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Transcutaneous Electrical Nerve Stimulation (TENS) Reduces Pain and Drug Intake in the Immediate Postoperative Period Following Proximal Femoral Fractures

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Authors' contributions

This work was carried out in collaboration between all authors. Author MBD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FSS, MMS and ABMZR managed the analyses of the study. Author FSS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of this study was to evaluate the action of TENS on the pain threshold and on the intake of analgesic drugs in patients with proximal femoral fractures.
Study Design: Randomized, double-blind, placebo-controlled clinical trial.
Place and Duration of Study: Department of Orthopedics and Traumatology. Santa Luzia Hospital, between September 2015 and July 2016.
Methodology: Forty-two patients, homogeneous for age, color and sex, were allocated into three groups. The groups were divided into TENS treatment (n = 14), placebo TENS (n = 14) and control (n = 14), with application for a period of seventy-two hours postoperatively, assessing pain, by

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visual analogue scale, and drug intake (tenoxicam, dipyrone, tramadol, morphine and diazepam).
Results: Long-term TENS reduced postoperative pain and drug intake significantly (P<0.05). The pain threshold (P<0.05) and the administration of drugs tenoxicam, dipyrone, tramadol and morphine (P<0.05) after TENS treatment showed significant improvement. The other groups did not present these alterations.
Conclusion: TENS, when used ininterrupedly, was shown to be effective both for pain reduction and drug administration in the immediate postoperative period.

Keywords: Transcutaneous electrical stimulation; femoral fractures; analgesics; opioid.

ABBREVIATIONS

VAS : Visual Analogue Pain Scale
TENS : Transcutaneous Electrical Nerve Stimulation

1. INTRODUCTION

Proximal femoral fractures are considered a major problem worldwide [1]. This dysfunction is increasingly present in hospital routines and in daily life due to the population's increased life expectancy in recent decades [1]. Increased survival further influences the risk of developing comorbidities in the elderly population, such as changes in muscle strength, balance, reflexes, visual impairment, neurological deficiency and reduction of physical activity and bone mineral density, resulting in osteopenia and, later, in osteoporosis [2]. The treatment recommended for patients with proximal femoral fractures is, preferably, the surgical one, with placement of synthesis material or prosthesis, aiming at stability and an earlier functional return [3].

This type of fracture is one of the main causes of mortality and functional disability among the elderly, representing today one of the main public health problems in several countries [4]. These traumas have considerable economic repercussions in society, such as direct costs, which are defined as costs of hospital care and, after discharge, indirect costs, taking into account non-productivity, that is, withdrawal from work due to illness [4,5].

In the immediate postoperative period, patients with bone trauma suffer from painful discomfort, which may lead to altered metabolism, affecting the pulmonary, cardiovascular, gastrointestinal, urinary, neurological and endocrine systems [6]. Analgesia is essential for the postoperative care of these patients [6]. Treatment with analgesic and anti-inflammatory drugs through the intravenous route is recommended, being often used to manage postoperative pain in most hospitals [6]. Notwithstanding, there are side effects with the use of these opioids, such as nausea, vomiting and pruritus [6].

Transcutaneous electrical nerve stimulation (TENS) is a low frequency electrical modality, which is used as a physiotherapeutic resource of clinical purpose in the symptomatic relief of pain [7]. It is considered an efficient, easy-to-apply, non-invasive, non-toxic, comfortable procedure for the patient in 95% of cases, and is a relatively low-cost method [8,9]. The application is made through an electric current generated by the device and transmitted by means of electrodes that are placed on the skin [10]. The mechanism of action of TENS works according to the gate control theory postulated by Melzack and Wall [11]. Overstimulation of type A gamma fibers promotes the blockade of stimulus entry by type C fibers (nociceptors) in the gates of the posterior horn of the spinal cord (gelatinous substance) influence the first central transmission (T) cells of spinal cord, thus promoting analgesia [8,11]. Due to the effect of TENS, it can be administered in the postoperative routine of several surgical conditions, as an adjunct to conventional opioid analgesia [12].

The objective of this study was to evaluate the action of TENS on the pain threshold and on the intake of analgesic drugs in patients with proximal femoral fractures.

