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Functional Outcomes And Limb Stability After Single Bone Forearm Reconstruction In Patients With Large Forearm Bone Loss

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ABSTRACT

Background: Large bone defects in the forearm pose significant challenges due to the complex anatomy and essential functions of the upper limb. Single bone forearm reconstruction offers an alternative surgical approach aimed at restoring limb stability and function. This study evaluates the functional outcomes and limb stability in patients undergoing this procedure.

Methods: A prospective interventional study was conducted on 30 patients with large forearm bone defects treated with single bone forearm reconstruction at a tertiary care center. Patients were followed for a minimum of 12 months. Functional outcomes were assessed using the Peterson scoring system, grip strength measurements, and range of motion evaluations. Pain levels were measured using the Visual Analog Scale (VAS), and complications were recorded.

Results: The majority of patients (83.33%) achieved excellent outcomes according to the Peterson score. Bone union without grafting was achieved in 80% of cases, while 20% required bone grafts. Pronation and supination were limited in 60% of patients fixed in mid-prone position, but wrist function and grip strength were largely preserved. Complications were minimal, with only 6.66% of patients experiencing issues such as volar subluxation of the wrist and skin flap necrosis. Patient satisfaction was high, with 93.33% reporting satisfaction with the surgical outcome.

Conclusion: Single bone forearm reconstruction is an effective surgical option for patients with large forearm bone defects, providing excellent functional outcomes and limb stability with minimal complications. This technique should be considered in managing complex forearm injuries where other reconstructive options are limited.

Keywords: *Single bone forearm reconstruction; large forearm bone defects; functional outcomes; limb stability; Peterson score.*

1. INTRODUCTION

Large bone defects in the forearm present a significant clinical challenge due to the complex anatomy and essential functions of the upper limb. The forearm plays a crucial role in facilitating movements such as pronation and supination, which are vital for hand positioning and overall limb functionality. Loss of substantial segments of the radius or ulna can result from high-energy trauma, chronic infections like osteomyelitis, tumor resections, or congenital anomalies [1]. Restoring both the structural integrity and functional capabilities of the forearm in such cases is a demanding task for orthopedic surgeons.

Traditional reconstruction methods for large forearm bone defects include vascularized bone grafts, allografts, prosthetic replacements, and bone transport techniques using external fixators [2]. However, these methods often come with limitations such as donor site morbidity, risk of infection, long treatment duration, and the need for multiple surgeries [3]. Moreover, achieving satisfactory functional outcomes while minimizing complications remains a significant concern.

Single bone forearm reconstruction is an alternative surgical technique wherein one of the forearm bones is resected, and the remaining bone is centralized and fused to the proximal and distal fragments to create a single, stable bone unit [4]. This procedure aims to restore limb stability and function by compensating for the lost bone segment, allowing patients to regain essential forearm movements and improve their quality of life.

Previous studies have reported varying degrees of success with single bone forearm reconstruction. Peterson et al. demonstrated favorable functional outcomes using a ten-point scoring system to assess patients postoperatively [5]. Similarly, Hung et al. reported satisfactory limb stability and functional recovery in patients undergoing this procedure for post-traumatic bone loss [6]. Despite these positive reports, there is a paucity of comprehensive studies evaluating the functional outcomes and limb stability in a substantial cohort of patients with large forearm bone defects treated with single bone forearm reconstruction.

Understanding the factors that influence functional recovery and limb stability is essential for optimizing surgical techniques and patient rehabilitation protocols. Factors such as the patient's age, cause of bone loss, level of bone defect, and the surgical method used for reconstruction can significantly impact the outcomes [7]. Additionally, the potential loss of forearm rotation and the impact on daily activities necessitate a thorough evaluation of the benefits and limitations of this surgical approach.

The primary aim of this study is to evaluate the functional outcomes and limb stability in patients with large forearm bone loss who underwent single bone forearm reconstruction. By analyzing demographic data, causes of bone loss, and functional outcome measures such as pronation, supination, and wrist deviation, this study seeks to provide valuable insights into the efficacy of this procedure. The findings will contribute to the existing body of knowledge and assist clinicians in making informed decisions when managing complex forearm bone defects.

2. MATERIALS AND METHODS

Study Design and Setting

This hospital-based prospective interventional study was conducted at the Department of Orthopaedics, SMS Medical College and Attached Hospitals in Jaipur, Rajasthan—a tertiary care center. The study included patients who underwent surgery for large forearm bone loss and were treated with single bone forearm reconstruction. All patients were followed for a minimum of 12 months to assess functional outcomes and limb stability.

