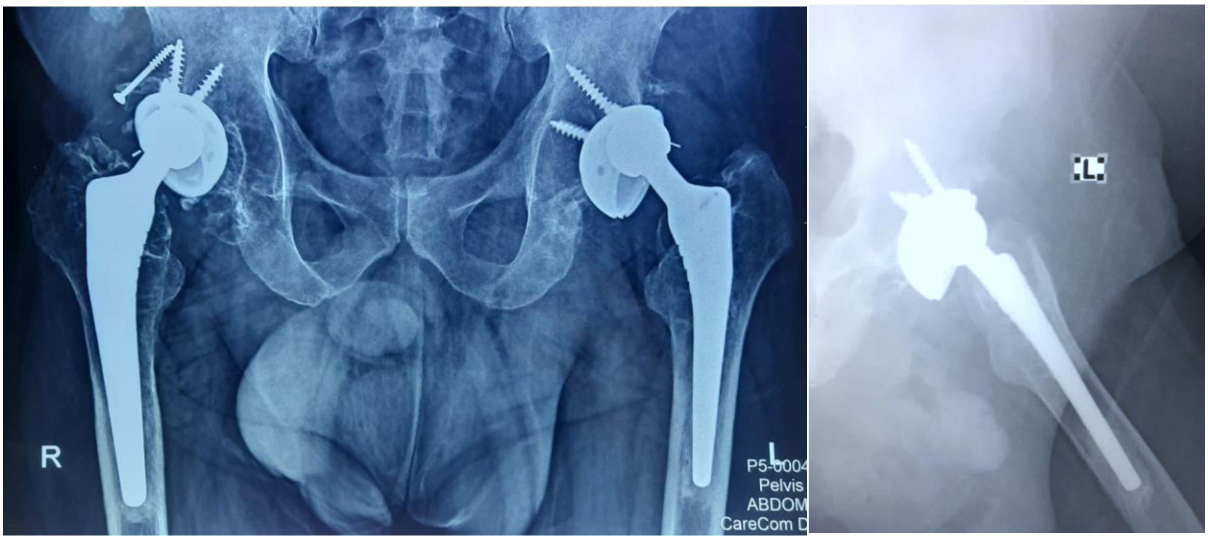

Figure 76: pre-operative x-rays

Figure 77: Removed loose acetabular component

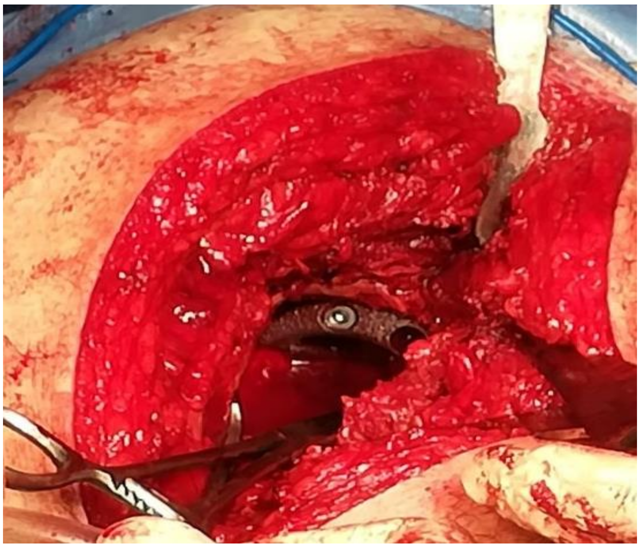

Figure 78: Intra-operative photo for augment

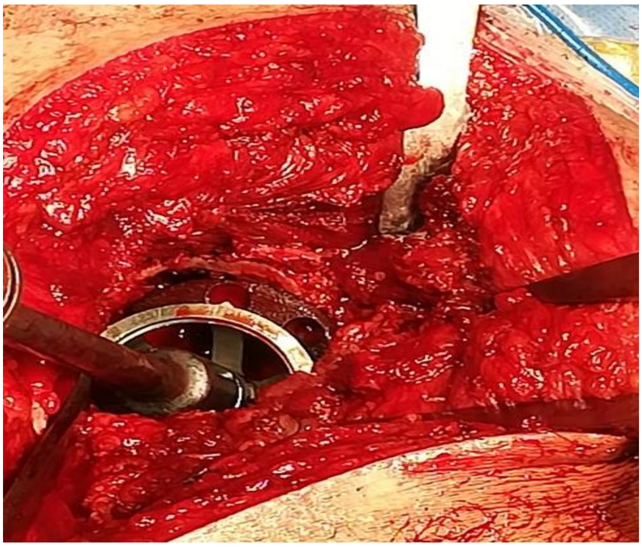

Figure 79: Augment with the trial cup

Figure 80: Augment with the cup after fixation

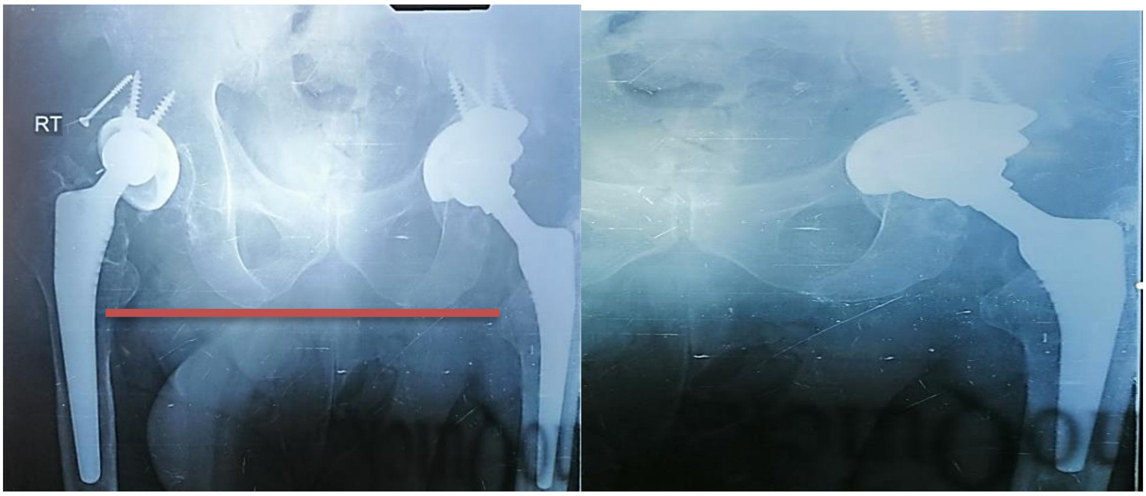

Figure 81: post-operative x-rays

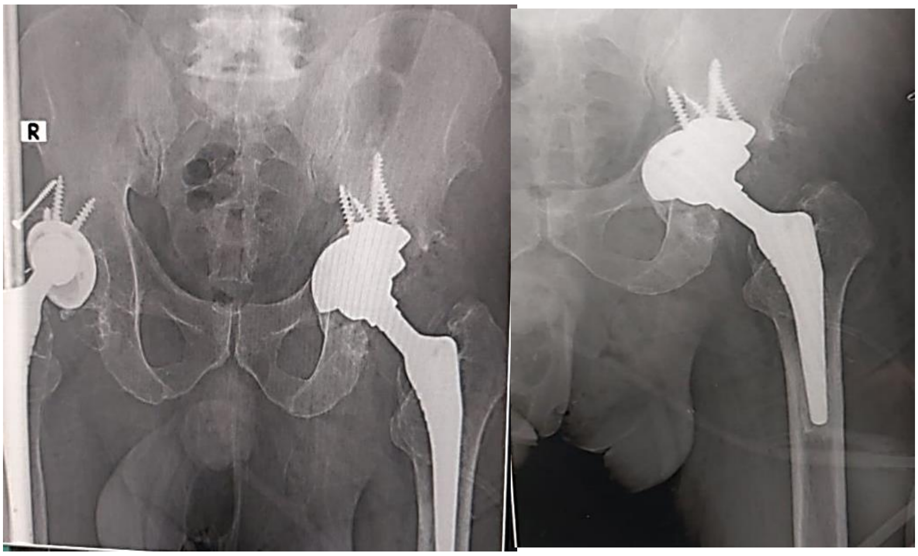

Figure 82: follow up x-ray after 6 weeks

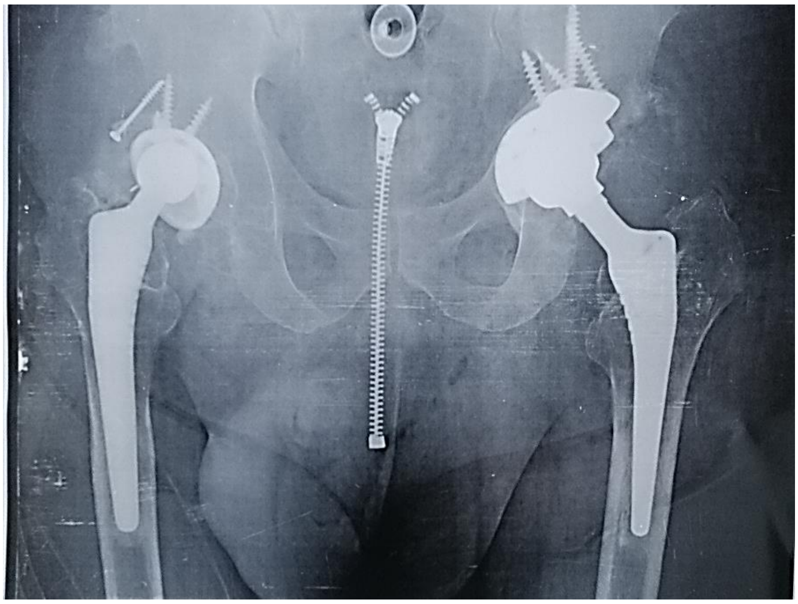

Figure 83: follow up x-ray after 3 months

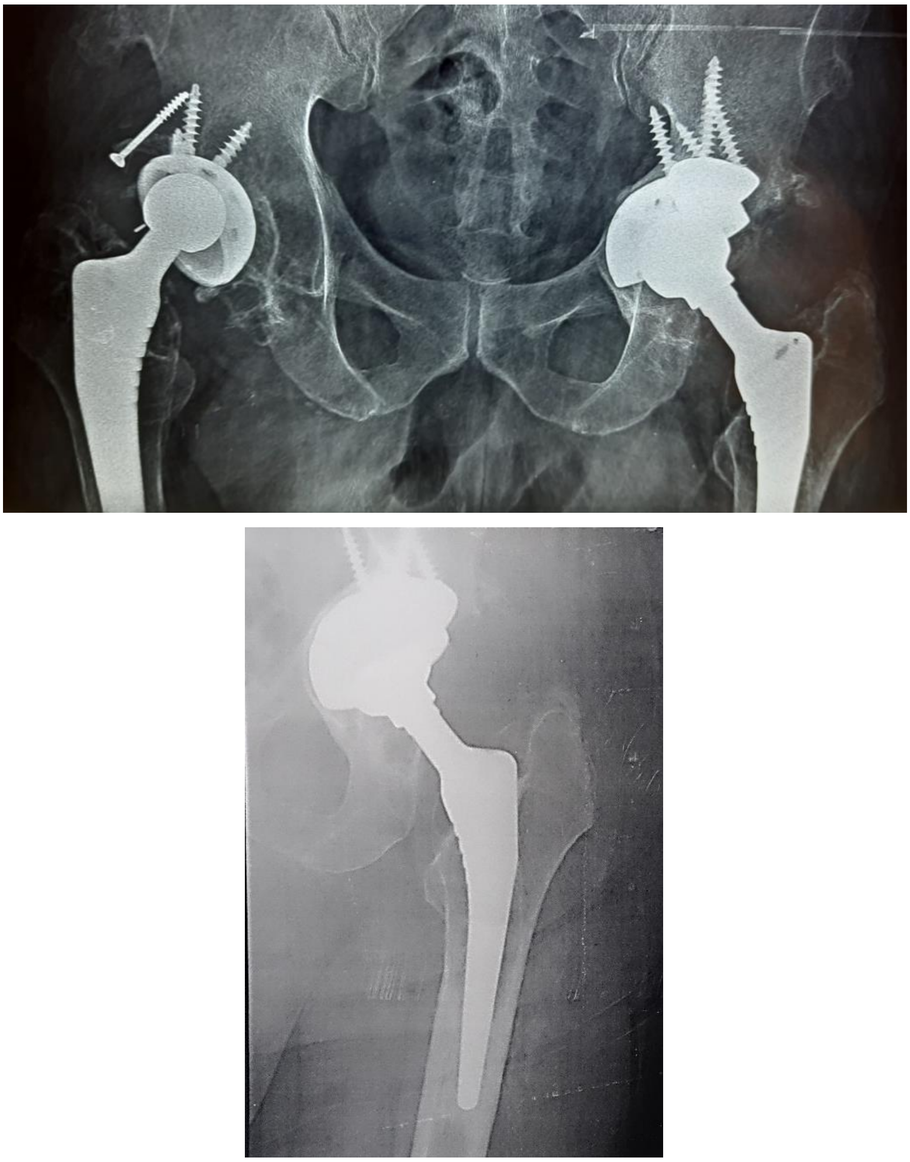

Figure 84: follow up x-ray after 6 months

Figure 85: clinical photos for the patient (A: standing without aids, B,C: hip flexion, D: straight leg raising, E,F: hip abduction).

At the final follow up patient has good range of motion and OHS is 41.

DISCUSSION