2. MATERIALS AND METHODS

The present study was characterized as a randomized, double-blind, placebo-controlled clinical trial. It was approved by the Ethics and Research Committee of the Mãe de Deus Hospital under opinion No. 1.228184. The research was applied during the period from September 2015 to July 2016 in the Department of Orthopedics and Traumatology of the Santa

Luzia Hospital, in the city of Capão da Canoa/RS. In all, 65 patients hospitalized with a diagnosis of proximal femoral fracture participated in this study. Of these, 42 patients met the eligibility criteria and finalized the study.

The inclusion criteria of the study were patients older than 18 years who presented a diagnosis of proximal femoral fracture and signed the free and informed consent form (FICF). Exclusion criteria were age less than 18 years, cognitive impairment, sequelae of stroke (CVA), loss of consciousness, patients with proximal femoral fracture submitted to reintervention, death during the research, patients with lack of superficial sensitivity, and dropout during the study. 23 patients were excluded from the study, nine due to cognitive deficits, five with previous sequelae of stroke, two due to loss of consciousness, two undergoing reintervention of an old fracture, and one who withdrew from the study in the intervention period. In addition, four patients died in the trans- or postoperative period.

After signing the free and informed consent form, patients were randomized through envelopes containing the name of the group to which the patient would belong: control group (n = 14), TENS group (n = 14) and placebo TENS group (n = 14).

The analgesic routine adopted by the assistant doctors of the team was the same for all subjects, maintained unchanged. The medication prescription protocol was adopted by all surgeons of the medical team in the Department of Orthopedics and Traumatology of the institution. This included: tenoxicam 20 mg every 12 hours in case of pain, sodium dipyrone 1000 mg in case of pain or fever, tramadol 100 mg in case of pain, morphine 3 mg every 3 hours in case of pain and diazepam 10 mg in case of pain or excessive agitation.

2.1 Evaluation Protocol

The evaluations were performed by a blind evaluator, that is, an evaluator who did not know to which group the patient belonged to. These took place in four different moments: the first evaluation was during the period of preoperative hospitalization, shortly after hospitalization and prior to randomization. The second evaluation occurred 24 hours after the surgical procedure. The third one occurred 48 hours postoperatively, and finally the final evaluation, on the third postoperative day (Fig. 1).

Pain measurement was done through visual analogue scale (VAS). The patient was asked about his/her degree of pain, with zero meaning total absence of pain and ten indicating maximum bearable pain.

Daily and total drug intake were recorded on an evaluation form both in the preoperative evaluation and on each of the three days following the surgical procedure in each study group. After that, the percentage of reduction of medication consumption in each of the intervention groups was calculated in relation to the control group.

2.2 Intervention Protocol

The TENS intervention protocol started in the surgical recovery room after consent of the nurse responsible for the surgical block. The intervention was maintained 24 hours a day and closed after 72 hours of surgery. The equipment was only switched off for patient hygiene.

A Neurodyn III portable TENS equipment, brand IBRAMED®, was used. The patients underwent TENS in the conventional mode, continuously, with two channels positioned to surround the surgical wound. Self-adhesive electrodes (5x5 cm) were used. The parameters used were: frequency of 120 Hz with a phase duration of 100 μs and stimulation intensity according to the patient's reported sensation of paresthesia, in order to promote intense stimulation without, however, causing discomfort. The intensity in the TENS group was raised every three hours in order to avoid current accommodation at the patient's sensory level. Patients in the placebo TENS group received the same protocol, but with zero current intensity (Fig. 2). Both groups received the same standard protocol of physiotherapy during the study period.

2.3 Statistical Analysis

Initially, data were descriptively expressed as mean and standard deviation. Afterwards, they were statistically analyzed by one-way analysis of variance (ANOVA) for repeated measures, followed by Bonferroni post hoc test for intragroup comparisons. Analysis of variance (ANOVA) was used for intergroup comparisons, followed by post hoc Tukey test. The significance level established for the statistical test was $p<0.05$. SPSS (Statistical Package for the Social Sciences) version 17.0 was used as statistical package.

3. RESULTS

Sixty-five patients with proximal femoral fractures were initially hospitalized in the Department of Orthopedics and Traumatology of the hospital. Of these, 42 patients signed the free and informed consent form and fit the inclusion criteria for the study participation. The mean age was 79.4 ± 13.32 years. Twenty-five patients were female (59.53%). All patients were white. The most prevalent type of fracture was femoral neck fracture (50%), followed by transtrochanteric fractures (40.47%). The groups were homogenous regarding gender, age, skin color and type of fracture (Table 1).