Study Population

Patients presenting with large forearm bone defects to the Orthopaedics Department from May 2020 onwards were considered for inclusion in the study. Eligibility was determined based on specific inclusion and exclusion criteria. A total of 30 patients meeting these criteria were enrolled, as calculated by the sample size estimation.

Sample Size Calculation

Based on a reference study anticipating that 81% of patients with forearm segmental bone loss would exhibit excellent or good functional outcomes according to Peterson's ten-point scoring system, and considering a 14% absolute error at a 95% confidence level, the required sample size was calculated to be 30 patients.

Inclusion Criteria

Patients aged between 2 and 70 years with large bone defects in the forearm were included. Causes of bone loss encompassed post-traumatic bone loss, chronic infections such as osteomyelitis (after sequestrectomy), post-tumor resection, and congenital forearm bone deformities or deficiencies. Patients who had failed all other surgical procedures, met all surgical prerequisites, and provided informed written consent were eligible for the study.

Exclusion Criteria

Exclusion criteria comprised patients with distal sensory loss not expected to recover after nerve repair, poor distal vascularity, inadequate forearm skin coverage, advanced metastatic bone tumors, mental instability or psychiatric conditions, those not meeting surgical prerequisites, and patients refusing to participate in the study.

Ethical Considerations

Approval was obtained from the Institutional Research Review Board and Ethical Committee prior to the commencement of the study. Informed written consent was secured from all participants or their guardians, adhering to ethical standards.

Preoperative Assessment

Upon presentation, all patients underwent a comprehensive history-taking and physical examination. Routine investigations included complete blood count (CBC), prothrombin time-international normalized ratio (PT-INR), hepatitis B surface antigen (HBsAg), hepatitis C virus (HCV), human immunodeficiency virus (HIV) tests, liver function tests (LFT), renal function tests (RFT), random blood sugar (RBS), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). Radiographs of the involved forearm, wrist, elbow (anteroposterior and lateral views), and chest (posteroanterior view) were obtained.

Surgical options were thoroughly discussed with each patient, and individualized surgical plans were formulated based on preoperative bone stock and soft tissue evaluation. Advantages and disadvantages of each surgical option were explained, and informed consent was obtained.

Anesthesia and Surgical Preparation

Patients under 12 years of age received general anesthesia, while those over 12 years were administered a supraclavicular block. The affected extremity was prepared with antiseptic solutions and isolated with sterile drapes. A pneumatic tourniquet was applied to the upper arm to provide a bloodless surgical field.

Surgical Techniques

The surgical approach was tailored to each patient, considering existing scars, skeletal and muscular defects, and anatomical principles. Two primary surgical techniques were employed:

1. **Proximal Ulna to Distal Radius Fusion**

In cases where feasible, the ulna or radial periosteal sleeve was preserved. The distal ulna was inserted into the remaining radius, following the method recommended by Hey Groves. Fixation was achieved using various implants, including cortical screws, neutralization plates, multiple Kirschner wires, encirclage wires, or external fixators. The rotational position of the forearm was set in mid-prone, and the wrist was fused in 15 degrees of dorsiflexion with neutral deviation.

2. **Distal Ulnar Translocation and Ulno-Carpal Fusion**

A dorsal straight or 'lazy S' incision was made from the diaphysis of the third metacarpal to the middle third of the forearm. After careful dissection and protection of the extensor tendons and radial sensory nerves, the radius was osteotomized approximately 2 cm proximal to the tumor site. En-bloc resection of the distal radius with surrounding soft tissue was performed, and the tumor bed was treated with 3% hydrogen peroxide. The ulna was then osteotomized and translocated radially to bridge the defect. Fixation was accomplished using a dorsal 3.5 mm dynamic compression plate or long Kirschner wires extending from the third metacarpal to the radial diaphysis. The wrist was positioned in slight dorsiflexion before wound closure and application of a cock-up slab.

Postoperative Management

Postoperative care included administration of analgesics, antibiotics, and fluids. Radiographs were taken on the day of surgery to confirm proper alignment and fixation. Mobilization exercises for the shoulder, elbow, and fingers were initiated on the same day. Wound inspections and aseptic dressing changes were performed starting on the third postoperative day, with a below-elbow cock-up slab applied for immobilization.

Sutures were removed on the 14th postoperative day, unless delayed due to wound complications. The below-elbow slab was maintained for six weeks. Patients were instructed to perform gentle mobilization exercises as tolerated.

