

Pulsed Electromagnetic Field Stimulation on Closed Tibial Rats Fracture Enhances Callus Formation Based on Radiographic Measurement

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ABSTRACT

Introduction. Complication of delayed union and nonunion is the most common problems found in the Tibia fracture, especially tibia fracture with intact fibula who risk for delayed union and nonunion. Previous studies have been conducted primarily for the augmentation of fracture healing by enhancing callus formation, among others, with internal and external stimulation. Whereas with external stimulation such as pulsed electromagnetic field (PEMF) which the inductive coupling of a non invasive technology.

Materials and methods. This experimental studies with a simple random design .sample of adult male rats of Wistar strain. The tibia was osteotomy transversely carried at all animals. The treatment group preformed the provision of PEMF stimulation and compare with the control group. Radiographic examination has done in week first, second and fifth. Then, the analysis using a Tiedemann score was performed.

Results. The result showed that effect of the PEMF stimulation on callus formation demonstrated were significantly different ($P < 0.05$) on both groups. At the Treatment groups were callus formation in the second week increased two folds, while at the end fifth weeks increased 3 folds compared the control group.

Conclusions. We conclude that PEMF stimulation can be enhancement callus formation.

Keywords: fracture, PEMF, callus formation

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Stimulasi *Pulsed Electromagnetic Field* Fraktur Tertutup Tibia Tikus terhadap Pembentukan Kalus Berdasarkan Pengukuran Radiografi

ABSTRAK

Pendahuluan. Komplikasi *delayed union* dan *nonunion* merupakan masalah yang paling sering didapatkan pada fraktur tulang. Fraktur tibia dengan fibula intak yang mempunyai resiko untuk terjadinya komplikasi *delayed union* dan *non union*. Untuk mencegah komplikasi tersebut telah dilakukan penelitian dengan augmentasi penyembuhan fraktur dengan meningkatkan pembentukan kalus melalui internal stimulasi dan eksternal stimulasi. *Pulsed Electromagnetic Field* merupakan suatu eksternal stimulasi yang bersifat *inductive coupling*.

Bahan dan cara kerja. Penelitian eksperimental yang dirancang acak sederhana melibatkan hewan coba tikus jantan dewasa galur wistar sebanyak 32 yang dibagi dalam 2 kelompok dan telah dilakukan frakturisasi konfigurasi transversal. Pada kelompok perlakuan dilakukan pemberian stimulasi PEMF selama 6 hari dalam waktu 5 minggu dengan perlakuan 4 jam sehari dan dibandingkan dengan kelompok kontrol. Dilanjutkan pemeriksaan radiografi pada minggu ke-1, ke-2, dan ke-5. Setelah itu dilakukan analisa terhadap hasil radiografi dengan menggunakan skor Tiedemann dalam menilai pembentukan kalus. Analisis dilakukan dengan uji Mann Whitney.

Hasil. Pada hasil penelitian menunjukkan bahwa rerata pengaruh pemberian stimulasi PEMF pada pembentukan kalus terhadap kelompok perlakuan dan kelompok kontrol terjadi perbedaan secara signifikan ($p < 0,05$) dari minggu ke-1, ke-2 dan ke-5. Terjadi peningkatan pembentukan kalus pada minggu ke-2 rerata 2 kalinya sedangkan pada minggu ke-5 terjadi peningkatan pembentukan kalus rerata 3 kalinya dibandingkan kelompok kontrol.

Simpulan. Kesimpulan yang didapat bahwa PEMF meningkatkan pembentukan kalus berdasarkan penilaian radiografi.

Kata kunci: fraktur, PEMF, pembentukan kalus

Introduction

Every year, there was estimated 6 million people dying of fracture in North America, about 5 – 10% has delayed union or nonunion. Otherwise, in India, from the statistic showed that each year, 16% of 24 million people with fracture has delayed union and nonunion. ¹In the year of 2009 the patient who was hospitalized at Orthopaedic ward Hasan Sadikin Hospital Bandung as much as 10% is long bone fracture with the complication of non union. ²