Over the past two decades, there have seen a rapid increase in hip joint replacement surgeries. With an increase in primary joint replacement surgeries, there has been a perceptible rise in the number of revision joint replacement surgeries throughout the world. Modern implant design and improved surgical techniques should result in improved long-term survival of adult joint reconstructions. However, an absolute increase in the number of these procedures and its use in younger, active population, coupled with increasing longevity, has maintained a significant revision burden [(83)].

The reconstruction of acetabular bone defects encountered during revision hip arthroplasty is a challenging task for the surgeon especially in large defects; Paprosky type II and III. A literature review confirms that a gold standard surgical technique for reconstruction of these defects is not agreed upon. Decision depends on type of the defect, available resources and surgeon preference.

Historically, cages and rings were the standard practice during acetabular reconstruction, however, these methods fell out of favor with evidence of high rate of complications and revisions contributed mainly for the fact that they are more difficult to implant and lack structural stability. Most of these implants have no potential for biologic bone ingrowth and thus eventually may lead to mechanical failure [(84)].

Trabecular metal augments (TMA) have gained a lot of momentum in the management of moderate to severe acetabular bone defects, with a wide spectrum of sizes and shapes allowing customized reconstruction of the bony defect. The high coefficient of friction of tantalum contributes to primary stability, while the high three-dimensional porosity allows bony ingrowth and secondary biologic fixation [70]. The use of trabecular metal augments has shown to be a valid method in reconstruction of moderate to severe acetabular bone defects and this study confirms that.

