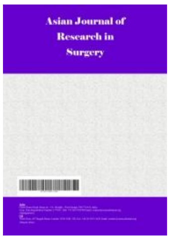

Asian Journal of Research in Surgery

5(4): 23-28, 2021; Article no.AJRS.69119

Correlation between the Closest Pin Distance of the Fracture line to the Stability of the External Fixation: A Biomechanical Study on Bovine Tibia

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Authors' contributions

This work was carried out in collaboration among all authors. Author DAK conceptualized the study and performed study investigation, methodology, software, validation, visualization and wrote the original draft of the study. Author UHN did data curation, formal analysis and collected funding acquisition. Authors DAK and UHN reviewed and edited the manuscript. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Wagih Mommtaz Ghannam, Mansoura University, Egypt.
Reviewers:
(1) Sanjeev V Jakati, Maharashtra University of Health Sciences, India.
(2) Shachar Kenan, Zucker School of Medicine, USA.
Complete Peer review History: http://www.sdiarticle4.com/review-history/69119

Original Research Article

Received 17 March 2021
Accepted 27 May 2021
Published 28 May 2021

ABSTRACT

Aims: To determine the effect of the closest pin distance from the fracture line on the stability of the external fixation which is applied axial compression force.
Study Design: This study was an experimental study with a post-test only controlled group design, using bovine tibia.
Place and Duration of Study: This research was conducted in the Orthopedic and Traumatology Department of Dr. Moewardi Hospital and Engineering Laboratory of Sebelas Maret University from June to September 2020.
Methodology: External fixation stability measured using a Universal Testing Machine. There were three treatment groups with different closest pin spacing (2 cm, 3 cm, 4 cm).
Results: This study used 30 bovine tibial bones (10 bones for each treatment group). The closest 2 cm pin distance group has the largest mean value of compressive strength 7036.56 ± 453.37

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Newton. Linear regression analysis shows the value of p = 0.000 with a regression coefficient of -912.55. The significant relationship proves the near-far law theory, where the pins are placed as close as possible from the fracture line could give the greater amount of external fixation stability.
Conclusion: Shorter pin distances from the fracture line were associated with increased compressive strength.

Keywords: Axial compression; closest pin distance; bovine tibia; external fixation stability.

1. INTRODUCTION

External fixation is a common practice for the management of trauma patients with fractures.

It is indicated as part of damage control measures, especially in patients with severe soft tissue damage where it may be used as a definitive treatment for fractures. Considerations about the rigidity and biomechanical aspects of the implant influence bone healing, and the vascularity of the fracture area [1-3].

Stability is the fundamental characteristic of external fixation. The stability required must be precise, allowing micro-movement for the bone consolidation process, without compromising the strength of the external fixation stability. One way to increase the rigidity of the external fixation device is to increase the number of pins. Biomechanical studies reveal that the 6 pin construction is more rigid and has better stability than the 4 pin construction. This is due to the smaller pin distance on the external 6 pin fixation compared to the 4 pin construction. The smaller the pin distance, the greater the stiffness and the smaller the flexor moment [4].

Use of external fixation with a unilateral frame that is often used has the disadvantage of stability to bending, compression, and torsion forces. The displacement of the Schanz screw within the bone also frequently affects the rigidity of the external fixation. The stability of the external fixation is influenced by many things, one of which is the distance of the pin to the fracture line.[5] Ideally, to gain stability in the 6 pin construction, the location of the first pin is as close as possible to the fracture, and the other pins are as far as possible to the fracture [6,7]. However, the literature has not been stated at what distance from the fracture line the maximum stability is obtained.

This study was conducted to compare the results of biomechanical tests on the external technique of unilateral frame fixation on tibia fractures with 6 pin construction at several locations measured from the fracture line by assessing the resistance to compression forces. This study aims to get the most ideal pin distance from the fracture line in order to obtain the maximum stability of the tibial fracture, which is attached externally to the unilateral frame.