Fracture healing is a complex metabolism process which needs interaction of many factors, including withdrawal of the reparation cells and genes. If all of its factors is inadequate or if its process was broken, the healing will be delayed or interrupted, thus will cause the complication of delayed union or nonunion to the bone. ³⁻⁶The outcome of a complication of fracture such as delayed union and non union prolong the injured patient to be able to do activities, work or recreation as well as before and it has great impact to the economic of the country

and community with the largest productive age group between 20 – 40 years old. Tibial fracture is the most common case for this complication. ^{7,8}

Based on Wolff's law that "every changes of bone function is followed by certain change in bone's internal and external structure based on mathematical law" which is concluded that bone healing through the osteogenesis, modelling and remodeling because of the mechanical stress. The bone dynamically adapted to the mechanic load by its regular mechanism that quantitatively controls cellular grading and depends on mechanic stimulus. ^{6,9,10} Fracture healing can be manipulated by external stimulation (biomechanic) and internal stimulation (biology). ^{3,4,6,10} Biology intervention such as autogen and allogeneic bone graft, a replacement substance for bone graft medicamentous while external stimulus such as mechanical and physical intervention like static and dynamic method for stabilization in operative procedure, and use of noninvasive procedure such as electromag-

netic and ultrasound.^{4,6}

The research is to analyzed that mechanical power move an electricity signal in bone which is influence the osseus activity (piezoelectric) inducing callus formation had been established.^{4,11} PEMF is a magnetic field that has permeative ability to the body especially the body cells and capable in producing frequency difference as same as Magnetic Resonance Imaging. In in vitro study, at cellular stage the use of electricity and electromagnetic flow is very related to cell's transduction trans membrane signal which is related to fracture healing, stimulates cell's proliferation and with synthesis of the cell's growth factor promote fracture healing, makes osteoprogenitor cell's differentiation and proliferation and extracellular matrix sedimentation.^{6,8}

PEMF stimulation research to the 45 nonunion tibial fracture patient was obtained 35% union fracture at week-10 and 85% at week-4.¹² Research of delayed union tibial fracture was obtained 45% union fracture after be stimulated by PEMF and 12% union of placebo group for 12 weeks.¹³ Union fracture research is about 38% use low intensity ultrasound to the human tibial fracture.¹⁰

The purpose of this research is to analyze the use of PEMF to the fresh tibial fracture with intact fibula which has high risk for delayed union. Using this device is able to accelerate the callus formation so the rate of delayed union or non union case will be decreased.

Materials and Methods

To be established an experimental research to the animal object as much as 32 wistar strain male rats at the age of 2 – 3 months old and weight at 200 grams and to be divided into 2 equal quantity of group by simple randomized that had been adapted to the environment for 1 week, then to be done an osteotomy to the right tibia and then to

be immobilized by plester of paris, and to the first group is given the pulsed electromagnetic stimulation by EBI-Bone Healing System® (New Jersey, USA), a stimulator machine with pulse rate at 4msec with the frequency 15 Hertz which is linked to the solenoid (a magnetic coil with Helmetz coil wire 0,5 mm as much as 150 twist) at the coil with the length about 2 cm, width 1,6cm and depth 2cm, which had functionally and effectively tested at the Bandung Technology Institute, Laboratory of Electricity, started at day-3 weekly, every 4 hours a day, 6 days per week and last for 5 weeks (figure 1), while the second group did not accept any treatment. And then an anteroposterior and lateral view radiography test is done to the right tibia at the end of the first week, second week and fifth week. After that, a growth analytic of callus is established use the Tiedemann scoring of the anteroposterior and lateral view of radiography.

Results

Two rats in treatment and one in control group were dropped out. The evaluation was done by radiographic, in anteroposterior (AP) and lateral (LAT) views during interval scale at each timing of radiography (figure 2-3). Normal distribution of the both variables (AP&LAT) was tested by Komogrov-Smirnov test. After that, the multivariate test were taken with the assessment of the AP and LAT views result at the both groups using software SPSS 18 which can be seen completely at the table shown below. Mean and standard deviation score of Tiedemann demonstrating the average similarity of two independent measurements for the AP view at first, second, and fifth week can be seen at table 1.