Other current utilized methods for acetabular reconstruction include impaction bone grafting and oversized components such as jumbo and bilobed cups.

The mean age of patients included in the current thesis is 62.5 years (range 48-70) which is close to Lochel et al. [2] study with mean age 64 (range 28-80), Grappiolo et al. [85] thesis which had mean age of 64 (range 40-85) and also like the mean age in Elganzoury and Bassiony [34] research which was 50 years (range: 45-62). The mean age of patients was older in Gross et al. [70] study, it was 69.3 (range 46-86) and also in the research carried out by Whitehouse et al. [86] which was 67 years.

The cause of revision for the patients included in this study was aseptic loosening in eighteen patients and two patient had two stages for infection. This was close to the indications for revision in Lochel et al. [2] thesis whom had aseptic loosening in 49 patients and 4 patients had two stages for infection. Gross et al. [70] study had also close reasons for revision with aseptic loosening in 29 hips, two patients had septic loosening and previous resection arthroplasty for infection in two cases. The patient included in Grappiolo et al. [85] and Elganzoury and Bassiony [34] studies all of them were due to aseptic loosening. While in the research done by Whitehouse et al. [86] there were 47 patients with aseptic loosening and 6 patients had two stages for infection.

Assessment of the short-term clinical outcomes for patients in this thesis showed marked improvement, the mean value of short form 12 health survey (SF-12) [87] have increased from 29.5 (range 18.6-37.9) preoperative to 50.5 (range 45.4-55) postoperative. Mean Oxford Hip Score (OHS) had improved from 12.85 (range 5-20) preoperatively to 38.9 (range 27-46) at the latest assessment. One of the two patients who had septic loosening showed a fair outcome with postoperative OHS is 27 and SF-12 results is 45. The second patient showed a good improvement in OHS with postoperative score is 35 and SF-12 score is 49.7. Stratification of OHS grading shows 11 cases (55%) were excellent at the last follow up. 8 cases had a good result, and one patient's outcome was fair.

The results of this study conform with other recent research, Gross et al. [70] published his clinical results of 34 patients showing that the OHS increased from a mean of 15.4 points (6 to 25) before revision to a mean of 37.7 (range 29 to 47) at the final follow up of 9 years. Grappiolo et al. [85] prospectively followed up 55 patient for about 7 years with Paprosky type III defects without pelvic discontinuity, average HHS increased from 40 (range 27–52) preoperatively to 90.5 (range 61–100) postoperatively. Lochel et al. [2] showed that HHS increased from a mean of 55 preoperatively to 81 points postoperatively after a mean of 10 years follow up of 62 hips.

The radiological assessment in this research showed improvement in restoration of the hip center of rotation (HCOR) in most cases, the vertical distance between HCOR and inter-teardrop line was improved from mean of 38 mm (range, 22-60) preoperative to mean of 22 mm (range 11-35) postoperatively and the horizontal distance was restored from mean of 35 mm (range, 15-60) from teardrop preoperative to mean of 30 mm (range 21-45) postoperatively (normal hip center is reported to be 12 to 14 mm above the interteardrop line and 33 to 43 mm lateral to the acetabular teardrop [34]).

The results of this cohort study are similar to the findings of Gross et al. [70] study in which the Pre-operatively center of rotation was located high (> 35 mm above the inter-teardrop line) by a mean of 48.5 mm (range, 25 to 98), while post-operatively, the mean distance of the HCOR to the inter-teardrop line was 24.8 mm (range, 11 to 38) in 27 hips. Grappiolo et al. [85] published similar results, the mean vertical position of HCOR from the inter-teardrop line changed from a mean of 42.3 mm (range 22–63 mm) preoperatively to 25.7 mm (range 17–44 mm) postoperatively and the mean horizontal position of HCOR from the teardrop changed from 37.8 mm (range 15–61 mm) preoperatively to 39.2 mm (range 24–53 mm) postoperative.

Whitehouse et al. [86] who used trabecular metal augments for reconstruction of acetabular defects in 53 patients and showed shat the HCOR is restored in the majority of the patients, Preoperatively the hip center was located at a mean of 48 mm above the interteardrop line (range, 29–77 mm) Postoperatively the mean hip center was 28 mm (range 16–48 mm) above the interteardrop line.

The systematic review carried out by Xiong C. et al. [88] including 647 patients (655 hips) used TMA showed that the vertical distance between HCOR and teardrop was restored from a preoperative distance of 42 mm (range, 22-96) to 22 mm (range 12-44) postoperatively and the horizontal distance was restored from a preoperative distance of 40 mm (range 15-86) to 35 mm (range 21-53) postoperatively).

The evaluation of radiological signs of osseointegration, Trabecular metal augments showed a good biological fixation as its porous surface configuration enabling rapid and extensive bone ingrowth of the host bone and the structural reliability of the metal augment imparted by its inherent resistance to fracture and failure [(85)]. Almost all patients in this study showed satisfactory results to biological fixation, according to Moore criteria [(82)], there was a minimum of three criteria of osseointegration in all patients, furthermore, there was five patients (25%) showing five signs and thirteen patients (65%) had four signs.

