

ORIGINAL ARTICLE

Accuracy and Functional Outcomes of Ilizarov-Based Gradual Correction of Genu Varum: A Prospective Study

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ABSTRACT

Background: Genu varum is a common lower limb deformity in Bangladesh, often causing pain and functional limitation. While Ilizarov-based gradual correction is increasingly utilized, data on its accuracy and functional outcomes in the local population remain sparse. **Objective:** To evaluate the accuracy of correction and functional outcomes following Ilizarov-based gradual correction of genu varum. **Methods & Materials:** This prospective observational study was conducted at National Institute of Traumatology & Orthopedic Rehabilitation (NITOR), Dhaka, from January 2021 to July 2025. A total of 30 patients with genu varum underwent Ilizarov-based gradual correction. Preoperative and postoperative mechanical axis deviation (MAD), tibiofemoral angle, and functional scores were recorded. Data were analyzed using SPSS version 23.0. **Results:** The mean preoperative MAD was 45.2 ± 12.4 mm, which corrected to 4.8 ± 3.2 mm postoperatively ($p < 0.001$). The mean tibiofemoral angle improved from $14.6^\circ \pm 4.2^\circ$ varus to $2.8^\circ \pm 1.6^\circ$ valgus. Excellent functional outcomes were achieved in 76.7% of patients. Pin site infection occurred in 23.3%, and delayed union in 6.7%. **Conclusion:** Ilizarov-based gradual correction provides accurate deformity correction and favorable functional outcomes in patients with genu varum, with acceptable complication rates. This technique is a reliable option for managing this deformity in resource-limited settings.

Keywords: Deformity correction, Ilizarov external fixator, Functional outcome, Genu varum, Mechanical axis deviation

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INTRODUCTION

Genu varum, commonly referred to as bowleg deformity, is a lower limb malalignment characterized by lateral deviation of the mechanical axis of the lower extremity, resulting in abnormal loading of the medial compartment of the knee joint [1]. This condition may arise from a variety of etiologies, including idiopathic causes, Blount's disease, rickets, skeletal dysplasias, achondroplasia, and post-traumatic or post-infectious sequelae [2]. Regardless of the underlying cause, uncorrected genu varum leads to progressive medial compartment overload, which accelerates articular cartilage wear and predisposes patients to premature knee osteoarthritis, pain, and functional disability [3]. The consequences of genu varum extend beyond joint degeneration. Patients often experience gait abnormalities, altered joint kinematics, muscle weakness, and diminished quality of life. The abnormal mechanical axis shifts the weight-bearing line medially, increasing stress on the medial tibial

plateau and the medial collateral ligament complex [4]. Over time, this biomechanical disturbance may lead to progressive instability, worsening deformity, and eventual knee joint failure. Consequently, surgical correction of the deformity is frequently recommended to restore normal alignment, redistribute joint forces, and prevent or delay the onset of osteoarthritis [5]. A variety of surgical techniques have been described for the correction of genu varum, including acute correction with internal fixation, hemiepiphyseodesis in skeletally immature patients, and high tibial osteotomy with plate or wedge fixation [6]. However, in cases of severe deformity (greater than 20 degrees), significant angular or rotational malalignment, or when limb length discrepancy coexists, gradual correction using external fixation has emerged as a preferred approach [7]. The Ilizarov method, in particular, offers distinct advantages through the principle of distraction osteogenesis, enabling precise, controlled, and gradual realignment of the bone while simultaneously