Based on this results in Table 1 can be concluded that average score Tiedemann at the first week, second week, and fifth week different significantly AP view ($p < 0.05$)

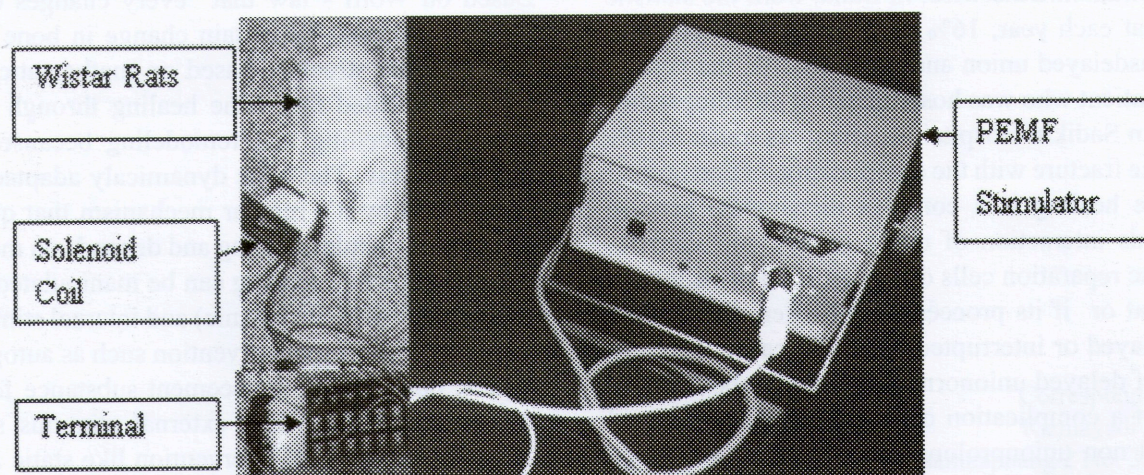


Figure 1. Diagram Bloc

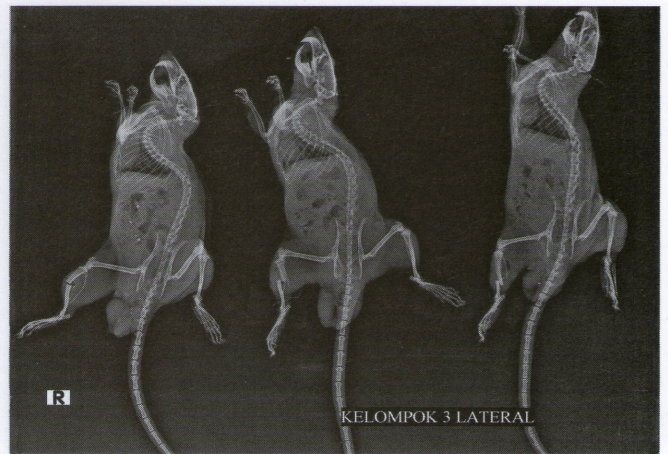
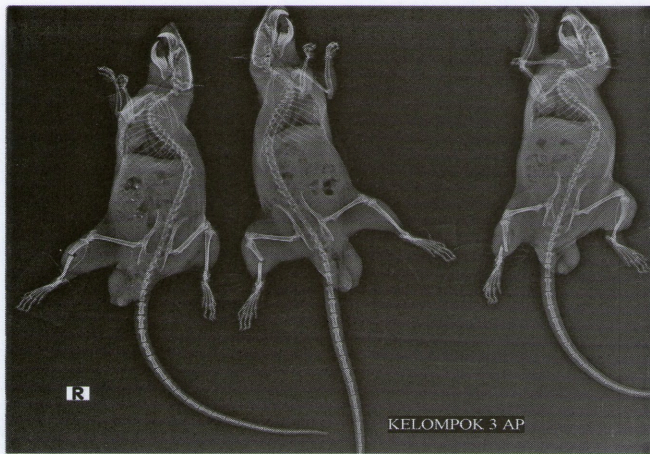


Figure 2. Control group radiographics evaluation at first week (top), second week (middle), and fifth week (bottom)



Figure 3. Treatment group radiographic evaluation at first (top), second (middle) and fifth week (bottom)

