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ORIGINAL ARTICLE

Impact of Type 2 Diabetes Mellitus on Bone Healing in Patients with Long Bone Fractures: A Cross- Sectional Clinical Study

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ABSTRACT

Background: Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder that adversely affects bone metabolism and fracture repair. Impaired angiogenesis, accumulation of advanced glycation end products, and compromised immune function contribute to delayed healing and higher complication rates in diabetic patients.

Objective: To evaluate the impact of T2DM on bone healing in patients with long bone fractures and to compare healing outcomes with non-diabetic patients.

Methods: This cross-sectional clinical study was conducted at the Department of Orthopedic Surgery, University of Lahore Teaching Hospital, Lahore, Pakistan, between June 2022 and February 2023. A total of 90 patients with acute long bone fractures were included, comprising 45 diabetic and 45 non-diabetic patients. Demographic data, fracture characteristics, glycemic control (HbA1c), and treatment modalities were recorded. Healing outcomes were assessed clinically and radiologically at 6, 12, and 16 weeks. Delayed union, nonunion, and postoperative infection rates were documented. Data were analyzed using SPSS version 26, with independent t-tests and chi-square tests applied. A p-value < 0.05 was considered significant.

Results: The mean healing time was significantly prolonged in diabetics (16.4 ± 2.6 weeks) compared to non-diabetics (12.7 ± 2.1 weeks, $p < 0.001$). Delayed union occurred in 33.3% of diabetics versus 8.9% of non-diabetics ($p = 0.004$). Nonunion was observed in 11.1% of diabetics compared to 2.2% of controls. Postoperative infections were also higher in diabetics (17.8%) than non-diabetics (4.4%, $p = 0.046$).

Conclusion: T2DM significantly delays bone healing and increases the risk of delayed union, nonunion, and postoperative infections in patients with long bone fractures. Strict glycemic control and comprehensive perioperative management are essential to optimize healing outcomes in diabetic patients.

Keywords: Type 2 Diabetes Mellitus, Bone Healing, Long Bone Fractures, Delayed Union, Nonunion

INTRODUCTION

Bone healing is a dynamic and highly regulated process involving inflammation, repair, and remodeling phases[1]. Following a fracture, a cascade of cellular and molecular events occurs, including hematoma formation, recruitment of inflammatory cells, angiogenesis, osteoblast activation, and eventual remodeling of bone to restore structural integrity. Several local and systemic factors influence this process, and among them, Type 2 Diabetes Mellitus (T2DM) has emerged as a major condition associated with impaired bone healing[2].

T2DM is a chronic metabolic disorder characterized by insulin resistance, relative insulin deficiency, and persistent hyperglycemia. According to the International Diabetes Federation (IDF), the global prevalence of diabetes is rising rapidly, with Pakistan ranked among the top ten countries with the highest number of cases[3]. Recent estimates suggest that more than 33 million adults in Pakistan are living with diabetes, and the burden is expected to increase substantially in the coming decades. This rise is attributed to urbanization, sedentary lifestyles, obesity, and genetic susceptibility[4].

The negative effects of diabetes on bone biology are multifactorial. Chronic hyperglycemia leads to the accumulation of advanced glycation end products (AGEs), which alter collagen cross-linking and impair bone matrix quality[5]. Microangiopathy reduces blood supply to fracture sites, hindering oxygen and nutrient delivery essential for bone regeneration. Additionally, hyperglycemia and oxidative stress impair osteoblast proliferation, enhance osteoclast activity, and delay callus formation. Diabetic patients also exhibit altered immune function, which increases susceptibility to postoperative infections that further compromise healing[6].

Fractures of long bones such as the femur, tibia, and humerus are common injuries requiring timely union for restoration of mobility and function. In patients with T2DM, however, delayed union, nonunion, malunion, and postoperative complications are reported more frequently compared to non-diabetic individuals[7]. This not only prolongs hospital stays but also increases the financial and psychological burden on patients and their families. Furthermore, inadequate fracture healing in diabetics can lead to prolonged immobilization, disability, and reduced quality of life[8].

Although several studies from developed countries have documented the adverse impact of T2DM on fracture healing, there is limited clinical data from Pakistan where the prevalence of diabetes is exceptionally high and healthcare resources are often constrained. Understanding the relationship between T2DM and bone healing is critical for developing targeted strategies to improve patient outcomes[9].