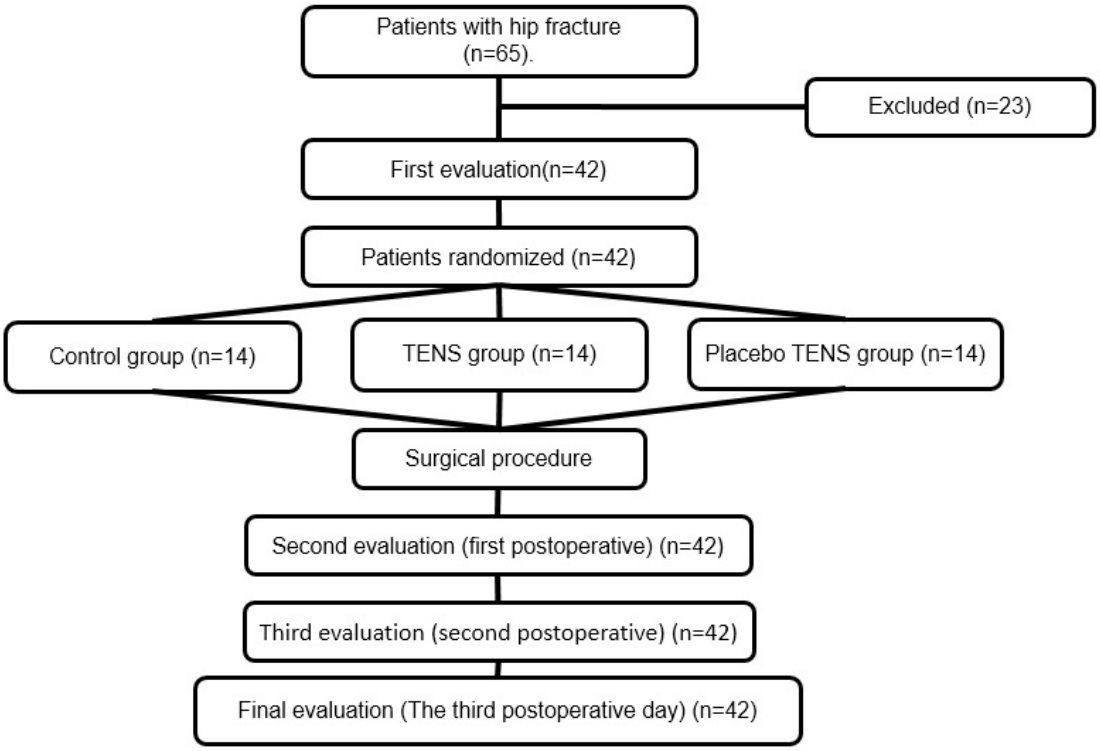

Fig. 1. Study flowchart

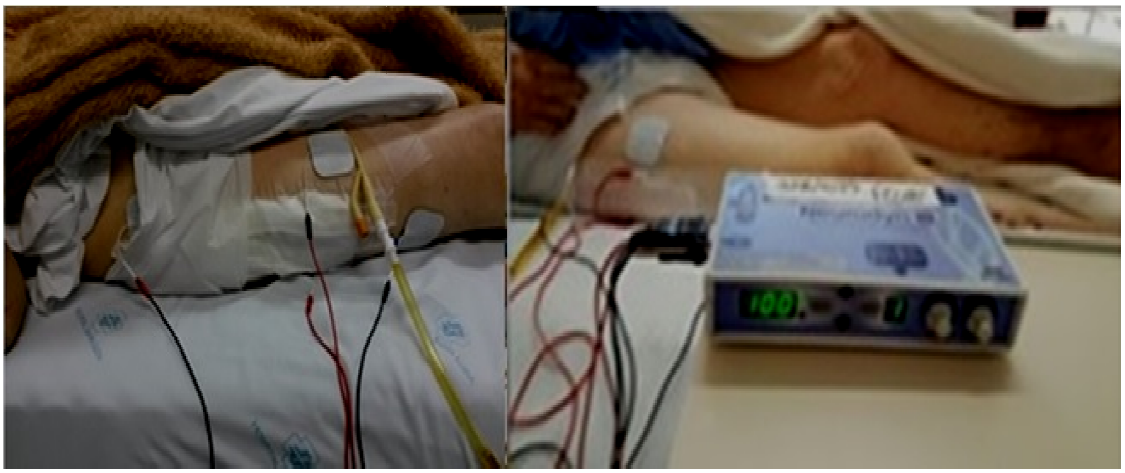

Fig. 2. Positioning of the electrodes of the TENS current

Table 1. Characterization of the study sample (n=42)