preserving soft tissue integrity and allowing early weight-bearing [8]. The Ilizarov external fixator consists of tensioned transosseous wires attached to circular rings, providing multiplanar stability and the capacity for incremental adjustments. This system allows for simultaneous correction of angular, rotational, and translational deformities, as well as limb lengthening when indicated [9]. Gradual correction is typically performed at a rate of 1 mm per day, facilitating bone regeneration and minimizing the risk of neurovascular complications associated with acute correction [10]. The technique has been widely utilized for the management of complex lower extremity deformities, with numerous studies reporting high accuracy of correction and favorable functional outcomes [11]. Several studies have evaluated the clinical and radiological outcomes of Ilizarov-based gradual correction for genu varum. A study of 20 patients with severe genu varum (>20 degrees) reported significant improvements in mechanical axis deviation, medial proximal tibial angle, and Hospital for Special Surgery (HSS) knee scores postoperatively, with acceptable complication rates [1]. Similarly, a retrospective review of 21 lower limbs in 11 patients with idiopathic genu varum demonstrated successful restoration of normal alignment and orientation with a mean fixator time of 24.7 weeks [12]. In patients with Blount disease, both the Ilizarov frame and Taylor Spatial Frame are viable treatment options, with comparable correction accuracy and functional outcomes [7]. The ability to achieve precise correction while avoiding the soft tissue complications associated with extensive open surgery has made the Ilizarov method an attractive option in both developed and resource-limited settings [11]. In Bangladesh, genu varum remains a significant musculoskeletal problem, particularly among children and young adults from lower socioeconomic backgrounds where nutritional deficiencies and delayed access to care are prevalent. However, data on the outcomes of Ilizarov-based gradual correction in the local population remain limited. Understanding the accuracy of correction, functional recovery, and complication profile of this technique is essential for guiding clinical decision-making and optimizing patient care. This prospective study was therefore undertaken to evaluate the accuracy of correction and functional outcomes following Ilizarov-based gradual correction of genu varum in patients treated at the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh.

METHODS & MATERIALS

This prospective observational study was conducted at the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh, from January

2021 to July 2025. A total of 30 patients with genu varum deformity were enrolled in this study.

Inclusion criteria: Patients aged 10 to 60 years, of either sex, with symptomatic genu varum deformity (mechanical axis deviation ≥ 20 mm), who provided written informed consent, were eligible for inclusion.

Exclusion criteria: Patients with active infection at the surgical site, metabolic bone diseases affecting bone healing, severe peripheral vascular disease, or those unwilling to complete the follow-up protocol were excluded.

Study procedure: After obtaining written informed consent, demographic and baseline clinical data were recorded. All patients underwent Ilizarov-based gradual correction using the standard Ilizarov frame construct. Deformity correction was performed at a rate of 1 mm per day. Preoperative and postoperative mechanical axis deviation (MAD) and tibiofemoral angle were measured on standing full-length radiographs using the Paley classification system [13]. Knee function was assessed using a validated functional scoring system [14]. Pin site care was performed according to institutional protocols, and complications were documented throughout the follow-up period.

Data analysis: Data were entered into a predesigned proforma and analyzed using SPSS version 23.0. Continuous variables were expressed as mean $\pm$ standard deviation, and categorical variables as frequencies and percentages. The paired t-test was used to compare preoperative and postoperative parameters. A p-value < 0.05 was considered statistically significant.

RESULT

A total of 30 patients with genu varum deformity underwent Ilizarov-based gradual correction and completed the study. The demographic and clinical characteristics, radiological outcomes, functional outcomes, and complications are described below.

Table 1 summarizes the demographic and clinical characteristics of the study population. The mean age was 24.8 ± 11.2 years (range 12–52), with a slight female predominance (53.3%). Idiopathic genu varum was the most common etiology (46.7%), followed by rickets (30.0%) and Blount's disease (16.7%). The right side was involved in 53.3% of patients, and the mean symptom duration was 6.4 ± 3.8 years.