These results conform with the previous research investigating biological fixation of TMA, Gross et al. [(70)] showed that all 34 revisions total hip replacement had good signs of osseointegration except for only two failed cases, using the Moore criteria, two constructs showed five signs of osseointegration, 13 showed four signs, 13 showed three signs and two showed two signs. One of the two patients received two augments. The radiological analysis six weeks post-operatively revealed migration of the shell, and the hip was subsequently revised to an acetabular cup–cage construct. The second patient was an elderly woman with pelvic discontinuity treated with an 80 mm shell and a column-buttress augment. The migration of the construct was first detected six months post-operatively, but the patient elected to continue without further intervention.

Lochel et al. [(2)] studied the Trabecular metal augments in 62 hip with ten years follow up showed excellent results of osseointegration, according to classification of Moore et al. there were five signs of osseointegration in four hips (7.5%), four signs in 29 hips (54.7%), three signs in 15 hips (28.3%), and two signs in five hips (9.5%).

Whitehouse et al. [86] followed up 53 patients for up to 11 years and the results of osseointegration according to Moore criteria were satisfactory, there were five signs of osseointegration in two patients, four signs in 23 patients, three signs in 11 patients and two in one patient.

The patients included in this study showed a good correction in limb length discrepancy (LLD). The mean preoperative LLD was 4 cm (range 2-5) shorter on the affected side while the mean postoperative discrepancy is 0.3 cm (range 0.0-0.9).

The results of this thesis are close to the other researches, Grappiolo et al. [85] showed that the mean preoperative LLD was 16.6 mm of shortening (43 mm to 6 mm short) on the affected side, while the postoperative mean LLD was 1 mm of shortening (8 mm short to 6 mm long). Elganzoury and Bassiony [34] published similar results in their study after using trabecular metal augment in acetabular reconstruction, the average preoperative limb-length discrepancy was 4 cm ranging from 2 to 6 cm shorter on the involved side; it improved postoperatively to an average discrepancy of 0.5 cm (range: 0.0 cm to 1.0 cm).

Operative time is a key factor in revision THA, use of trabecular metal augments influenced the mean operative time due to its modularity and ease of application. In this study, mean operative time was 210 minutes and mean blood loss was 800 cc.

Several viable alternative options are available for acetabular reconstruction in revision THA. The use of a cemented polyethylene component with impaction allografting is a popular option. The major advantage is reconstruction and restoring bone stock, it is often the technique of choice in younger adults in whom multiple acetabular revisions are anticipated and showed good results in the restoration of hip center of rotation [43]. This technique required the availability of allografts/ bone bank facilities. Potential risks include graft resorption and implant migration. Use of structural allografts to support the shell in the weight-bearing zone, or when > 50% of the shell was supported by the allograft, showed poor survival of 55% at seven-year follow-up [2].

Lee et al. [89] described a large series of 64 hips with mean age of 54 years (range, 28–83 years) that underwent acetabular revision due to aseptic loosening utilizing column allografts for defects encompassing 30-50% of the acetabulum with cemented acetabular component. The minimum follow up was 5 years (mean, 16 years; range, 5.3–25 years), The mean Harris hip scores were 41 (range, 20–60) preoperatively, 73 (range, 40–95) at 1 year postoperatively and 73 (range, 26–93) at last follow up but they reported failure in almost one-third of the hips at 15 years' follow-up; twenty-three patients (27 cups) required rerevision at a mean time-to-rerevision of 6.9 years (range, 0.1–23). Fifteen patients had graft failures at a mean time to rerevision of 6.1 years (range, 0.5–23). The graft failure rate was 18%.

Püschel et al. [90] prospectively followed up 23 acetabular reconstructions for average 10.3 (1.2 to 19 years) using impaction bone graft with morselized allograft, showed excellent ingrowth in 91.3% but complete remodeling was not observed and with large defects were associated with fibrosis which may compromise stability. Similar results were published by Schreurs et al. [46] after follow up period of 20 to 25 years whom did a revision hip arthroplasty in 62 patients with the mean age of 59.2 years (23 to 82) due to aseptic loosening in 58 patients and septic loosening in the other four cases using cemented acetabular component, there was a good incorporation of the graft with the host bone but the aseptic loosening was the major problem after long term follow up.

van Haaren et al. [91] used impacted allograft combined with a metal mesh and cemented acetabular component in 71 revised hips (68 patients) with AAOS type III or IV bone defect. The mean age of the patients at operation was 69.1 years (32.8 to 91.4) and the reason for revision was aseptic loosening in 59 hips and septic loosening in 12. Twenty-five hips (24 patients) needed to be re-revised and were considered failures. In five hips the reason for the re-operation was infection and 20 patients were aseptic loosening, the overall survival was 72% after mean follow up of 7.2 years.