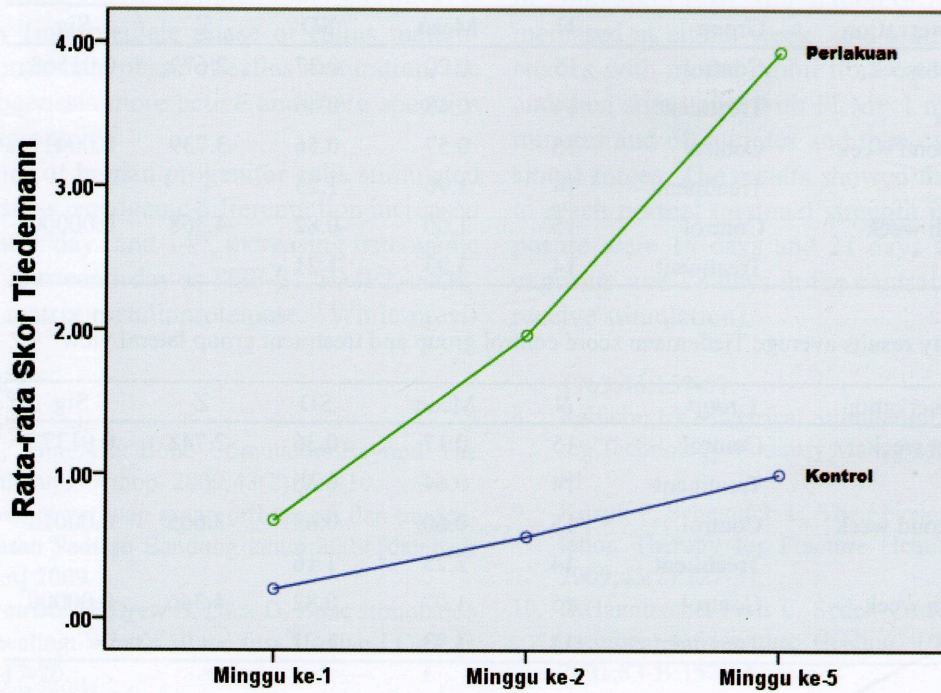


Figure 4. Comparison of mean Tiedemann score of anteroposterior view

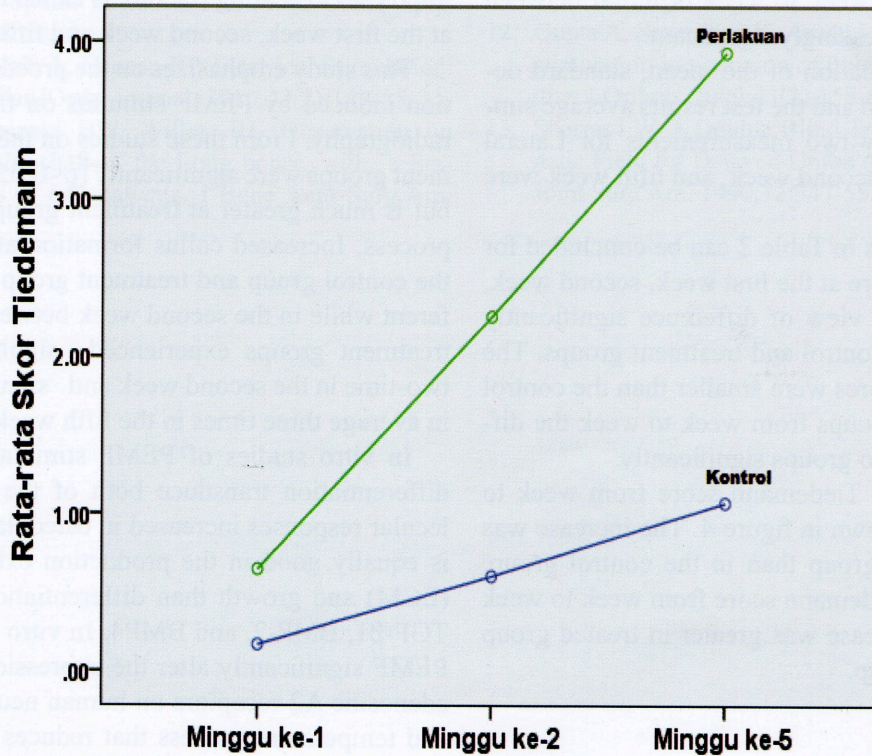


Figure 5. Comparison of Mean Tiedemann score of lateral view

Table 1. Equality assay results average Tiedemann score control group and treatment group anteroposterior view