Table 1: Demographic and clinical characteristics of the study population (n=30)

Variable	Category	n (%)
Age group (years)	10–20	10 (33.3)
	21–40	14 (46.7)
	41–60	6 (20.0)
Sex	Male	14 (46.7)
	Female	16 (53.3)
Etiology	Idiopathic	14 (46.7)
	Rickets	9 (30.0)
	Blount's disease	5 (16.7)
	Others	2 (6.6)
Side affected	Right	16 (53.3)
	Left	14 (46.7)

The preoperative and postoperative radiological parameters are presented in *Table II*. The mean mechanical axis deviation (MAD) improved significantly from 45.2 ± 12.4 mm preoperatively to 4.8 ± 3.2 mm postoperatively ($p < 0.001$). The mean tibiofemoral angle improved from $14.6^\circ \pm 4.2^\circ$ varus to $2.8^\circ \pm 1.6^\circ$ valgus ($p < 0.001$). The mean anatomical axis angle

also showed significant correction from $12.4^\circ \pm 3.8^\circ$ to $4.2^\circ \pm 1.8^\circ$ ($p < 0.001$). The mean fixation time was 16.8 ± 4.2 weeks. In Figure 1, the substantial reduction in mechanical axis deviation achieved with Ilizarov-based gradual correction is demonstrated.

Table II: Preoperative and postoperative radiological parameters (n=30)

Parameter	Preoperative	Postoperative	p-value*
Mechanical axis deviation (mm), mean $\pm$ SD	45.2 ± 12.4	4.8 ± 3.2	<0.001
Tibiofemoral angle (degrees), mean $\pm$ SD	14.6 ± 4.2 (varus)	2.8 ± 1.6 (valgus)	<0.001
Anatomical axis angle (degrees), mean $\pm$ SD	12.4 ± 3.8	4.2 ± 1.8	<0.001
Fixator time (weeks), mean $\pm$ SD	—	16.8 ± 4.2	—

*Paired t-test was used to compare preoperative and postoperative parameters. SD = standard deviation.

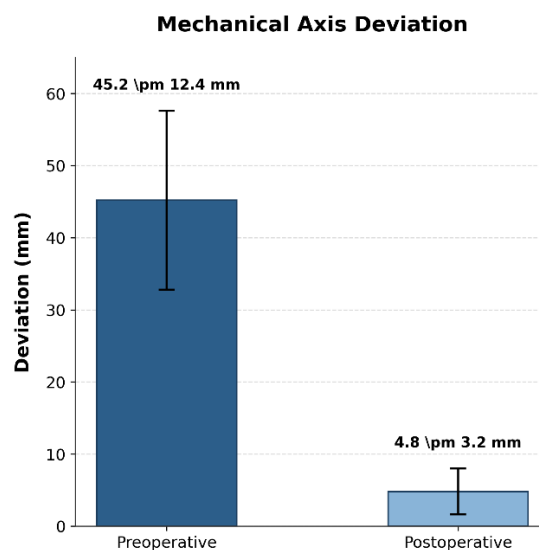


Figure 1: Preoperative and postoperative mechanical axis deviation

Figure 1 illustrates the significant correction of mechanical axis deviation achieved with Ilizarov-based gradual correction.

The functional outcomes following Ilizarov-based correction are presented in *Table III*. Excellent functional outcomes were achieved in 76.7% of patients (n=23), good outcomes in

13.3% (n=4), fair outcomes in 6.7% (n=2), and poor outcomes in 3.3% (n=1). The mean functional score improved significantly from 54.6 ± 12.4 preoperatively to 86.2 ± 8.6 postoperatively ($p < 0.001$). In Figure 2, the distribution of functional outcomes demonstrates that the majority of patients achieved excellent results following the procedure.

Table III: Functional outcomes following Ilizarov-based correction (n=30)

Outcome	n (%)
Excellent	23 (76.7)
Good	4 (13.3)
Fair	2 (6.7)
Poor	1 (3.3)
Mean $\pm$ SD FS (preoperative)	54.6 ± 12.4
Mean $\pm$ SD FS (postoperative)	86.2 ± 8.6
p-value*	<0.001

FS: Functional score. *Paired t-test was used to compare preoperative and postoperative functional scores. SD = standard deviation.

