The Effects of Dynamization and Destabilization of the External Fixator on Fracture Healing: A Comparative Biomechanical Study in Dogs

Mehmet Arazı, MD*  
Hakan Yalcın, DVM†  
Necmettin Tarakçıoğlu, PhD‡  
Zafer Dasci, DVM†  
Abdurrahman Kutlu, MD*

Abstract

This study compared the effects of axial dynamization and staged destabilization on fracture healing. Bilateral midshafts of canine tibiae were osteotomized and fixed with an external fixator. The hind limbs were divided into two groups: the destabilized group in which the fixator’s stiffness was progressively reduced over time and the axially dynamized group in which the fixator was axially dynamized. The healed tibiae were tested for 3-point bending in the anteroposterior plane. The biomechanical tests performed 2 months postoperatively revealed that the side with the destabilized fixator was more rigid than the side with the axially dynamized fixator, but the differences were insignificant (P=0.20). This study showed staged destabilization of the fixator’s stiffness was as effective on the enhancement of fracture healing as axial dynamization.

Many devices are commonly used for external fixation of long-bone fractures and each has various biomechanical properties. The process of fracture healing under external fixation is an interesting focus for investigators, and many clinical and experimental studies have been reported. However, the parameters related to the mechanical environment, which have an important impact on the healing process, are unclear.

Axial dynamization and progressive destabilization of the fixator are used to enhance healing. Axial dynamization allows unrestricted axial loading of the fracture with physiologic weight bearing, while bending and rotational loading are controlled by the external fixator. This is a successful and widely used treatment of long-bone fractures.1-6 Progressive or staged reduction of the fixator’s stiffness also is known to stimulate healing, which can be used in both ring type and monolateral fixators by demounting some parts of the fixator during the course of healing.7,8 Although destabilization of the fixator is commonly used in different external fixators, this finding has not yet been confirmed in clinical practice.

This study investigated and compared the effects of progressive destabilization of the external fixator and axial dynamization on fracture healing.

MATERIALS AND METHODS

Study Population

Thirteen adult mongrel dogs, weighing 20-26 kg, were used. The investigation was approved by the institutional review board committee. Animal maturity was confirmed by closure of the proximal tibial physis radiographically.

Surgical Technique

Animals were anesthetized with xylazine hydrochloride and ketamine hydrochloride. Both hind limbs were shaved and cleaned with antiseptic solution using standard techniques.

A special, custom-made alignment jig was used to insert the Schanz screws, keeping the distance between the pins constant. The jig was oriented to place the fixator in the anteromedial plane (approximately 30° of anteverision). Self-tapping 4-mm Schanz screws were inserted through both tibial cor-

www.orthobluemagazine.com
ties in the proximal and distal parts of the tibiae. The distance between the longitudinal bone axis and the fixator was kept constant at 5 cm. A short, slightly curved, cranio-medial skin incision was made, and the tibial mid-shaft was exposed.

A transverse tibial osteotomy was performed with a Gigli saw, using the alignment jig. All osteotomy lines were created at the midpoint between the proximal and distal Schanz screws. The fibulae were fractured manually. A custom-made, unilateral, pin-clamp type external fixator with a 6-mm rod was mounted in the neutralization mode (no contact, no compression) on the osteotomy gap. The layers were closed in the standard manner. Radiographs of both tibiae were obtained immediately postoperatively. The limbs and fixators were bandaged with a padded dressing and covered with a plastic tube to prevent self-damage. Weight bearing was not controlled postoperatively.

Experimental Design

The limbs were divided into two groups: destabilized on the right side and axially dynamized on the left side. In the destabilized group, fixator stiffness progressively decreased with removal of some parts of the fixator (Figure 1). In the axially dynamized group, the fixator designed for axial dynamization was dynamized by unlocking the distal pin clamps 2 weeks postoperatively (Figure 2). The dogs were sacrificed 2 months postoperatively, and the tibiae were excised from all soft tissue for biomechanical testing (Figure 3).

Biomechanical Tests

Biomechanical tests were performed immediately after sacrifice, and the tibiae were kept in a moist environment throughout testing. All tests were performed using the JJ Lloyd T 50 K material testing machine (Southampton, England).

To evaluate pin loosening, the torque required for pin removal was measured in two proximal and two distal pins, as the four pins located at the inner side were removed during the study in the destabilized group. Pins that required <30 Ncm torque were considered loose. After evaluation, the distal and proximal ends of the tibiae were removed to adjust to the testing machine.

The tibiae were tested for 3-point bending in the anteroposterior plane on the testing machine. The load was applied through the original osteotomy site with a 50-mm span length, and the loading speed was 2 mm/min (Figure 4). The load was applied until the bone was fractured. The load and deflection values were measured as Newton (N) and millimeters (mm), respectively.