Variable	Group			p-value
	TENS (n=14)	Placebo TENS (n=14)	Control (n=14)	
Gender, M/F	7/7	5/9	5/9	0.67
Age, years (mean ± sd)	82.29 ± 10.96	77.79 ± 11.94	78.14 ± 16.83	0.50
Skin color, n (%)				1.00
White	14 (100.0)	14 (100.0)	14 (100.0)	
Black	0 (0.0)	0 (0.0)	0 (0.0)	
Type of fracture, n (%)				0.31
Femoral neck	9 (64.3)	6 (42.9)	6 (42.9)	
Transtrochanteric	5 (35.7)	5 (35.7)	7 (50.0)	
Subtrochanteric	0 (0.0)	3 (21.4)	1 (7.1)	

M=male; F=female

In comparison with the preoperative pain (4.21 ± 3.21), the TENS group presented a significant reduction immediately after surgery, i.e., on the first postoperative day (1.29 ± 1.82) (P = .01). This reduction in pain persisted on the second postoperative day (1.0 ± 1.62) (P = .01) and on the third postoperative day (0.64 ± 1.15) (P = .001) (Fig. 3).

The placebo TENS group showed a significant reduction regarding preoperative pain (5.14 ± 2.32) only for the second postoperative day (3.00 ± 2.48) (P = .05) and for the third postoperative day (3.07 ± 1.94) (P = .03). The control group did not show improvement in pain in any of the three postoperative days compared to the preoperative evaluation (Fig. 3).

The TENS group demonstrated a significant reduction of the pain level in all phases of the postoperative period compared to the placebo TENS and control groups (p<0.001) (Fig. 3).

There was a significant increase in the intake of tenoxicam, sodium dipyrone and tramadol in the immediate postoperative period in the placebo TENS and control groups (P = .05). In the TENS group, this increase was not observed, remaining at doses similar to the preoperative period (Table 2).

On the third postoperative day, the administered dose of tramadol was significantly higher in the control group (57.14 ± 86.16 mg) than in the TENS group (0.0 ± 0.0 mg) (P = .02). Yet the placebo TENS group significantly reduced the dose compared to the first postoperative day (14.29 ± 36.31 mg) (P = .02) (Table 2).

There were no significant differences in morphine administration between the study groups (Table 2).

On the first postoperative day, the placebo TENS and control groups showed a significant increase in the administered dose of tramadol in relation to the preoperative and the same day of the TENS group (P = .05). In the TENS group, the initial dose of tramadol in the preoperative period was 28.57 ± 61.12 mg. In the immediate postoperative period, the dose was 50.00 ± 75.96. Yet the placebo TENS group presented a preoperative dose of 14.29 ± 53.45 mg, increasing to 135.71 ± 108.18 mg on the first postoperative day (P = .02). The control group presented a dose of 7.14 ± 26.73 mg in the preoperative period, increasing to 128.57 ± 99.50mg in the first postoperative day (P = .01). On the third postoperative day, the dose of the TENS group was 0.00 ± 0.00 mg, whereas the dose of the control group was 57.14 ± 86.16 (P = .02). The placebo TENS group demonstrated a significantly lower dose than that administered on the first postoperative day (14.29 ± 36.31mg) (P = .02) (Fig. 4).

The total dose of tramadol administered in the TENS group was significantly lower than in the placebo TENS and control groups (P = .01). The total dose in the TENS group was 92.86 ± 82.87 mg. The placebo TENS group presented a total dose of 235.71 ± 182.32 mg. The control group obtained a total dose of 250.0 ± 85.48 mg (Fig. 5).

The TENS group showed a reduction of 62.85% in relation to the control group, and of 60.61% in relation to the placebo TENS group (P = .003) (Fig. 5).

The total dose of tenoxicam of the TENS group had a significant reduction compared to the placebo TENS and control groups, being of 45.72%, when compared to the control group, and of 40.63%, when compared to the placebo TENS group (P = .02) (Fig. 6).