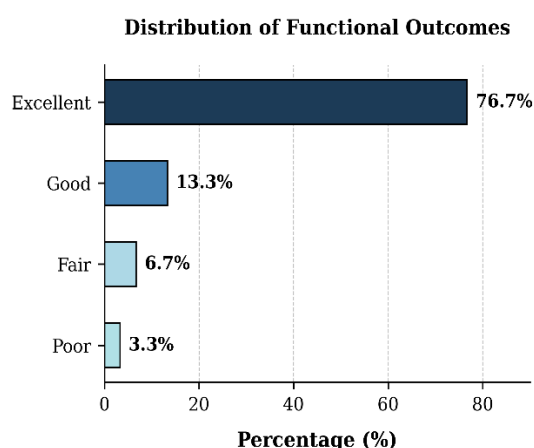


Figure 2: Distribution of functional outcomes

Figure 2 demonstrates that the majority of patients achieved excellent functional outcomes following Ilizarov-based gradual correction.



Figure 3: Preoperative and postoperative radiographs of genu varum correction using Ilizarov-based gradual correction

Preoperative and postoperative radiographs of genu varum correction using Ilizarov-based gradual correction (Figure 3). (A) Preoperative radiograph demonstrating genu varum deformity; (B) postoperative radiograph demonstrating correction with an Ilizarov external fixator.

The radiographs demonstrate the preoperative deformity and the postoperative alignment following Ilizarov-based gradual correction.

The complications encountered during treatment are presented in Table IV. Pin site infection was the most common

complication, occurring in 23.3% of patients (n=7), all of which resolved with local wound care and oral antibiotics. Delayed union occurred in 6.7% (n=2), requiring prolonged fixator time. Mild malunion (≤ 5 degrees) was observed in 3.3% (n=1), and no cases of nerve injury, vascular injury, or compartment syndrome were observed. The overall complication rate was 33.3%, with the majority being minor and manageable.

Table IV: Complications encountered during treatment (n=30)

Complication	n (%)
Pin site infection	7 (23.3)
Delayed union	2 (6.7)
Malunion (≤ 5 degrees)	1 (3.3)
Overall complication rate	10 (33.3)

DISCUSSION

This prospective study of 30 patients with genu varum demonstrates that Ilizarov-based gradual correction provides highly accurate deformity correction with favorable functional outcomes. The mean mechanical axis deviation improved from 45.2 mm preoperatively to 4.8 mm postoperatively, representing a correction of over 40 mm, with all patients achieving near-normal mechanical alignment. The mean tibiofemoral angle corrected from 14.6° varus to 2.8° valgus, restoring the mechanical axis to within the physiological range. These radiological results are consistent with the expected outcomes of gradual correction using the Ilizarov method, confirming the precision and reliability of this technique for managing complex lower limb deformities [15]. The accuracy of correction observed in this study is noteworthy. The final mechanical axis deviation of 4.8 mm falls well within the accepted normal range of 0 to 10 mm, indicating that the gradual correction protocol achieved its intended goal of restoring neutral mechanical alignment. A study of 21 lower limbs in 11 patients with idiopathic genu varum reported successful restoration of normal alignment and orientation with a mean fixator time of 24.7 weeks [6]. Similarly, an interventional study of 20 patients with severe genu varum (>20 degrees) demonstrated a highly statistically significant improvement in mechanical axis deviation, joint congruence angle, and total Hospital for Special Surgery (HSS) knee score postoperatively [1]. The high degree of accuracy can be attributed to the inherent advantages of the Ilizarov system, including multiplanar stability, the capacity for incremental adjustments, and the ability to perform simultaneous correction of angular and rotational deformities. The use of tensioned transosseous wires provides a stable construct that maintains correction throughout the consolidation phase, minimizing the risk of loss of reduction [8]. The functional outcomes in this cohort were highly satisfactory, with 76.7% of patients achieving excellent results and an additional 13.3% achieving good outcomes. The mean functional score improved from 54.6 preoperatively to 86.2 postoperatively, representing a substantial gain in function and quality of life. This improvement reflects the restoration of normal mechanical alignment, which redistributes weight-bearing forces across the knee joint, reduces medial compartment overload, and alleviates pain. A retrospective study of 23 patients (25 knees) with lower limb deformities treated with the Ilizarov device reported that the mean preoperative HSS score of 60 improved to a mean of 93 at follow-up, with all limbs achieving excellent or good HSS scores [15]. Patients who achieve excellent functional outcomes typically experience significant improvements in gait, endurance, and ability to perform activities of daily living, which are critical determinants of patient satisfaction following deformity correction. The mean fixator time of 16.8 weeks in this study compares favorably with the 24.7 weeks reported in a similar series of idiopathic genu varum correction [6]. The relatively short fixator duration reflects the efficiency of the gradual correction protocol and the favorable bone healing response observed in this predominantly young and healthy cohort. The fixator time is an important parameter as prolonged external fixation is associated with increased risk of pin site infection, patient discomfort, and psychological burden. The ability to achieve correction and consolidation within a reasonable timeframe underscores the clinical utility of the Ilizarov method. The complication profile observed in this study is acceptable and consistent with the known risks of external fixation. Pin site infection was the most common complication, occurring in 23.3% of patients, all