2. MATERIALS AND METHODS

This research is a laboratory experimental research. The research design used was a randomized post-test only control group design. After being given the treatment, the experimental group will be given a posttest, to determine the condition of the group after giving the treatment. This research was conducted in the Orthopedic and Traumatology Department of Dr. Moewardi Surakarta and the Engineering Laboratory of Sebelas Maret University, Sebelas Maret University from June to September 2020.

The research sample in this study used 30 bovine tibial bones that met the inclusion and exclusion criteria. Inclusion criteria include the following a) using the bovine tibia, b) age of the bovine tibial bone of 20-24 months, c) bone length 25-30 cm, mid-shaft diameter ± 6 cm, d) bone weight 2000 grams, e) bone condition normal bovine leg. Fractures occurring prior to treatment and spiral, oblique, or comminuted fracture patterns were excluded from the sample group. After collecting 30 tibia bones, they will then be divided into three groups, namely the control group (the closest pin distance group is 4 cm), the closest pin spacing group is 3 cm, and the closest pin spacing group is 2 cm, 10 bones each. In each research group, the same diameter, size pins and sidebar will be used. The distance between the pins outside the closest point is 5 cm, the distance between the sidebar and the bone is 50 mm (Fig. 1A).

The process of measuring the external stabilization test on the bovine tibial bone in this study is described: a) preparation of the tool and installation of external fixation by providing a gap between fracture fragments of 10 mm, placing the bone in the Universal Testing Machine, the compression test is carried out so that there is no fragment gap fracture, a measurement of the axial compression force in Newtons / mm (Fig. 1B).

This research uses univariate analysis and bivariate analysis. Univariate analysis is used to explain and describe the characteristics of each research variable and is presented in tabular form. Bivariate analysis is used to determine the direction of the relationship between the pin distance closest to the fracture line to the stability of the external fixation that is given axial compression force. The data will be analyzed using a linear regression test. Statistical data processing will be carried out using the Statistical Product and Service Solution (SPSS) program version 25.0 for Windows. In this study, a power of 90% was used with a 95% confidence interval. All analytical tests used $p < 0.05$.

A) External fixation model before treatment. The distance between the pins outside the closest point is 5 cm, the distance between the sidebar and the bone is 50 mm. B) External fixation model after treatment using Universal Testing Machine, there was no fragment gap fracture.