Table 2. Pain level and doses of medications during the study period (n = 42)

Variable	Assessments			
	Preoperative	1st postoperative	2nd postoperative	3rd postoperative
VAS				
TENS	4.21 ± 3.22	1.29 ± 1.82*	1.00 ± 1.62*	0.64 ± 1.15*
Placebo TENS	5.14 ± 2.32	3.93 ± 2.49#	3.00 ± 2.48*#	3.07 ± 1.94*#
Control	3.50 ± 3.01	5.21 ± 2.67#	4.64 ± 1.91#	2.64 ± 1.82#†$
Tenoxicam 20 mg, mg				
TENS	2.86 ± 7.26	7.14 ± 14.90	10.00 ± 15.19	7.14 ± 9.94
Placebo TENS	0.0 ± 0.00	14.29 ± 16.51*	17.14 ± 18.98*	14.29 ± 16.51*
Control	2.86 ± 7.26	18.57 ± 16.58*	15.71 ± 16.04	12.86 ± 12.67
Dipyrone 500 mg, mg				
TENS	214.29 ± 425.81	1.000.00 ± 1.240.35	785.71 ± 1.368.80	500.00 ± 1.091.93
Placebo TENS	214.29 ± 578.93	1.571.43 ± 1.342.46*	785.71 ± 974.96	642.86 ± 928.78
Control	285.71 ± 611.25	1.357.14 ± 744.95*	785.71 ± 1.050.90	857.14 ± 534.52*
Tramadol 100 mg, mg				
TENS	28.57 ± 61.12	50.00 ± 75.96	14.29 ± 36.31	0.00 ± 0.00
Placebo TENS	14.29 ± 53.45	135.71 ± 108.18*#	71.43 ± 106.90	14.29 ± 36.31†
Control	7.14 ± 26.73	128.57 ± 99.50*	57.14 ± 75.59	57.14 ± 86.16#
Morphine 3 mg, mg				
TENS	0.21 ± 0.80	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Placebo TENS	0.21 ± 0.80	1.07 ± 1.90	0.21 ± 0.82	0.00 ± 0.00
Control	0.00 ± 0.00	1.29 ± 2.27	0.43 ± 1.09	0.00 ± 0.00
Diazepam 10 mg, mg				
TENS	0.00 ± 0.00	1.43 ± 3.63	3.57 ± 4.97	3.57 ± 4.97
Placebo TENS	2.14 ± 4.26	7.14 ± 9.14#	7.14 ± 6.11	4.29 ± 5.14
Control	0.71 ± 2.67	2.14 ± 4.26	2.86 ± 4.69	3.57 ± 4.97

VAS = visual analogue pain scale.
** p<.05 compared to the preoperative evaluation.*
† p<.05 compared to the 1st postoperative evaluation.
& p<.05 compared to the 2nd postoperative evaluation.
 # p<.05 compared to the same TENS group.
ANOVA for repeated measurements and one-way ANOVA

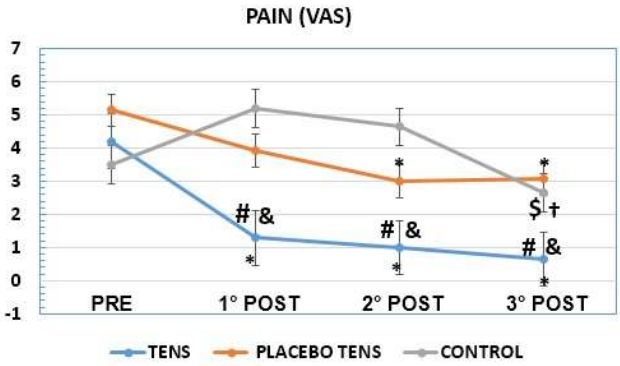

Fig. 3. Mean values of the Visual Pain Scale (VAS) for each study group

 # p<.05 compared to the control group. One-way ANOVA;
& p<.05 compared to the placebo TENS group. One-way ANOVA;
** p<0.05 compared to the preoperative evaluation of the same group. ANOVA for repeted measures;*
† p<.05 compared to 1st postoperative day of the same group. ANOVA for repeated measures;
$ p<.05 in relation to the 2nd postoperative day of the same group. ANOVA for repeated measures