Statistical Analysis

Chi-square test was used to evaluate significance of pin loosening. Student’s t-test determined the statistical differences between the destabilized fixator group and the axially dynamized fixator group. The differences were considered significant at P<.05.

RESULTS

Two dogs were eliminated from the study due to gross infection in the operation site and around the pins. The remaining 11 dogs were studied throughout the 2-month period. The dogs were walking on both hind limbs within 5 days postoperatively. Two weeks postoperatively, the dogs were walking with full weight bearing on both hind limbs.

Biomechanical Tests

No significant difference was obtained for the incidence of pin loosening between the destabilized fixators (18%) and the axially dynamized fixators (23%) (P=.59).

Three-point bending test for failure of the healed osteotomy 2 months postoperatively revealed that the side with the destabilized fixator was more rigid than the side with the axially dynamized fixator; however, the differences were not significant between the two groups (P=.20) (Table).

DISCUSSION

The biomechanical properties of the external fixator device compose a local
mechanical environment that affects the healing process directly. Many studies demonstrated that the healing process has an extreme sensitivity to mechanical factors. \(^\text{2,5-8,10,12-20}\) Whichever type of fixation is used, a measurable or immeasurable motion with quantitative methods can be detected at the fracture site in the early phase of healing. This motion is termed interfragmentary strain and has a positive effect on healing under limited values. In an extremely stiff system or strong inhibition fracture end movements, the repair process may be negatively affected. \(^\text{4,15,19,21,22}\) However, controlled micromotion has a beneficial effect on callus formation and the healing process. \(^\text{3,5,6,15-18,23,24}\) In contrast, excessive motion between the fracture ends inhibits healing and hypertrophic pseudoarthrosis may occur. \(^\text{9,20,23,26}\) Although several studies have reported this condition, the exact parameters of the optimal mechanical environment have not been explained.

In a recent study, Claes et al.\(^\text{23}\) reported strains \(<15\%\) and a hydrostatic pressure \(>0.15\) MPa induce enchondral bone formation. They showed larger strains resulted in connective tissue formation according to cell culture studies. Goodship et al.\(^\text{16}\) reported beneficial effects of this condition are significant and useful in the early period of healing. They showed a significant inhibition of the healing process when high strain rate stimuli were applied in the later healing period.

Controlled micromotion, axial skeletal dynamization, and progressive fixator destabilization under external fixation are used to stimulate healing. Early axial dynamization stimulates healing by reducing the distance between the fracture or osteotomy ends. Many reports demonstrated a significant increase in fracture healing with axial dynamization. \(^\text{12,3,7,15,24}\) Axial dynamization offers one-way dynamization and controls the shear forces. A shear effect at the fracture site may be deleterious on healing.

Staged destabilization provides a progressive and multidirectional dynamization. This may lead to bending micromotion with shear forces and also can be defined as bending dynamization. \(^\text{27}\) Although, the shear forces and bending dynamization are commonly addressed as detrimental, this finding has not been confirmed.\(^\text{27}\)

Park et al.\(^\text{18}\) explained the influence of shear motion on fracture healing in a rabbit model. They observed greater callus formation and higher torsional strength values in oblique tibial osteotomies with oblique sliding motion compared to axial motion or locked external fixation. However, this motion is only one type of shear force and did not include the bending dynamization concept. Their investigation can be considered a cornerstone study that strongly supports that some shear forces have a positive effect on fracture healing. Our results were similar to these findings. On the other hand, although ring fixators lower values of stiffness in all loading modes in biomechanical studies,\(^\text{7,27}\) they are popular and widely used in problem cases with higher union rates. \(^\text{27,29,30}\)

Physiologic loading also has a posi-
tive effect on repaired bone and for this reason weight bearing as early as after initial stabilization is advised in most fresh, long-bone fractures. Staged or progressive destabilization of the fixator reduces the bulk and stiffness of the fixator, which increases the load transmission through the fracture ends. In physiologic conditions, this loading is expected to enhance healing. This expectation was confirmed in our study, which showed a higher but insignificant (P=0.20) load value in the destabilized group. The incidence of pin loosening also was reduced in this group, but the difference was not statistically significant (P=0.59).

The findings of this study show that staged destabilization of the fixator or bending dynamization was as effective on the enhancement of fracture healing as dynamization. Some components of the ring type and monolateral fixators may be progressively demounted to stimulate healing based on their configuration. The effects of axial and bending dynamization, the ideal timing for fixator component removal, and the optimum conditions of the mechanical environment require further investigation.

REFERENCES