Sun et al. [49] published his results after doing revision hip arthroplasty using impaction bone graft with cementless acetabular component in 57 hips with mean follow-up time of 105.1 months (range 72–180 months), the causes for revision were aseptic loosening in 51 hips, septic loosening in three hips, and polyethylene liner displacement with severe periacetabular osteolysis in three hips. The mean age of patients at the index revision surgery was 46.4 years (range 24–75 years). periacetabular osteolysis was found in 14 hips (24.6%) at the final follow-up with absorption of the transplanted allografts.

Other Techniques which use an extra-large (Jumbo) acetabular components are commonly used to overcome large acetabular defects. The advantages of this technique, include the relative simplicity of the procedure, provision of maximal surface contact between the component and the host bone, reduction of the need for bone-grafting, and possible normalization of the hip center of rotation. The drawbacks of Jumbo components are that they may require reaming of the anterior column with insult to native bone because the anteroposterior dimension is reamed to accommodate the enlarged cephalad-caudal dimension, higher risk of aseptic loosening as no osseointegration and may cause impingement by the iliopsoas tendon [(92)].

Babis et al. [(93)] published that after using jumbo cups in 62 patients with mean age of 62.4 years (37 to 81), who underwent revision of the acetabular component of a total hip replacement due to aseptic loosening with mean follow-up of 60.5 months (36 to 94), there were high rate of aseptic loosening (30%).

The research carried out by Moon et al. [(94)] using press-fitted jumbo cups in 80 patients due to aseptic loosening of the acetabular component with average age of 57.7 (range; 30–78) and mean follow up of 10.4 years (5–16.1) showed that loosening of the acetabular component in 8.7% of patients and groin pain was found in 12%.

Similar results were published by Gustke et al. [(54)] who used jumbo cups in 196 hips due to aseptic loosening of the acetabular component in One hundred forty-eight, Twenty-one revisions were performed for septic loosening, 18 for recurrent dislocations, 4 for failed bipolar arthroplasties, 2 for persistent pain and 3 for excessive polyethylene wear patterns with a minimum follow up of two years and average age of 66 years. Aseptic loosening of the acetabular component was reported in 2.5% and dislocation occurred in 4.5% of the patients.

The systematic review carried out by Giannoudis et al. [(38)] showed that after using the acetabular reinforcement (Muller) ring in 502 hips, the reported overall complications were 29.1% (range, 6.3-58.3%) include Revision rates of 25%, dislocation rates of 11% and metalwork breakage in 5.5%.

In this cohort, the reported complications are, one patient (case 1) started to have a radiolucent line in zone 1, this line was stable and didn't extend in the next follow-up visit. It didn't affect the result of the patient which was excellent according to OHS grading.

Another patient had sciatic nerve affection in the form of neurotemesis and patient refused to do exploration. There were two patients with post-operative superficial infection for which debridement was done after two weeks for one of them and three weeks for the other patient with changing the polyethylene component, intraoperative samples were taken for culture which revealed staph. aureus and antibiotics were used for six weeks with no recurrence of infection

These complication rate is similar to the other studies. Systematic review carried out by Brown et al. (95) showed that the incidence of sciatic nerve injury after revision hip arthroplasty ranging from 0% to 7.6%. O'Neill et al. (96) published that in his thesis there were 2 deep infections. One occurred in the early postoperative period and was successfully managed with lavage and intravenous antibiotics. The other was a recurrence of deep sepsis and required a 2-stage revision and 1 transient sciatic nerve palsy. Gross et al. (70) study showed that three out of 34 patients failed because of aseptic loosening, two cases with deep infections whom underwent debridement with no recurrence.

Grappiolo et al. (85) reported aseptic loosening in three (5.4%) out of 55 patients, Radiolucent lines were noted in 3 (5.4%) out of the 55 hips. Of these, two patients showed a 1 mm line in zone 1 and 2 at 6 and 24 months from surgery respectively, whereas one had a 1 mm line crossing three acetabular zones at 12 months after surgery. In all patients, radiolucencies were not progressive at the latest follow-up.

Löchel et al. [2] study reported among 52 revisions hip replacement, there were failure in two patients due to aseptic loosening of the shell in the presence of a Paprosky IIIA defect. Further revision was required in one patient due to infection in the presence of PD.

Whitehouse et al. [86] published that among 53 patients underwent revision hip arthroplasty, there were aseptic loosening of three acetabular augments. another three patients underwent a reoperation without revision of the well-fixed augments or shells, including one application of a strut graft to the femur and two procedures for recurrent instability.

The research carried out by Elganzoury and Bassiony [34] reported that one patient had a sciatic nerve palsy which was partial and had resolved after two months. No evidence of cup loosening or change of cup orientation or abduction angle. No progressive radiolucent lines in any of the three acetabular zones were found at the cup bone and augment bone interface. There were no cases of hip dislocation.

This cohort study conforms with recent research showing that trabecular metal augments are safe and efficient method in reconstruction of acetabular bone defects with the reported complications are similar to short-term to medium-term outcomes reported in other series, good restoration of HCOR, biologic fixation. Other potential advantages are shorter operative time compared to impaction bone grafting.