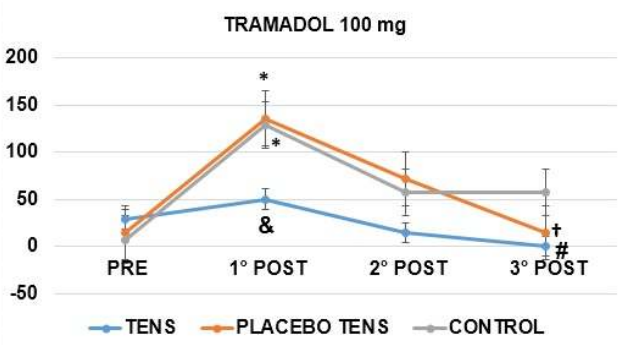

Fig. 4. Mean values of the use of tramadol 100 mg in the study groups

 # p<0.05 compared to the control group;
& p<0.05 compared to the placebo TENS group;
** p<0.05 compared to the preoperative evaluation of the same group;*
† p<0.05 compared to the 1st postoperative day of the same group;
One-way ANOVA and ANOVA for repeated measures

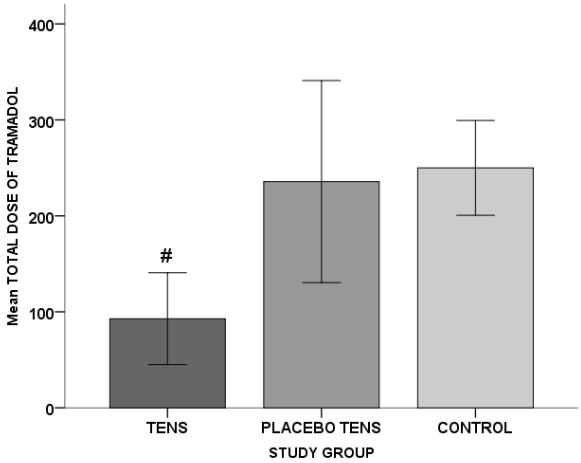

Fig. 5. Total dose of tramadol (mg) throughout the intervention period for each group

 # P =.0.03 compared to the control group and the placebo TENS group.
One-way ANOVA

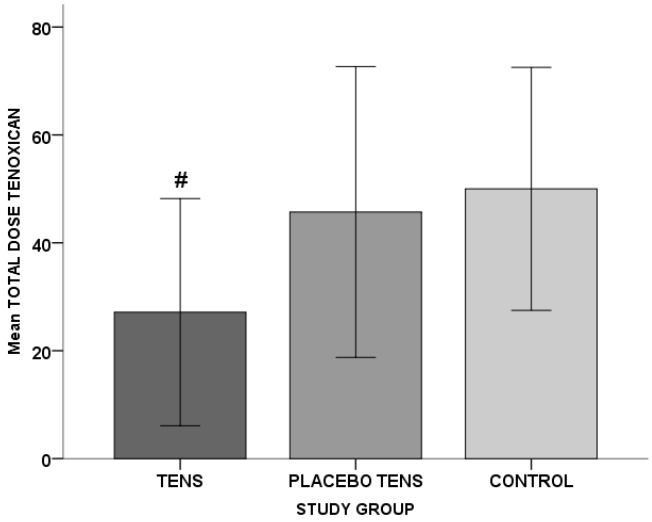

Fig. 6. Total dose of tenoxicam throughout the intervention period for each group
 # P = .02 One-way ANOVA compared to the control group and the placebo TENS group

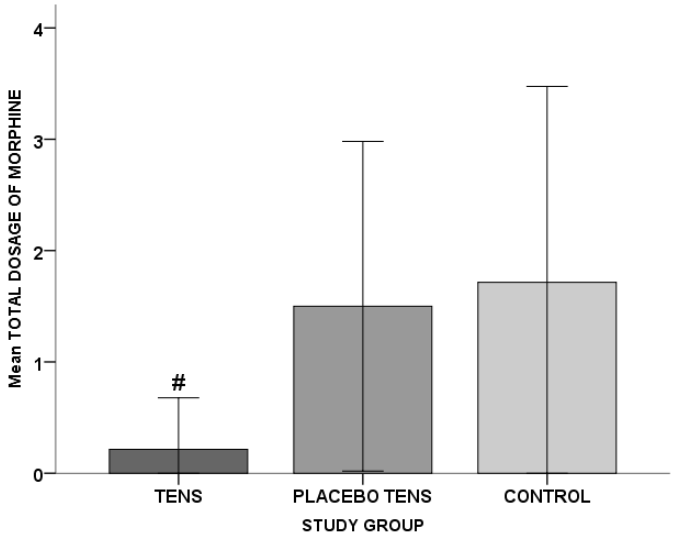

Fig. 7. Total dose of morphine (mg) throughout the intervention period for each group
 # P =.05. One-way ANOVA compared to the control group and the placebo TENS group

Regarding the total dose of morphine, the TENS group had a reduction of 87.72%, when compared to the control, and of 86%, in comparison with the placebo TENS group (P = .05) (Fig. 7 above).