Observation	Group	N	Mean	SD	Z	Sig
first week	Control	15	0.20	0.37	-2.672	0.01568
	Treatment	14	0.68	0.46		
second week	Control	15	0.57	0.56	-3.739	0.00011
	Treatment	14	1.96	1.23		
fifth week	Control	15	1.00	0.82	-4.368	0.00000
	Treatment	14	3.93	1.21		

Table 2. Equality assay results average Tiedemann score control group and treatment group lateral view

Observation	Group	N	Mean	SD	Z	Sig
first week	Control	15	0.17	0.36	-2.748	0.01375
	Treatment	14	0.64	0.46		
second week	Control	15	0.60	0.63	-3.665	0.00014
	Treatment	14	2.25	1.16		
fifth week	Control	15	1.07	0.82	-4.346	0.00000
	Treatment	14	3.93	1.21		

between the control and treatment groups. The average score Tiedemann smaller than the control group and treatment groups from week to week different between the two groups are increasingly significant.

The results of calculation of the mean, standard deviation score Tiedemann and the test results average similarity of independently two measurements for Lateral view of the first week, second week, and fifth week were presented in table 2.

Based on this results in Table 2 can be concluded for average Tiedemann score at the first week, second week, and fifth week Lateral view of difference significantly ($p < 0.05$) between the control and treatment groups. The average Tiedemann scores were smaller than the control group and treatment groups from week to week the difference between the two groups significantly.

Increase in average Tiedemann score from week to week in AP view is shown in figure 4. The increase was greater in the treated group than in the control group. Figure 5 shows the Tiedemann score from week to week in LAT view. The increase was greater in treated group than in the control group.

Discussions

Adult male wistar rats were used to eliminate hormonal influence, all sample were 2-3 months old to get relatively homogeny bone mature. Base on statistically, the variation of animal weight is not influence the result of

research. We used a score Tiedemann for radiograph evaluation to measurement callus formation. The most important to healing fracture is callus formation evaluate at the first week, second week and fifth week.⁴

This study emphasizes on the process of callus formation induced by PEMF stimulus on fracture healing by radiography. From these studies on the control and treatment groups were significantly ($p < 0.05$) increased callus, but is much greater at treatment group callus formation process. Increased callus formation at the first week in the control group and treatment group are not much different while in the second week between the control and treatment groups experienced significantly increased two-time in the second week and significantly increased in average three times in the fifth week .

In vitro studies of PEMF stimulation of osteoblast differentiation transduce both of the cellular and molecular responses increased in osteoblast proliferation. It is equally good in the production extra cellular matrix (ECM) and growth than differentiation factors such as TGF- β 1, BMP-2, and BMP4. In vitro studies the role of PEMF significantly alter the expression and function of adenosine A2 receptors on human neutrophils both time and temperature process that reduces production of superoxide on limited. Effect of the inflammatory response can be described so at time of the first week treatment group and control groups exhibited different significantly, although increase is still parallel. Previous histologi-

cal studies of the rats was done the fibula osteotomy and then stimulated using PEMF stimulator and sacrificed at twenty-third day (intermediate phase of callus maturation). In the intermediate phase of callus maturation, the process of osteogenesis more active and more specific on the stimulated group.^{12,13}

In vitro studies of human progenitor cells stimulated with PEMF to assess osteogenic differentiation increased mineralization at 9th day and 14th, increasing osteogenic marker genes at fourteenth day as TGF- β 1, BMP2, osteoprotegerin, and matrix metalloproteinase.¹¹ While previ-

ous studies on models at canine's tibia osteotomy gap of 2mm and PEMF stimulation of periosteal callus area increased at eighth week and tenth week. At previous studies with model rabbit tibia osteotomy is performed and then stimulated with PEMF 1 mm every day for 30 minutes and 60 minutes and then evaluated against torsional forces. The results showed that the time required to reach normal torsional strength in the 60-minute exposure were 14 days and 21 days while in 30-minute exposure was 28 days in the control group (who did not receive stimulation).

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