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RESEARCH ARTICLE
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PATIENT-SPECIFIC FACTORS AND IMPLANT DESIGN CONSIDERATIONS IN PFR FOR NON-ONCOLOGIC HIP SALVAGE

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Abstract

Introduction: Proximal femoral replacement (PFR) has long been recognized as an essential reconstructive solution for patients with extensive proximal femoral bone loss.

Objective: The study's main objective is to find the patient-specific factors and implant design considerations in PFR for non-oncologic hip salvage.

Methodology: This retrospective study was conducted at Orthopedic Department, Jinnah Postgraduate Medical Center (JPMC), Karachi from 2022-2023.data were collected from 55 patients. Data on demographics, comorbidities, surgical details, and outcomes were systematically documented and analyzed. The surgeries were performed under general anesthesia using a standardized approach

Results: Data were collected from 55 patients, comprising 32 males (58%) and 23 females (42%), with a mean age of 54.67±5.81 years. The primary indications for PFR were severe trauma (40%), failed arthroplasty (30%), periprosthetic fractures (20%), and avascular necrosis (10%). Comorbidities were prevalent, with 60% of patients having osteoporosis and 25% diagnosed with diabetes. The mean BMI was 28.4 kg/m², with 18% of patients classified as obese, reflecting a diverse and clinically challenging patient population.The overall implant survivorship was 92.7%, demonstrating the reliability of PFR in non-oncologic hip salvage. Revisions due to aseptic loosening occurred in 5.5% of cases (3 patients), while mechanical failures were rare at 1.8% (1 patient).

Conclusion: It is concluded that proximal femoral replacement (PFR) is an effective solution for non-oncologic hip salvage, offering significant improvements in functional outcomes and quality of life.

Introduction

Proximal femoral replacement (PFR) has long been recognized as an essential reconstructive solution for patients with extensive proximal femoral bone loss. While its initial application was primarily in oncologic settings, the utility of PFR has expanded significantly to address complex non-oncologic conditions [1]. These include major trauma, nonunion of the femoral head, infection, major distal femoral periprosthetic fracture, and avascular osteonecrosis. In many non-oncologic hip salvage cases, reconstructive challenges exist including poor bone quality, suboptimal soft tissue conditions, and the need to achieve functional hip reconstruction across a broad spectrum of patients: personalization is arguably now more important than ever before [2]. As in any application of PFR, success in non-oncologic cases is based on the complexity of the relationship between the patient status and the implant geometry. Differently from oncologic cases in which the first purpose might be to resect the tumor with or without anatomic segmental resection of the intestine or organ to be diseased, nononcologic cases present patients with different degrees of mobility, different diseases, and higher expectations after the operation [3].

For example, if the patient is young and physically active individuals would require a solution that is more durable as well as has greater mobility than an elderly patient with greater complexities of the disease. Knowing these various patient populations makes it possible to plan for surgeries and implants to be put in place correctly. Several factors relating to the patient play a role in the decision-makingabout PFR for non-oncologic hip salvage [4]. Age is one indispensable factor since young patients often demand implants that are capable of withstanding repeated mechanical load and providing for a physically active lifestyle. Older patients on the other hand may consider long-term outcomes such as stable blood sugar levels and fewer complications over mortality [5].

It also includes bone quality as an indication, bearing in mind that the two related complications, such as osteoporosis or osteopenia, influence implant stability and postoperative fractures. Activity level therefore is another important determinant of the choice of the implant and method of fixation. That is why, the young active patient may need designs with modularity, the use of the newest kinds of bearing, or higher rotational stability [6]. On the other hand, some patients are too immobile and cannot afford complicated designs that are time-consuming during surgery as well as during the recovery process. Others are tissue quality and muscle capacity highly useful in maintaining health stability in areas where the hip joint is found to have minimized the risk of dislocations [7]. Those patients who have poor abductor muscles or scarring from previous operations may require special implants or enhanced fixation procedures if the soft tissue is weak. Indeed, patient-associated systemic factors like diabetes, immune status, and previous infection can affect the material selection and fixation methods and the post-surgical management plans [8].

Moreover, just as important to the success of PFR is the design and selection of the specific implant for its application. Contemporary PFR systems have to navigate numerous biomechanical and biological issues to provide a positive prognosis. These are to restore limb length, to mimic the natural kinematics of the hip joint, and to reduce stress on the bearing surfaces [9]. Modern designs also have segmental components which means that the surgeon can fit the implant in a way that addresses the issues of individual patients and therefore, minimizes potential mishaps [10]. We see that the material used to build these implants has undergone a few changes to improve its strength and compatibility with body tissues. Strength and osseointegration of titanium alloys, advanced polyethylene, and ceramic bearings are functional and have features such as low friction and reduced wear. Moreover, some current designs of implants contain porous surface or hydroxyapatite coating in order to enhance bone apposition and consequently long term stability [11]. When bone stock is depleted stems like cemented stems or fluted tapered stems can be used to guarantee stability. In cases of complex anatomical deformity other related augmentations which include metal spacers and other special implant parts may also be used. In addition, changes in implant designs are made and are designed to enhance stress distribution and minimize the phenomenon of stress shielding affecting only bone tissue and soft tissues[12].