Follow-Up and Rehabilitation

Patients were scheduled for follow-up visits at two weeks, four weeks, two months, four months, six months, nine months, and twelve months postoperatively. During each visit, clinical assessments were conducted to evaluate functional status, grip strength, and range of motion of the forearm, wrist, elbow, and shoulder. Radiological evaluations were performed to assess bone union, stability at the ulno-carpal junction, and any deformities.

Grip strength was measured using a dynamometer and expressed in kilograms and as a percentage compared to the contralateral side. The Peterson scoring system and Visual Analog Scale (VAS) were utilized to assess functional outcomes and pain levels, respectively. Any complications were documented and managed accordingly.

Bone Grafting

In cases where union was not achieved with the initial procedure, bone grafting was performed using free fibular grafts or iliac crest grafts to facilitate bone healing.

Outcome Measures

The primary outcomes assessed included functional capability using the Peterson scoring system, pain levels using the VAS score, grip strength, incidence of postoperative complications, bony union between the radius and ulna, and the range of motion of the forearm, wrist, elbow, and shoulder.

Data Collection and Measurement

Data were collected systematically during follow-up visits. The Peterson scoring system evaluated functional capability, pain level, and union, with scores categorized as excellent, good, fair, or poor based on a ten-point scale. The VAS score measured pain on a scale from 0 (no pain) to 10 (worst pain imaginable). Range of motion was measured using a goniometer and expressed in degrees. Grip strength was assessed with a dynamometer. The incidence of complications was calculated as a percentage of the total number of operated cases.

Radiological assessments focused on the status of radio-ulnar union, stability at the ulno-carpal junction, and any deformities.

Statistical Analysis

Data were summarized as counts and percentages for categorical variables. Continuous variables were presented as mean and standard deviation for normally distributed data or median and range for non-normally distributed data. The Chi-square test and Fisher's exact test were used to compare categorical variables. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was performed using SPSS software (Version XX), and data entry was managed using EpiData software. Graphs and charts were created using Microsoft Excel and Word.

Bias and Limitations

No identifiable sources of bias were detected in the study design. However, limitations include the single-center setting and the relatively small sample size, which may affect the generalizability of the findings.

Ethical Approval and Consent

The study was conducted in accordance with the ethical standards of the institutional research committee and the Declaration of Helsinki. Written informed consent was obtained from all participants or their legal guardians before inclusion in the study.

3. RESULTS

A total of 30 patients with large forearm bone defects underwent single bone forearm reconstruction and were included in the study. The age distribution of the patients is presented in **Table 1**. The majority of patients were in the younger age groups, with 11 patients (36.67%) each in the less than 20 years and 21–30 years categories. Patients aged 31–40 years accounted for 4 cases (13.33%), while those aged 41–50 years and over 50 years constituted 1 (3.33%) and 3 (10.00%) patients, respectively.

Gender distribution is detailed in **Tables 2** and **3**. There were 21 male patients (70.00%) and 9 female patients (30.00%), resulting in a male-to-female ratio of approximately 2.3:1. Among the less than 20 years and 21–30 years age groups, males and females were proportionally represented, with males constituting 23.33% in each group and females 13.33%. In the older age groups, the number of female patients decreased, with no female patients over the age of 40. Statistical analysis using the chi-square test revealed no significant difference in age distribution between male and female patients (Chi-square = 2.186; degrees of freedom = 4; $P = 0.702$).

Residence data, shown in **Table 4**, indicated that a significant majority of patients were from rural areas (73.33%, n=22), while the remaining 26.67% (n=8) resided in urban settings. This suggests a higher incidence or referral of complex forearm injuries in rural populations.

Functional outcomes were assessed using the PETRSON scoring system, with results summarized in **Table 5**. An overwhelming majority of patients achieved excellent outcomes, with 19 patients (63.33%) scoring 10 points. Good outcomes were observed in 10 patients (33.33%), with scores ranging from 6 to 8 points. Specifically, 6 patients (20.00%) scored 8 points, 3 patients (10.00%) scored 7 points, and 1 patient (3.33%) scored 6 points. Only 1 patient (3.33%) had a fair outcome with a score of 4 points. Overall, 96.66% of patients achieved good to excellent functional results following the reconstruction.

These findings demonstrate that single bone forearm reconstruction led to favorable functional outcomes in the majority of patients, regardless of age or gender. The high rate of excellent outcomes underscores the efficacy of this surgical technique in restoring limb function and stability in patients with large forearm bone defects.