4. DISCUSSION

Postoperative pain is a condition that involves and concerns the multiprofessional health team, in order to choose the best way to ease it. Above all, it is necessary to take into account that its presence may hide surgical complications after the procedure, which may hinder physiotherapeutic care [13]. The incisional pain of a surgery, at rest or while performing some movement, is one of the forms of manifestation of the inflammatory processes and cellular lesions resulting from a surgical procedure, being often difficult to reduce by means of conventional analgesia with drugs [13].

Since 1970, TENS has been studied regarding its possible effects on pain modulation in acute and chronic phases [14]. The studies were expanded to also benefit the pain processes that occurred during the postoperative period of hospitalization [14]. This randomized, double-

blind, placebo-controlled clinical trial evaluated the action of TENS on the pain threshold and on the intake of analgesic and anti-inflammatory drugs in patients with proximal femoral fractures. A highly positive effect was found with TENS on pain modulation, besides decreased intake of drugs such as tenoxicam, tramadol, dipyrone and morphine ($P < .05$).

The conventional TENS, used for the treatment of acute conditions, works through a segmental mechanism and the electrodes are placed in a way to stimulate the A-beta fibers, which enter the same spinal segment as the nociceptive fibers associated with the origin of the pain [15]. Electrodes are usually applied to surround the painful area [15]. Several studies have demonstrated the effectiveness of TENS on the level of pain in various postoperative conditions. However, not all of them demonstrate a reduction in the need for drug administration during this period. The difference in drug intake may be related to the stimulation time used. Our results suggest that the TENS is applied uninterruptedly, controlling, throughout the stimulation time, the maintenance of the current sensory level. Thus, TENS can produce a more significant effect of closing the pain gate at the level of the spinal cord, avoiding an increase in the level of pain to the point of decreasing the need for drug administration. Tonella et al. [13] used TENS in pain relief related to postoperative physiotherapy in patients undergoing abdominal surgery. Three groups were formed, TENS intervention group, placebo TENS group and control group. As parameters, two channels surrounding the incision were used, with frequency of 150 Hz, with a phase duration of 150 to 250 pps, intensity according to the patient's sensation of paraesthesia and application for 30 minutes. The drugs administered in the postoperative period were morphine, dipyrone, tenoxicam, tramadol, adiphenine and promethazine. Thus, as in the present study, the researchers observed a decrease in pain in the group that used the TENS, but there was no reduction in the use of drugs. Gregorini et al. [14] evaluated the use of short-term TENS to reduce pain and the possible interference in respiratory muscle strength, lung volume and capacity in patients in the postoperative period of cardiac surgery. Patients were divided into TENS group and placebo TENS group. Two channels were placed beside the incision with adhesive electrodes, with frequency of 80 Hz, with a phase duration of 150 pps and intensity according to the patient's report, applied for four hours. TENS significantly reduced the level of postoperative pain compared to the placebo group. The results showed that TENS was effective in controlling pain in the postoperative period, being useful when patients present severe pain.

Santana et al. [16] used TENS to reduce pain and the need for pharmacological analgesia during the active phase of childbirth. Patients were allocated into intervention group and control group. Two channels were placed laterally 1 cm from the vertebral column, on both sides of it, between the 10th thoracic vertebra and the 4th lumbar vertebra, and between the 1st and 4th sacral vertebrae, which are the spinal levels responsible for receiving nociceptive information from the uterus, birth canal, and perineum. The frequency was 100 Hz, phase duration was 100pps and the intensity was set according to the sensitivity of the patient. The application was made for 30 minutes at the beginning of the active phase of childbirth, and as a result, the authors found a significant decrease in pain level. Notwithstanding, the application of TENS did not alter the location or distribution of pain. It was also observed that TENS delayed for a certain time the need for drugs for analgesia.

About-Setta et al. [17] carried out a systematic review in bibliographic databases with the objective of evaluating the benefits and harms of pharmacological and non-pharmacological interventions to control pain after a hip fracture. A total of 14 studies were included, between 1990 and 2010. Most studies investigated preoperative or intraoperative pain. The most commonly used interventions were nerve block, anesthesia and traction. It has been reported that nerve block may be effective in reducing acute pain in post-hip fracture patients, but there is a lack of stronger evidence in these studies, hindering conclusions about the benefits or harms of other resources for pain relief. The present study demonstrated that by maintaining a stimulation of the sensory nerve pathways with TENS throughout the postoperative period of patients with proximal femoral fractures, it is possible to promote effective analgesia.