The present study was designed to evaluate the impact of T2DM on bone healing in patients with long bone fractures treated at tertiary care hospitals in Pakistan. By comparing clinical and radiological healing outcomes between diabetic and non-diabetic patients, this study aims to provide evidence relevant to local clinical practice and highlight the importance of optimal glycemic control in orthopedic management[10].

MATERIALS AND METHODS

Study Design and Setting: This research was designed as a hospital-based cross-sectional clinical study. It was carried out in the Department of Orthopedic Surgery, University of Lahore Teaching Hospital, Lahore, Pakistan, over a defined study period from June 2022 to February 2023. The study site is a tertiary care center that receives a high patient turnover, thus providing an appropriate setting for evaluating fracture healing patterns among both diabetic and non-diabetic populations.

Sample Size: A total of 90 patients with acute long bone fractures were recruited during the study duration. The participants were divided into two equal groups, with forty-five patients having a confirmed diagnosis of Type 2 Diabetes Mellitus and forty-five non-diabetic patients serving as controls. The sample size was determined based on feasibility and the expected number of cases presenting to the orthopedic department within the study duration.

Inclusion Criteria: Patients of either gender aged between 18 and 65 years presenting with acute fractures of the long bones, including the femur, tibia, and humerus, were considered eligible

for inclusion. For the diabetic group, only patients with previously diagnosed Type 2 Diabetes Mellitus and a documented HbA1c level of ≥ 6.5% were included. All participants were required to provide informed written consent prior to enrollment.

Exclusion Criteria: Patients with Type 1 Diabetes Mellitus, those with pathological fractures caused by primary or secondary bone tumors, or metabolic bone diseases other than diabetes were excluded. Similarly, patients with comorbid conditions such as chronic kidney disease, advanced liver disease, or those on long-term corticosteroid or immunosuppressive therapy were not considered. Polytrauma patients with multiple systemic injuries were also excluded to avoid confounding effects on bone healing.

Data Collection Procedure: After obtaining consent, demographic information including age, gender, and body mass index was recorded for each patient. In diabetic patients, additional details such as duration of diabetes, current glycemic control, and HbA1c levels were documented. The type of fracture and mechanism of injury were noted in all patients. Depending on the clinical indication and fracture pattern, patients were managed either conservatively with immobilization or surgically through internal fixation.

Assessment of Bone Healing: Bone healing was evaluated during follow-up visits at the 6th, 12th, and 16th week after fracture management. Healing was assessed using both clinical and radiological parameters. Clinical union was defined as the absence of pain or tenderness at the fracture site, restoration of limb function, and the ability to bear weight in lower limb fractures or resume functional activity in upper limb fractures. Radiological union was determined on plain radiographs as the presence of bridging callus across at least three out of four cortices, cortical continuity, and the disappearance of the fracture line. Cases where fracture healing was not evident by 16 weeks were categorized as delayed union, while those showing no signs of progressive healing by six months were considered nonunion. Incidence of postoperative wound infections was also recorded in both groups.

Ethical Considerations: The study was conducted after receiving approval from the Institutional Review Board of the University of Lahore Teaching Hospital. All patients provided written informed consent prior to their participation. Confidentiality and anonymity of patient data were maintained throughout the research process.

Statistical Analysis: All collected data were entered into SPSS version 26.0 for statistical analysis. Quantitative variables such as age and time to fracture union were expressed as mean ± standard deviation. Qualitative variables such as gender, delayed union, nonunion, and infection rates were presented as frequencies and percentages. The independent t-test was used to compare means between the diabetic and non-diabetic groups, while the chi-square test was applied for categorical variables. A p-value less than 0.05 was considered statistically significant for all analyses.

RESULTS

A total of 90 patients with long bone fractures were included in the study, divided equally into 45 patients with Type 2 Diabetes Mellitus and 45 non-diabetic patients serving as controls. Both groups were comparable in terms of baseline demographic characteristics. The mean age of participants was 46.8 ± 11.9 years, with the diabetic group having a slightly higher mean age (47.9 ± 12.4 years) compared to the non-diabetic group (45.7 ± 11.3 years). This difference, however, was not statistically significant (p = 0.412). The gender distribution also showed male predominance in both groups, with a male-to-female ratio of 1.6:1. In diabetic patients, 27 were males and 18 females, while in the non-diabetic group, 29 were males and 16 females. No significant gender-related difference was observed (p = 0.654).