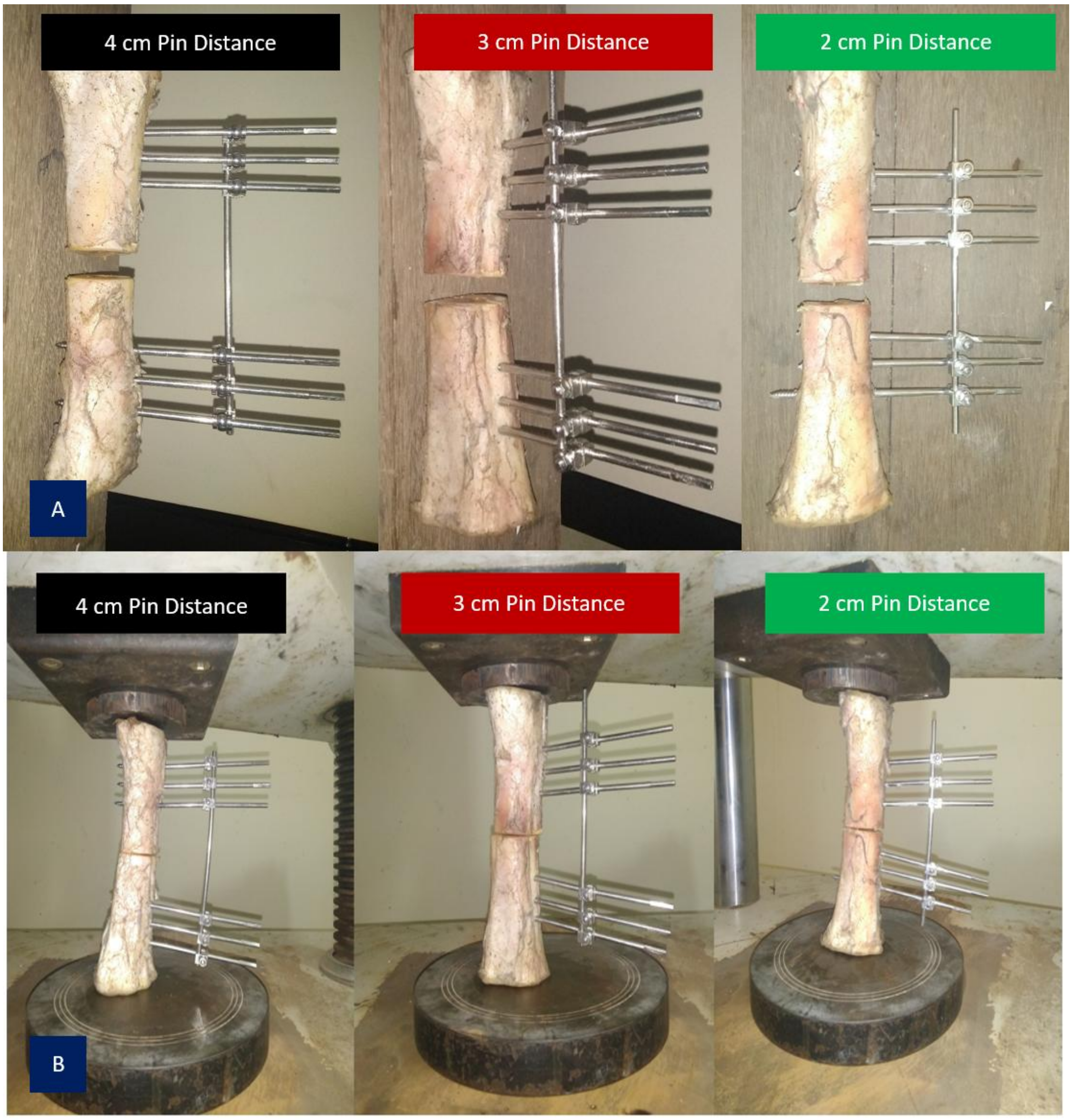

Fig. 1. External fixation model

3. RESULTS

Based on Table 1, a distance of 2 cm pin has a minimum compressive strength of 6241.79 newtons, a maximum compressive strength of 7596.15 newtons, and a mean value of 7036.56 ± 453.37. A distance of 3 cm has a compressive strength value of 6009.75 newtons, a maximum compressive strength of 6760.01 newtons, and a mean value of 6377.83 ± 231.71. For a distance of 4 cm, it has a minimum compressive strength of 4267.16 newtons, a maximum strength of 5871.35 newtons, and a mean value of 5211.47 ± 481.18.

The data normality test in this study used Shapiro-Wilk because the data were less than 50 samples. In Table 2. the compressive strength variable at a distance of 2 cm, a distance of 3 cm, and a distance of 4 cm, has a p value > 0.05, which means the data is normally distributed.

The results of the regression analysis Table 3. shows the value of $p = 0.000 < 0.05$, so there is a significant difference between the pin distance and the compressive strength of the external fixation that is given axial compression force. The regression coefficient value of -912.55 shows that with each additional 1 cm pin distance from the fracture line, the fixation pressure strength decreases by 912.55 newtons.

Table 4 shows the linear regression coefficient of determination of 0.775. This shows that the compressive strength of 77.5% is influenced by the variable of the closest pin distance, while 22.5% is influenced by other variables not examined.

4. DISCUSSION

The results showed that there was a significant difference in the compressive strength of the external fixation between all groups. The most influential thing is the 2 cm pin distance to the external fixation press output. This result is consistent with the near-far law theory, where the pins are placed as close as possible from the fracture line and placed as far as possible on each side of the fracture. The closest pin is placed as close as possible from the fracture line to stabilize the fracture segment [8,9]. The 2 cm pin distance group has a compressive value of 7036 newtons, this group made the greatest value of the compressive strength of all groups.

