Effect of Isometric Plantar Flexor Muscles Exercises on the Callus Formation of Patients with Tibial Shaft Fracture

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Abstract: Osteoblast activity affects the fracture healing process. There is evidence that mechanical stimulation during rehabilitation treatment after surgery will trigger the osteoblast activity. However, the effect of isometric plantar flexor muscle exercise is not yet known. One of the osteoblast activity markers is callus formation. This study aims to examine the effect of isometric plantar flexor muscle exercise on callus formation examined by radiographic scoring method for tibial fractures (Hammer scale) among patients with tibial shaft fracture. The study used two-group post-test-only randomized experiment. The intervention group was given a standard of passive knee and ankle range of motion exercises and the addition of isometric training of plantar flexor muscles, while the control group only received the standard of passive knee and ankle range of motion exercises. The Hammer scale to describe the callus formation was compared using a two-sample t-test for independent samples with unequal variances. The results show that the intervention group had a significantly better Hammer scale than the control group, 2.63 and 3.06, respectively (p-value = 0.033), indicating better fracture healing. The study highlighted the effect of the addition isometric plantar flexion exercises with range of motion exercises on fracture healing among patients with tibial shaft facture.

1 INTRODUCTION

Tibial shaft fractures are one of the most common long bone fractures, mostly found among young males, (Court-Brown et al., 1998) related to sport activities and vehicle accidents (Robertson et al., 2012; Robertson et al., 2014; Bode et al., 2012). Similar to any acute fracture, the treatment of tibial shaft facture includes optimal fracture immobilization and appropriate rehabilitation to restore of normal physical functioning (Court-Brown et al., 2006). Several surgical interventions are used to treat tibial shaft fracture including intramedullary (IM) nailing, open reduction and internal fixation (ORIF), external frame fixation, functioning (Court-Brown et al., 2006), and cerclage wire fixation (Habernek, 1991; Habernek et al., 1989; DeLisa, 2005). Then followed by timely rehabilitation trainings are passive and active range of motion (ROM), isometric exercises, strength training, physical modalities, gait and proprioceptive training (Radomski & Latham, 2008). The success of a surgical treatment is heavily influenced by the compliance of physical therapy recommendation after surgery. Although, isometric and ROM exercises are known to increase muscle strength (Court-Brown et al., 2006), few studies have assessed the influence of the combination of ROM and isometric plantar flexion on callus formation particularly for tibial shaft fracture.

The aim of this study was to compare the outcomes of the callus formation among patients with tibial shaft fracture administering rehabilitation exercises with either ROM only or combination ROM with isometric exercises after having ORIF surgery.

2 METHODS

This two-group posttest-only randomized study was conducted in Zainoel Abidin Hospital, Banda Aceh - Indonesia. From July 2014 to January 2015, 34 patients with a tibial shaft fracture who has undergone ORIF surgery received rehabilitation treatment both at the hospital and at the patients'

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home. The criteria for inclusion in the study were having open fracture of the tibial shaft with category of 1/3 medial, 1/3 proximal, and 1/3 non-articular distal bones, being aged between 20 to 45 years at the time of having the rehabilitation treatment, and willing to participate in the study. Exclusion criteria were patients with impaired consciousness, having multiple fractures related to knee joint and ankle, history of diabetes, and having surgical treatment other than ORIF.

All included patients received rehabilitation treatment after surgery either ROM only or the combination of ROM and isometric plantar flexion exercises depending on the randomization. Each patient was assigned to an identified number in the study. Patients with odd number received the combination of ROM and isometric exercises as the intervention group, while patients with even number received the ROM exercise only as the control group.

2.1 Procedure

The control group received a standard procedure of passive knee and ankle joint ROM exercise. The detail procedure of the ROM as follows:

- The patient was lying supine with the lower leg in a straight state, the knee joint extension and the ankle joint in neutral position.
- The therapist performed the flexion movement of the knee joint to the full or the tolerance limit of the patient's pain then returned to its original position. The movement was repeated up to 10 times.
- The therapist then performed dorsiflexion of the ankle to the full or the tolerance limit of the patient's pain then returned to its original position. The movement was repeated up to 10 times.
- Furthermore, the therapist performed an ankle flexion movement until the full or patient tolerance limit of pain the patient then returned to its original position. This movement was repeated up to 10 times.
- The ROM training was conducted for one session, and each session was repeated for 10 times.

The intervention group received passive knee and ankle joint ROM exercise and the addition of isometric training of plantar flexor muscles in a structured manner. The ROM exercise was similar to the control group. The detail of the isometric plantar flexion exercise is explained as follows:

- The patient was lying on his back with the lower leg position in a straight and ankle joint at a neutral position. The therapist performed fixation on the ankle joint by means of one hand holding the patient's footprint and the other hand holding the patient's calf.
- The patient performed isometric contraction of the plantar muscle of the flexor.
- Assessment of contraction of plantar muscle is done by palpation on the patient's calf. Long contraction was conducted for 10 seconds counted using stopwatch.
- Each training was performed for three sessions and each session was performed with 10 repetitions with each rest period of 10 seconds.
- Exercise socialization was first conducted on the healthy foot.