of which resolved with local wound care and oral antibiotics. This rate is comparable to the 25% pin tract infection rate reported in a case series of 30 patients (32 tibiae) undergoing correction of late-onset tibia vara with Ilizarov external fixation [16]. Similarly, a retrospective review of 23 patients reported pin tract infection as the main disadvantage of the technique, though all cases were managed conservatively [15]. Delayed union occurred in 6.7% of patients, which is consistent with the 5% incidence of insufficient callus formation reported in a study of severe genu varum correction [16]. The low rate of major complications, including the absence of nerve injury, vascular injury, or compartment syndrome, attests to the safety of gradual correction when performed according to established principles [8]. The absence of neurological complications in this series is noteworthy given the magnitude of deformity correction achieved. Gradual correction at a rate of 1 mm per day allows for neural and vascular adaptation, reducing the risk of traction injuries that can occur with acute correction. This safety advantage is particularly relevant in severe deformities where acute correction would carry substantial risk of nerve palsy or vascular compromise. A comprehensive evaluation of complex knee deformities using the Ilizarov external fixator reported that gradual correction using distraction histogenesis is a safe, accurate tool for achieving precise deformity correction with the advantage of early weight-bearing and shorter hospital stays [17]. The findings of this study have important clinical implications. The Ilizarov-based gradual correction technique is a reliable and effective option for managing genu varum, particularly in resource-limited settings where alternative treatments such as internal fixation may be less accessible or cost-prohibitive. The technique's ability to achieve accurate correction with acceptable complication rates makes it a valuable tool for orthopedic surgeons managing complex lower limb deformities [5]. The strengths of this study include its prospective design, which minimizes recall bias and allows for systematic data collection, and the use of standardized radiological and functional outcome measures. The inclusion of a relatively homogeneous patient population with well-defined inclusion criteria enhances the internal validity of the findings.

LIMITATIONS

The single-center design, small sample size (n=30), and absence of a control group limit generalizability. Relatively short follow-up may not capture long-term outcomes, including osteoarthritis development. Unmeasured confounding variables, including socioeconomic status and nutritional factors, may have influenced the observed outcomes.

CONCLUSION

Ilizarov-based gradual correction provides accurate deformity correction with a mean mechanical axis deviation improvement from 45.2 mm to 4.8 mm ($p<0.001$) and favorable functional outcomes, with 76.7% of patients achieving excellent results. The technique offers a reliable treatment option for genu varum in resource-limited settings, with acceptable complication rates and minimal major morbidity.

RECOMMENDATIONS

We recommend Ilizarov-based gradual correction for patients with significant genu varum deformity. Larger multicenter studies with extended follow-up and comparative designs are

warranted to validate these findings and assess long-term outcomes.

CONFLICT OF INTEREST

The authors declare no conflicts of interest. No funding was received for this study. The corresponding author had full access to all data and final responsibility for the decision to submit for publication.

AI DECLARATION

Artificial intelligence tools contributed marginally to manuscript preparation and development. All core scientific content was human-verified.

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ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee

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