Table 1. Baseline characteristics

Pin Distance	Minimum	Maximum	Mean	Std. Deviation
2 cm	6241.79	7596.15	7036.56	453.37
3 cm	6009.75	6760.01	6377.83	231.71
4 cm	4267.16	5871.35	5211.47	481.18
Total	4267.16	7596.15	6208.62	861.06

Table 2. Normality test

	Pin Distance	Shapiro-Wilk		
		Statistic	df	Sig.
Compressive Strength	2 cm	0.948	10	0.644
	3 cm	0.972	10	0.907
	4 cm	0.947	10	0.633

Table 3. Bivariate analysis

Variable	Pin Distance	N	Mean±SD	CI 95% (Confidence Interval)	P-value
Compressive Strength	2 cm	10	7036.56±453.37	6712.24-7360.89	0.000
	3 cm	10	6377.83±231.71	6212.07-6543.58	
	4 cm	10	5211.47±481.18	4867.25-5555.68	

Table 4. Regression linear analysis

Variable	Regression Coefficient	P-value
Pin Distance	-912,55	0.000

In this study, besides the factor of the distance between the pins closest to the fracture line, the number of pins can also influence the results of the study. According to Bojrab M et al., increasing the number of pins will distribute forces against the pins and increase the stiffness of the construction as a whole. However, increasing the number of pins can increase the risk of damage to the surrounding anatomical structures and increase the portal of infection. Increasing the diameter of the pin core will increase the torsional strength, as a 6mm diameter pin is five times stronger than a 4mm pin. The larger the pin diameter, the maximum construction stiffness can be achieved, but the pin diameter should not be more than one-third of the bone diameter to avoid pin-hole fracture [7].

According to Moss DP et al., external fixation can be used as a definitive treatment for fractures. The location of the first pin is as close as possible to the fracture and the other pins as far as possible with the fracture. Considerations about the rigidity and biomechanical aspects of implants greatly influence bone healing, besides the vascularity of the fracture area [10]. In certain fractures, external fixation has advantages over other fixation models, such as Open Reduction Internal Fixation (ORIF) and intramedullary (IM) nailing. External fixation can be used in high-energy multiple trauma patients who may have open wounds, severe soft tissue damage, comminuted fractures, or bone loss incompatible with the use of ORIF or IM nailing.

There are several factors that affect the stability of the construction on external fixation, including maximizing the size of the pins, the number of pins, the distance between pins, the closeness of the pins to the fracture line, the bar for clamping the bone to the clamp, and the diameter of the pin / connecting rod [8]. Ideal position for placement is based to near-far law where the pin is placed as close as possible to the fracture line and placed as far as possible on each side of the fracture. The stiffness can also be increased by a double arrangement of connecting rods [11].

The results showed that there was a significant effect on the distance of the closest pin from the fracture line to the stability of the external fixation that was given axial compression force. External fixation is a method of obtaining alignment to the bone using a combination of pins, wire, clamp, and bar/ring. This type of fixation was first introduced by Lambotte in the early 20th century [1,9,12].

According to the results of this study, a surgeon should place external fixation pins as close as possible to the fracture site in order to achieve the strongest fixation. This however must be balanced with a surgeon’s desire to keep pins far away from the zone of injury to avoid contamination for a planned second procedure in the future.

This study was successful in proving a significant relationship between the closest pin distance and the compressive strength of external fixation. The closer the pin distance to the fracture line will increase the compressive strength of the external fixation. Further research is needed to test other stability measurement tools such as tension, shear, and bending tests.

5. CONCLUSION

Shorter pin distances from the fracture line were associated with increased compressive strength.

CONSENT

It is not applicable.

ETHICAL APPROVAL

Principles of laboratory animal care (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/69119