The pattern of long bone fractures was also analyzed, and the femur emerged as the most frequently involved bone, accounting for 38 cases (42.2%) across the entire study population. The tibia was the second most commonly fractured bone, with 33 cases (36.7%), while humeral shaft fractures were noted in 19 cases (21.1%). The distribution of fracture sites was almost uniform between diabetic and non-diabetic patients, indicating that the site of fracture did not differ significantly between groups. Among diabetic patients, the mean HbA1c was 8.2 ± 1.5%, reflecting poor glycemic control in a large proportion of cases.

When fracture healing was compared, significant differences were observed between groups. The mean time to radiological union in the diabetic group was 16.4 ± 2.6 weeks, whereas non-diabetic patients achieved union earlier at 12.7 ± 2.1 weeks. This difference of nearly four weeks was statistically significant ($p < 0.001$) and highlights the adverse effect of diabetes on bone metabolism and repair (Table 1).

In terms of complications, the incidence of delayed union was considerably higher among diabetic patients. A total of 15 patients (33.3%) in the diabetic group developed delayed union compared to only 4 patients (8.9%) in the non-diabetic group. The difference was statistically significant ($p = 0.004$). Similarly, nonunion was more frequently observed in diabetics, affecting 5 patients (11.1%), while only 1 patient (2.2%) in the non-diabetic group exhibited nonunion. Although the difference in nonunion rates did not reach strong statistical significance ($p = 0.089$), the clinical relevance of this finding is considerable, as nonunion carries long-term implications for functional outcomes (Table 1).

The incidence of postoperative wound infections was also significantly higher in diabetic patients. A total of 8 patients (17.8%) from the diabetic group developed infections following surgical fixation, whereas only 2 patients (4.4%) from the non-diabetic group experienced infections. This difference was statistically significant ($p = 0.046$), highlighting the increased vulnerability of diabetic patients to surgical site infections due to impaired immune function and poor vascularity. Clinically, these infections further contributed to delays in fracture healing (Table 1).

Table 1: Comparison of Healing Outcomes Between Diabetic and Non-Diabetic Patients

Parameter	Diabetics (n = 45)	Non-Diabetics (n = 45)	p-value
Mean Age (years)	47.9 ± 12.4	45.7 ± 11.3	0.412
Male : Female Ratio	27 : 18	29 : 16	0.654
Mean HbA1c (%)	8.2 ± 1.5	–	–
Mean Healing Time (weeks)	16.4 ± 2.6	12.7 ± 2.1	<0.001
Delayed Union	15 (33.3%)	4 (8.9%)	0.004
Nonunion	5 (11.1%)	1 (2.2%)	0.089
Postoperative Infections	8 (17.8%)	2 (4.4%)	0.046

Table 1 demonstrates that patients with Type 2 Diabetes Mellitus had significantly longer healing times, higher rates of delayed union, nonunion, and infections compared to non-diabetic patients.

To further analyze outcomes, healing patterns were stratified according to the site of fracture. Femoral fractures showed the greatest delay in diabetics, with a mean healing time of 17.2 ± 2.8 weeks, compared to 13.1 ± 2.0 weeks in non-diabetics. Similarly, tibial fractures in diabetics healed in 16.1 ± 2.4 weeks versus 12.4 ± 2.1 weeks in controls. Humerus fractures also followed this trend, with diabetics requiring 15.3 ± 2.2 weeks compared to 12.1 ± 1.8 weeks in non-diabetics ($p < 0.05$ for all comparisons). This pattern indicates that the negative impact of diabetes on healing was consistent across different long bones (Table 2).

Table 2: Mean Healing Time (Weeks) According to Fracture Site

Fracture Site	Diabetics (n=45)	Non-Diabetics (n=45)	p-value
Femur	17.2 ± 2.8	13.1 ± 2.0	<0.001
Tibia	16.1 ± 2.4	12.4 ± 2.1	<0.001
Humerus	15.3 ± 2.2	12.1 ± 1.8	0.003

Table 2 shows fracture site-specific healing times, with diabetics consistently taking longer to achieve radiological union compared to non-diabetics.

The results of this study clearly establish that Type 2 Diabetes Mellitus has a significant negative impact on bone healing in long bone fractures. As seen in Table 1, diabetic patients not only had prolonged healing times but also faced more frequent complications in the form of delayed union, nonunion, and infections. Moreover, as demonstrated in Table 2, the delay in bone healing was evident across all major long bones, with femur and tibia fractures showing particularly prolonged healing durations. These findings indicate that the impaired healing observed in diabetes is systemic in nature and not limited to any particular bone.