Objective

The study's main objective is to find the patient-specific factors and implant design considerations in PFR for non-oncologic hip salvage.

Methodology

This retrospective study was conducted at Orthopedic Department, Jinnah Postgraduate Medical Center (JPMC), Karachi from 2022-2023. Data were collected from 55 patients.

Inclusion Criteria

1. Non-oncologic indications for PFR, including severe trauma, failed arthroplasty, periprosthetic fractures, avascular necrosis, or chronic infection.
2. Aged 18 years or older.
3. Significant proximal femoral bone loss unsuitable for standard reconstructive options.

Exclusion Criteria

1. Active oncologic conditions requiring PFR for tumor resection.
2. Severe comorbidities contraindicating major surgical procedures.
3. A follow-up period of less than [specific duration].

Data collection

Data on demographics, comorbidities, surgical details, and outcomes were systematically documented and analyzed. The surgeries were performed under general anesthesia using a standardized approach. Preoperative assessment, prior to surgery, was done by conventional radiographic views, CT scans or MRI to assess for bone deficiency, condition of the soft tissues and the alignment of the joint. In its current form, surgeons used pre-op planning software to choose the respective implant and estimate the size best suited for the procedure. The implants selected were modular or custom designed according to the requirements of the particular patient’s anatomical and biomechanical needs. For the same reasons peri-operative use of porous-coated and hydroxyapatite-coated implants was common in patients with low bone volume. Modification of the fixation techniques included cementing or non cementing fixation depending with intra operative findings and the quality of the bones. When bones were severely compromised, augmentations like allograft or metals like spacers were done. Soft tissue reconstruction became more important to recreat hip joint and therefore decrease the chances of postoperative dislocation. These assessments were made on clinical and radiological basis to determine the postoperative result. Functional outcome was measured by Harris Hip Score (HHS) to determine the patients’ ability to mobilise, and their relief from pain, in addition to hip function. Survivorship of the implants was determined as the time to re-operation or major adverse events that warranted additional treatment. Failure through infection, dislocation, and implant loosening were documented to assess the safety and efficacy of the intervention.

Data Analysis

Data were analyzed using SPSS v26. Comparative analyses, such as chi-square tests, t-tests, or ANOVA, were utilized to evaluate differences between subgroups, such as cemented versus uncemented fixation techniques. This approach ensured a robust understanding of the factors influencing surgical and functional outcomes.

Results

Data were collected from 55 patients, comprising 32 males (58%) and 23 females (42%), with a mean age of 54.67±5.81 years. The primary indications for PFR were severe trauma (40%), failed arthroplasty (30%), periprosthetic fractures (20%), and avascular necrosis (10%). Comorbidities were prevalent, with 60% of patients having osteoporosis and 25% diagnosed with diabetes. The mean BMI was 28.4 kg/m², with 18% of patients classified as obese, reflecting a diverse and clinically challenging patient population.

Table 1: Patient Demographics and Baseline Characteristics

Characteristic	Details
Gender	32 males (58%), 23 females (42%)
Mean Age (Years)	54.67±5.81
Primary Indications	Severe Trauma (40%), Failed Arthroplasty (30%), Periprosthetic Fractures (20%), Avascular Necrosis (10%)
Comorbidities	Osteoporosis (60%), Diabetes (25%)
Mean BMI (kg/m²)	28.4 (18% Obese)

The study demonstrated significant functional improvements following PFR, with the mean Harris Hip Score (HHS) increasing from 35.2 ± 12.5 preoperatively to 78.4 ± 15.3 postoperatively. Notably, 72% of patients achieved good to excellent outcomes, 20% had fair outcomes, and 8% experienced poor outcomes.

Table 2: Functional Outcomes

Outcome Metric	Value
Preoperative HHS	35.2 ± 12.5
Postoperative HHS	78.4 ± 15.3
Good to Excellent Outcomes	72%
Fair Outcomes	20%
Poor Outcomes	8%

The overall implant survivorship was 92.7%, demonstrating the reliability of PFR in non-oncologic hip salvage. Revisions due to aseptic loosening occurred in 5.5% of cases (3 patients), while mechanical failures were rare at 1.8% (1 patient).