Both trainings in control and intervention group were conducted every day started from the second day after surgery until the 28th day. When patients were allowed to leave the hospital, the physiotherapists continued the rehabilitation exercises by visiting patients in their houses. The rehabilitation training was conducted by a physician and his assistant for all the patients in both groups. On the 29th day, patients were examined for the callus formation by having an x-ray examined using radiographic scoring method for tibial fractures by Hammer et al. (1985). If the 29th day was the holiday (for example Saturday, Sunday or national holidays when the hospital is closed) then the x-ray was performed at the earliest day after holiday. The Hammer scale is classified as described on table 1 which indicates the lower the scale, the better fracture healing process. The radiograph examination was performed by a radiologist who was blinded to the patients' training methods.

Table 1. Radiographic Scoring Method for Tibial Fractures by Hammer et al. (1985)

Grade	Callus Formation	Fractures Line	Stage of Union
1	Homogeneous, bone structure	Obliterated	Achieved
2	Massive, bone trabeculae crossing fracture line	Barely discernible	Achieved
3	Apparent bridging of fracture line	Discernible	Uncertain
4	Trace, no bridging off fracture line	Distinct	Non-achieved
5	No callus formation	Distinct	Non-achieved

2.2 Statistical Analysis

Statistical analyses were performed in SPSS 22 with use of the independent t test to compare the Hammer scale difference after surgery to examine the callus formation which is related to fracture healing between the patients who received ROM training and those who received the combination ROM and isometric plantar flexion training. The test significance was defined as $p<0.05$.

3 RESULTS

Out of a total sample of 34 patients, two of them were excluded because they missed the training more than 4 days, resulting in 32 patients for final analysis with 16 patients in each group. More men (72%) than women enrolled in the study. The mean age of all patients were 34.5 years old.

The results of the radiographic scoring method for tibial fractures are presented in Table 2. It shows that there is a statistically significant difference of Hammer scale, at 0.05 level of significance, between the intervention and the control groups indicating the patients who received the combination training had lower scale (2.62) than those who received the ROM training only (3.06). The lower the Hammer scale, the better the callus formation, resulting in better fracture healing.

Table 2. Mean difference of independent t-test of Hammer scale between control and intervention groups

Variable	ROM and isometric training (n=16)		ROM only (n=16)		95% CI for Mean Difference	t	df	p-value
	M	SD	M	SD				
Hammer scale	2.62	0.71	3.06	0.25	-0.83, -0.03	-2.3	18.57	0.033

4 DISCUSSION

For patients with limb fractures**,** one of the important rehabilitation goals are reducing pain and edema, restoring range of motion and strength, preventing muscle weakness and atrophy at the early stages, and returning to normal physical function (Garrison, 2003). According to the results of this study, the rehabilitation interventions by combining range of motion and isometric training improved the callus formation indicating better fracture healing than having range of motion exercise only.

The result is consistent with other studies. For example, Khosrojerdi et al., (2018) concluded that isometric exercise reversed muscle strength among patients with lower limb fractures. Similarly, Rhyu et al., (2015) found that isometric movements exercise was an effective rehabilitation method for enhancing muscle activity. A study by Khalid et al., (2006) indicates that isometric exercise may prevent muscle atrophy for patients with tibial shaft fracture. Yousefi et al., (2012) suggested that isometric trainings are effective in increasing bone density of patients with lower limb injury.

Osteoblasts have receptors to pressure that receives mechanical load stimuli which include mechanical stresses, compressive and shear stresses. The contraction of plantar flexor muscle during isometric exercise provides the mechanical load to the injured area which stimulates the osteogenesis process (Turner & Pavalko, 1998). The process is channeled through the extracellular matrix to osteoblasts, osteocytes, periosteal cells, and osteoclasts. These local mechanical stimuli produce mechanotransduction, which is the conversion of physical signals into signals typical of intracellular biochemistry that discharge bone matrix to enhance bone matrix mineralization. Osteoblasts cell wall is activated by pressure from the receptor. This type of mechanical stimulation can increase the proliferation and anabolism of osteoblasts to facilitate the reconstruction of bone tissue, contributing to the healing process of homeostasis of bone tissue (Burger & Klein-Nulend, 1999). Although the study has reached its aim, the result may be confounded by medication taken by patients particularly analgesics as researchers did not control the medication during the rehabilitation training. Analgesics can affect the molecular and cellular processes of bone regeneration that have a significant effect on healing (Gerner & O'Connor, 2008).

5 CONCLUSION

This study suggested that the combination of range of motion and isometric exercises may improve the callus formation and faster fracture healing than using range of motion only after surgery for patients

with tibial shaft fracture. The combination exercise can be recommended as a standard training for physiotherapists especially for tibial shaft fracture. Further research is needed to assess the effect of the combination exercise on different characteristic patients with different fractures.

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