DISCUSSION

The present study demonstrates that Type 2 Diabetes Mellitus (T2DM) significantly impairs bone healing in patients with long bone fractures[11]. Diabetic patients in this study exhibited longer times to radiological union, as well as higher rates of delayed union, nonunion, and postoperative infections compared to non-diabetic controls. These findings highlight the multifactorial negative influence of diabetes on musculoskeletal recovery and have important implications for clinical practice in orthopedic surgery[12].

One of the most important observations of this study was the significantly prolonged healing time in diabetic patients, averaging 16.4 weeks compared to 12.7 weeks in non-diabetic patients. This delay of nearly one month is clinically meaningful, as it prolongs immobilization, increases dependency, and raises the risk of secondary complications such as joint stiffness and muscle wasting[13,14]. Similar results have been reported in international studies, where diabetes was consistently associated with impaired fracture healing and extended time to union. Hyperglycemia is believed to disrupt the normal cascade of bone repair by interfering with collagen cross-linking, reducing osteoblast differentiation, and promoting accumulation of advanced glycation end products (AGEs), which impair the biomechanical properties of the healing callus[15,16].

The higher rate of delayed union and nonunion among diabetics observed in this study also correlates with existing literature. In our series, delayed union occurred in 33.3% of diabetic patients compared to only 8.9% in non-diabetics, while nonunion was observed in 11.1% versus 2.2%, respectively[17]. Although nonunion did not reach strong statistical significance, the trend is clinically important and consistent with previous findings that diabetics have a two- to three-fold increased risk of poor healing outcomes. The mechanisms underlying this phenomenon involve microangiopathy, impaired angiogenesis, chronic low-grade inflammation, and altered osteo-immune interactions. Collectively, these changes hinder the recruitment and function of osteoprogenitor cells at the fracture site, leading to compromised regeneration[18,19].

Postoperative infections were also significantly more frequent in diabetic patients, occurring in 17.8% compared to 4.4% among controls. This reinforces the well-established association between diabetes and increased susceptibility to infections, which is primarily due to impaired neutrophil chemotaxis, reduced phagocytic activity, and compromised microvascular circulation[20]. Infection not only prolongs healing but can also lead to implant failure, chronic osteomyelitis, or the need for revision surgery. Hence, infection prevention and perioperative glycemic control are critical for optimizing surgical outcomes in this high-risk group[21].

Our findings are further supported by the site-specific analysis of fracture healing. Regardless of whether the fracture involved the femur, tibia, or humerus, diabetic patients consistently demonstrated longer healing durations. The consistency of this pattern indicates that the effect of diabetes is systemic rather than bone-specific. These observations align with large-scale studies that have reported impaired fracture healing across both axial and appendicular skeletal sites in diabetic populations[22].

The clinical implications of this study are significant. Orthopedic surgeons managing diabetic patients should anticipate delayed healing and increased risk of complications. Multidisciplinary management involving endocrinologists, dieticians, and physiotherapists is essential to optimize outcomes[23]. Strategies such as strict glycemic control, nutritional supplementation, smoking cessation, and use of bone growth stimulators may enhance healing. Furthermore, meticulous perioperative wound care and infection control measures are particularly important in diabetic patients undergoing surgical fixation of fractures[24].

This study has some limitations. The cross-sectional design precludes assessment of long-term outcomes such as functional recovery and quality of life. The sample size, although adequate for statistical analysis, remains relatively small and was limited to a single center. Additionally, variability in glycemic control among diabetic patients may have influenced healing outcomes, but subgroup analysis was not performed. Despite these limitations, the study adds valuable local data to the existing evidence base and underscores the urgent need for targeted strategies to improve fracture healing in diabetic patients in Pakistan[25].

CONCLUSION

This study concludes that Type 2 Diabetes Mellitus has a significant adverse effect on bone healing in long bone fractures. Diabetic patients demonstrated delayed radiological union, prolonged healing times, and higher rates of delayed union, non-union, and postoperative infections compared to non-diabetic patients. These findings reinforce the importance of strict glycemic control and comprehensive perioperative management to improve fracture outcomes in this high-risk group. Early identification of delayed healing, aggressive infection prevention strategies, and multidisciplinary care are crucial to optimize recovery and reduce disability among diabetic fracture patients.

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Authors' Contributions:

KMF: Study conception, patient recruitment, surgical management, drafting of manuscript.
RS: Research design, data analysis, critical revision of manuscript.
SAS and AA: Data collection, clinical follow-up, preparation of results section.

All authors approved the final manuscript and are accountable for its content.

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