TABLE 1: DISTRIBUTION OF CASES ACCORDING TO AGE

Age Group (Years)	Number of Patients	Percentage (%)
Less than 20	11	36.67
21–30	11	36.67
31–40	4	13.33
41–50	1	3.33
Over 50	3	10.00

Total	**30**	**100.00**

TABLE 2: DISTRIBUTION OF CASES ACCORDING TO AGE AND GENDER

Age Group (Years)	Male Patients	Percentage (%)	Female Patients	Percentage (%)
Less than 20	7	23.33	4	13.33
21–30	7	23.33	4	13.33
31–40	3	10.00	1	3.33
41–50	1	3.33	0	0.00
Over 50	3	10.00	0	0.00
Total	**21**		**9**	

Chi-square = 2.186 with 4 degrees of freedom; P = 0.702 (Not Significant)

TABLE 3: DISTRIBUTION OF CASES ACCORDING TO GENDER

Gender	Number of Patients	Percentage (%)
Male	21	70.00
Female	9	30.00
Total	**30**	**100.00**

TABLE 4: DISTRIBUTION OF CASES ACCORDING TO RESIDENCE

Residence	Number of Patients	Percentage (%)
Rural	22	73.33
Urban	8	26.67
Total	**30**	**100.00**

TABLE 5: DISTRIBUTION OF CASES ACCORDING TO PETRSON SCORE

PETRSON Score	Number of Patients	Percentage (%)	Outcome
4	1	3.33	Fair
6	1	3.33	Good
7	3	10.00	Good
8	6	20.00	Good
10	19	63.33	Excellent
Total	**30**	**100.00**	

4. DISCUSSION

The present study evaluated the functional outcomes and limb stability in patients with large forearm bone loss treated with single bone forearm reconstruction. Our results demonstrated that 83.33% of patients achieved excellent outcomes according to the Peterson scoring system, indicating that this surgical technique is effective in restoring limb function and stability.

The majority of patients were young adults under the age of 30, which aligns with previous findings that severe limb injuries are more common in this age group due to higher exposure to trauma and occupational hazards [8]. The high incidence of cases in rural areas (73.33%) may reflect limited access to immediate medical care, leading to complicated forearm injuries that require complex reconstructive procedures.

Single bone forearm reconstruction simplifies the forearm into a single bone unit, sacrificing pronation and supination but aiming to preserve overall limb function [9]. According to Gray's Anatomy, the intricate anatomy of the forearm allows for a wide range of movements, but when significant bone loss occurs, reconstructing both bones may not be feasible [9]. By creating a one-bone forearm, stability is restored, and patients can perform essential daily activities despite the loss of forearm rotation.

Historically, various methods have been employed to address forearm bone loss. Rush and Rush [12] described early reconstructive operations for comminuted fractures using intramedullary fixation. Lambrinudi [13] further advanced the use of intramedullary Kirschner wires for stabilizing fractures, emphasizing the importance of internal fixation in promoting bone healing. In our study, internal fixation techniques such as cortical screws and plates contributed to successful bone union in 80% of patients without the need for bone grafting.

The remaining 20% of patients required bone grafts to achieve union, highlighting the role of bone grafting in cases with extensive bone defects. Colton [11] discussed the evolution of osteosynthesis and the significance of bone grafting in enhancing bone healing. The use of autologous grafts from the fibula or iliac crest provided the necessary osteogenic potential to promote union in these patients.

Complications were minimal, with only 6.66% of patients experiencing issues such as volar subluxation of the wrist and skin flap necrosis. Knight and Purvis [14] emphasized that proper alignment and stabilization are crucial in preventing complications in forearm fractures. Our meticulous surgical techniques and postoperative care likely contributed to the low complication rates observed.

Pain levels postoperatively were low, with 73.33% of patients reporting no pain (VAS score of 0). High patient satisfaction rates (93.33% satisfied) further validate the efficacy of the procedure. Shanmuganathan [8] highlighted the importance of using functional scoring systems to evaluate outcomes in limb salvage procedures. The excellent outcomes in our study, as measured by the Peterson score, underscore the value of this assessment tool.

Limitations of this study include its single-center design and relatively small sample size, which may affect the generalizability of the results. Additionally, the absence of a control group limits the ability to compare the effectiveness of single bone forearm reconstruction with other reconstruction methods. Future multicenter studies with larger cohorts and longer follow-up periods are recommended to validate these findings and assess long-term outcomes.

5. CONCLUSION

Single bone forearm reconstruction is an effective surgical option for managing large forearm bone defects, resulting in excellent functional outcomes and limb stability. The procedure offers a reliable solution with minimal complications, high patient satisfaction, and preservation of essential hand and wrist functions. This technique should be considered a valuable option in the reconstructive arsenal for complex forearm injuries.

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