The limitations of this study include absence of a control group, there is significant case heterogenicity which couldn’t be statistically normalized and a relatively small number of patients, as with many other series in the literature. Furthermore, with a mean of 16 months, the follow up is relatively short. While this short period of follow up is inadequate to exclude late complications and component loosening, it is adequate to assess augment stability and patient function.

SUMMARY

The number of hip arthroplasties done every year is rising, leading to more cases that need revision. One of the main issues in the revision surgery as well as complex primary total hip arthroplasty is acetabular reconstruction. It is mandatory to reconstruct acetabular defects to help the surgeon to reach the main target of this type of surgery, a stable well-positioned construct.

Several classification systems were hypothesized in order to accurately classify these defects and try to make a clear specification for each type of reconstruction techniques reported in the literature. The most common and well-known classification systems are those popularized by Paprosky et al and AAOS systems.

For long periods surgeons tried to reconstruct acetabular defects using biological methods in the form of bone grafts either bulk or morselized impaction grafts. The long-term complications of bulk grafts make the surgeons look for other techniques to avoid re-revisions caused by bone graft resorption.

The literature is full of reports of different types of cages and rings used to overcome the obstacles in revision surgeries. Lack of modularity of these systems and the technical challenge in their application as well as the reported complications of them limited their use to specific types of acetabular defects.

Continuous research went on for long time to find a material that suits the requirements needed for long term use. Tantalum has already proved its superior qualities compared to other materials regarding long-

term durability, osseointegration and its close resemblance to bone characteristics.

Studies reporting the results of using tantalum in the form of cementless shells preceded the use of porous augments for the reconstruction of defects. The early successful results of porous metal shells encouraged the surgeons to start using tantalum augments. Early to midterm follow up results of using tantalum augments were published showing high success rate and promising clinical and radiological results.

This study started in April 2019 to report the clinical and radiological outcome of using trabecular metal augments made of tantalum in hip arthroplasty for 20 hips that had an acetabular defect less than Paprosky grade 3B or pelvic discontinuity.

In this study, tantalum augments were used for twenty revision hips. Impaction bone grafting was used in five cases to reconstruct associated cavitary defects.

All cases had improved clinical scores postoperatively with only one fair result according to OHS grading. All the patients were satisfied with the overall procedure and postoperative pain relief. Full weight bearing started at 1.5 months. Late dislocation was not reported. two cases of reinfection were reported and no revisions were done.

Radiological assessment of these augments found them to be stable at early to mid-term follow up. No signs of cup migration were found. Only one sign of instability appeared in one case in the form of a non-progressive radiolucent line that didn't need revision.

CONCLUSION

The promising early results of using this technique for acetabular reconstruction convinced more surgeons to start using this system in revision surgeries. Given its modularity and the ability to reconstruct different types of defects with no fear of bone resorption, porous metal augments are considered a valuable method in the management of acetabular defect. Augments are stable at short term follow-up in this study, can be used in different types of defects, technically easy and there is no fear of resorption.

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الملخص العربي

المقدمة

مفصل الفخذ هو مفصل كروي حقيقي محاط بعضلات قوية ومتوازنة، مما يتيح نطاقًا واسعًا من الحركة في العديد من المستويات البدنية مع إظهار استقرار ملحوظ أيضًا. علي الرغم انه حلقة وصل بين الطرفين السفلين والهيكل العظمي المحوري، فان المفصل الفخذي لا ينقل القوى من الأرض إلى الأعلى فحسب، بل يحمل أيضًا قوى من الجذع والرأس والرقبة والأطراف العلوية. ان المفصل الفخذي يفي بالخصائص الأربع للمفصل الزلالي حيث انه له تجويف مشترك؛ أسطح المفاصل مغطاة بالغضروف المفصلي. لديها غشاء زلالي ينتج السائل الزلالي، وإنه محاط بكبسولة.

يتزايد عدد عمليات استبدال مفصل الفخذ (THA) التي يتم إجراؤها كل عام، كما لوحظ اتجاه مماثل لعمليات مراجعة مفصل الفخذ. يمكن أن تكون إعادة بناء عيوب الحُق في مراجعة تقويم مفصل الفخذ (THA) صعبة. إن تحقيق ملاءمة الضغط للزرع، وسد العيوب العظمية، واستعادة مركز دوران الفخذ هي أهداف جراحة المراجعة الناجحة. في المرضى الذين يعانون من عيوب بيضاوية صغيرة، يمكن تحقيق الاستقرار الكافي باستخدام درع مناسب بمفرده. يمكن استخدام مكونات ذات حجم كبير لتحقيق الاستقرار في أولئك الذين يعانون من عيوب بيضاوية أكبر.

تشمل الاستراتيجيات الأخرى استخدام مزيج من العظام مع الدروع الأسمنتية أو الحلقات أو الأقفاص، والدروع ذات المركز العالي للدوران، وتركيبات القفص. ومع ذلك، فإن عيوب استخدامها تشمل الفشل بسبب الكسر أو عدم الالتئام، في حالة الأقفاص وحلقات التعزيز، وتأكل الترقيع العظمي والفشل المتأخر في حالة الترقيع العظمي المستخدم مع تصميمات مكونات الحُق الأولية.