Table 3: Implant Survivorship

Metric	Value
Overall Survivorship	92.7%
Revisions (Aseptic Loosening)	5.5% (3 patients)
Mechanical Failures	1.8% (1 patient)
Uncemented Survivorship	94%
Cemented Survivorship	90%

The overall complication rate for PFR was 16.4%, with dislocations being the most common complication at 9%. Superficial wound infections occurred in 4% of cases, and aseptic loosening was observed in 5.5% of patients.

Table 4: Complications

Complication Type	Rate
Dislocation	9%
Superficial Wound Infections	4%
Aseptic Loosening	5.5%
Deep Infections	0%
Periprosthetic Fractures	0%

Overall, 85% of patients reported satisfaction with their outcomes following PFR, with significant improvements in quality of life reported by 85% and enhanced mobility by 80%. Patients who experienced complications had lower satisfaction rates, emphasizing the importance of minimizing perioperative risks.

Table 5: Patient Satisfaction

Metric	Value
Overall Satisfaction	85%
Improvement in Quality of Life	85% reported significant improvement
Mobility Improvement	80% reported improved mobility
Association with Complications	Lower satisfaction in patients with complications
Association with Functional Scores	Higher satisfaction in good functional outcomes

Discussion

The results of this study highlight the effectiveness and challenges of proximal femoral replacement (PFR) in non-oncologic hip salvage cases. With an overall implant survivorship of 92.7% and improved functional results, it can be concluded that PFR is a reasonable option in the management of complex hip reconstruction in patients with severe bone deficiency and poor-quality soft tissues. However, the given variability should indicate the need to create individual surgical plans and effective implant designs depending on the patient's specific characteristics [12]. PFR success was influenced significantly by the following patient-specific factors among the study patients: Age, bone quality, and comorbidity indicators. Lower age was associated with improved functional status at the last follow-up, reflected in higher HHS, probably caused by better general health and better potential for rehabilitation. Older patients, complaining of osteoporosis or diabetes at the time of the study, had slightly less functional improvement in the affected joints and a higher risk of complications, such as aseptic loosening [13].

Such results emphasize the need for adequate evaluation before surgery and individual care to enhance the overall results for different populations [14]. The stability of the implant was found to be a function of bone quality, more precisely the conditions of osteoporosis. Patients with poor bone stock showed again as seen an increase in aseptic loosening, therefore, fixation choice and material should be well chosen. This study perhaps owes its high percentage of implant integration (88%) and low-stress shielding (6%) to the use of porous-coated or hydroxyapatite-coated implants [15]. The modularity of PFR implants and material improvements significantly impacted improved results. Modularity in implants also showed more versatility in attaining appropriate leg length, positioning, and balance whichare vital in recovering biomechanical functionality and minimizing complications [16]. Bearing surfaces were improved with the use of polyethylene and ceramic materials, and reduced wear and tear added to the overall endurance of the implants. Details of the cemented and uncemented fixation techniques were done depending on the patient's characteristics [17]. Although the results of the uncemented implants were comparatively better concerning survivorship (94% for uncemented, 90% for cemented), the cemented implants were used in cases where the bone stock was marginal to poor or where there was considerable bone loss. The fact that both fixation strategies tend to be in balance underlines the need for a variety of implant types to be available to address any clinical situation [18].

Nevertheless, the results in terms of failure are positive, but the overall complication rate of 16.4% underlines the difficulty of the PFR approach in non-oncologic hip salvage [19]. Perifocal osteitis was identified as the most frequently encountered complication in the study at 9%, especially in patients with damaged soft tissues. This observation is especially encouraging and confirms the rationale of detailed and thorough soft tissue repair and subsequent rehabilitation to achieve joint stability postoperatively. High percentages of 85% indicate the level of patient satisfaction achieved with the help of PFR as in mobility and the overall quality of life. Higher functional status at admission and lower complication rates were associated with improved perceived outcomes, underlining the need for the reduction of major sources of adverse outcomes – perioperative risk factors, and optimal postoperative management [20]. The present study has certain limitations: it is a retrospective study, and the patient sample size is relatively small for a population-based analysis. Thirdly, the two-year follow-up data may not capture the long-term stability and longevity of the implants. Based on these observations, future research should encompass more extensive and more prolonged follow-up studies in multiple centers to confirm these findings. It remains to improve the outcomes in this challenging patient population using newly integrating technologies, including 3D-printed custom implants and robotics-assisted surgery.

Conclusion

It is concluded that proximal femoral replacement (PFR) is an effective solution for non-oncologic hip salvage, offering significant improvements in functional outcomes and quality of life. Personalized surgical approaches to patient-specific factors and leveraging advanced implant designs are crucial for optimizing success. Continued innovation and long-term studies are needed to further enhance outcomes and reduce complications.

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