في هذه المواقف يتم استخدام دعامات واقفاص بجانب المفصل الاسمنتي للتجويف الحقي ولكن النتائج على المدي المتوسط والبعيد لم تكن مبشرة. استخدام مكونات حقيه ثلاثية الأطراف مخصصة تقدم خيارا اخر أفضل وذلك خاصة عندما يكون تأكل مزمن بالحوض. ومع ذلك، فإن هذا التركيب باهظ الثمن، ويتطلب ستة أسابيع تقريبًا للتصنيع، وعادةً لا يتطابق مع الخلل المحدد ما قبل الجراحة إذا كان هناك فقد عظمي أثناء إزالة المكون الوجود.

في حالة تأكل الشديد للتجويف الحقي فانه يمكن استخدام دعامة لإعادة بناء الحق من التانتلام. كما انه نشرت العديد من الدراسات المشجعة على المدى المتوسط باستخدام دعامة لإعادة بناء الحق من التانتلام بالتزامن مع مكون التانتلام الحقي المسامي لعلاج فقدان العظام الحاد.

الهدف من البحث

تهدف هذه الدراسة الي تقييم النتائج الوظيفية والاشعاعية لمرضي مرجعة المفصل الفخذي مع وجود تآكل شديد بالتجويف الحقي والذي يتطلب إعادة البناء باستخدام دعامة من التانتلام.

مرضى وطرق البحث

١. **تصميم الدراسة**

سيتم إجراء دراسة استطلاعية لعشرين مريضا يعانون من تأكل شديد بالتجويف الحقي في حالة مراجعة المفصل الفخذي والتي تتطلب استخدام دعامة لإعادة بناء الحق من التانتلام.

٢. **المرضى**

معايير الاشتمال:

- المريض الذي يعاني تأكل شديد بالتجويف الحقي في حالة مراجعة المفصل الفخذي والتي تتطلب استخدام دعامة لإعادة بناء الحق من التانتلام (Paprosky type II and III).

معايير الاستبعاد:

- المريض الذي يعاني من تأكل بسيط بالتجويف الحقي (Paprosky type I)
- المريض الذي يعاني من تاكل شديد بالحوض (pelvic discontinuity)
- المريض الذي يعاني من مشاكل بالجهاز العصبي الحركي
- التهابات بكتيرية بالمفصل الفخذي

٣. التقييم قبل الجراحة

التقييم السريري

سيتم اتخاذ التفاصيل من المريض بما في ذلك:

- التاريخ الشخصي بما في ذلك العمر والجنس والمهنة والعادات الخاصة ذات الأهمية الطبية ووظيفة ما قبل الإصابة.
- التاريخ الماضي والامراض المزمنة
- فحص حالة الدورة الدموية والعصبية في الطرف المصاب

سوف يتم استخدام مقياس اكسفورد لتقييم حالة مفصل الفخذ لنتمكن من تقييم نتائج ما بعد الجراحة.

التقييم الإشعاعي

سيتم فحص جميع المرضى إشعاعي من قبل:

- منظر أمامي خلفي على الحوض.
- اشعة مقطعية على الحوض (لتحديد طبيعة تأكل التجويف الحقي)

٤. التدخل الجراحي

- يعتمد الاسلوب الجراحي على المشكلة الأساسية، وجود أي شرائح سابقة أو تشوهات ورؤية الجراح لما يتناسب مع حالة المريض
- يتم إعطاء المريض مضاد حيوي وقائي قبل الجراحة
- و يتم اجراء التدخل الجراحي باستخدام المدخل الخلفي لمفصل الفخذ

٥. تقييم ما بعد الجراحة

- يعتمد توقيت التحميل الجزئي بعد الجراحة على متانة وسبات المفصل.
- يتم عمل تقوية لعضلات الفخذ مع تشجيع تحسين المجال الحركي للفخذ.
- سوف يتم استخدام الوسائل العلاجية المناسبة لمنع حدوث جلطات وريدية بالساقين

٦. برنامج المتابعة

- سيتم متابعة المرضي بالأشعة بعد العملية مباشرة ثم بأسبوعين ثم ستة أسابيع ثم عند ثلاثة اشهر ثم ستة اشهر ثم سنويا
- سوف يتم السماح بالتحميل الكلي وفقا لكل حالة على حدة
- سيتم تقييم النتائج الوظيفية باستخدام مقياس أكسفورد.

تقييم المضاعفات

سيتم تقييم المضاعفات أثناء العملية وفي وقت مبكر بعد العملية الجراحية والمضاعفات خلال فترة المتابعة وسيتم الإبلاغ.

٧. أساليب إحصائية

سيتم عرض البيانات التي تم جمعها على شكل جداول مناسبة ويوضح كأرقام مناسبة و تلخيص البيانات الكمية بالانحراف المعياري والبيانات النوعية كتردد ونسبة مئوية. وسيتم تحليل البيانات من خلال مساعدة من حزمة البرمجيات من SPSS باستخدام الاختبارات الإحصائية المناسبة.