Lang et al. [18] evaluated the efficacy of TENS in the acute pain of patients with hip trauma during emergency transport to the hospital. Two groups were created, TENS group and placebo TENS group. Two channels were positioned near the anterosuperior iliac spine and the major trochanter of the femur, with a frequency of 100 Hz, a phase duration of 200 pps and intensity

according to the sensitivity of the patient for a time of 30 minutes. The results suggest that TENS was useful in the acute phase of severe hip pain after trauma to patients in an emergency ambulance, reducing the pain threshold and maintaining normal heart rate, making patients more relaxed and less anxious. It is believed that electrical stimulation can be comfortable for the patient in 95% of the cases [8,9].

Lee et al. [19] investigated the effect of TENS on postoperative pain in patients with Colles' fracture, creating two groups: intervention and placebo. Treatment with TENS started between four and six hours after the surgical procedure. A channel with frequency of 50 Hz was used and the stimulus was only sufficient to produce a visible muscle contraction, with stimulation time of 15 minutes per day for five days. The evaluated items were pain level (by VAS), use of drugs such as cataflam 75 mg, morphine 40 mg and butyrophenone 60 mg, as well as the number of vomiting (per day and total). No differences were found between the two groups. However, the authors suggested that TENS could be effective if the stimulation had been maintained for 24 hours. In this study, we achieved a reduction rate of drug intake of 45.72% for tenoxicam, 62.85% for tramadol, 28.57% for dipyrone and 87.72% for morphine. It is also suggested that in acute-phase lesions a high stimulation frequency is used to stimulate type A fibers, which promote the blockade of stimulus entry by type C fibers in the gates of the posterior horn of the spinal cord (gelatinous substance) and in T cells, thus promoting more expressive analgesia [8,11].

Fiorelli et al. [20] analyzed the effects of TENS on cytokine levels, pain, respiratory function and drug intake in post-thoracotomy surgery patients. Subjects were allocated into intervention group and placebo group. A channel with electrodes was positioned 2 cm from the suture line, with frequency of 80 Hz, phase duration of 250 pps and intensity with comfortable tingling sensation. In the first 48 hours, the application of electrical stimulation was performed every 30 minutes, with an interval of 4 hours between each application. In the following period, it was maintained until the 5th postoperative day, twice daily, maintaining the same 30 minutes. The results showed that TENS may be a valuable strategy to relieve post-thoracotomy pain, reducing the production of cytokines, which has a positive effect on lung ventilation and on the reduction of morphine use. The findings of this study corroborate our findings, where a reduction of 87.72% was obtained for morphine use. Cipriano et al. [21] measured the effects of TENS on the treatment of postoperative pain, pulmonary function and muscle electrical activation of patients who underwent cardiac surgery. Subjects were divided into intervention group and placebo group. Two channels with self-adhesive electrodes were arranged at approximately two to three centimeters from the suture line, with frequency of 80 Hz, phase duration of 150 pps and intensity according to patient tolerance. The treatment was maintained for four hours after the surgical procedure. There was a significant improvement in the reduction of pain level and positive effects on lung function and muscle electrical activation of patients after cardiac surgery.

One of the difficulties found in the literature for the analysis of the effect of TENS in post-surgical states is the stimulation parameters. Kerai et al. [22] made a systematic review on treatments using TENS for analgesia and decreased side effects such as nausea and vomiting in patients in the postoperative period. The initial search identified 377 studies. Based on the title and abstract, 29 studies were included. Most of them demonstrated a clinically significant reduction in pain intensity and use of analgesics. Consequently, there was a decrease in side effects. Nonetheless, the authors found a variance between the parameters used in TENS such as duration, intensity, stimulation frequency and electrode location. In this study, we used 5x5 cm self-adhesive electrodes. The parameters used were phase duration of 100 μs, frequency of 120 Hz and intensity of stimulation according to the patient's reported sensation, in order to promote intense stimulation without causing discomfort. Melzack initially proposed that the mechanism of action of TENS is given by a modification of the perception of pain through counter-stimulation of the peripheral nervous system under the premise of the pain gate theory [23]. Further investigations attributed the mechanism of pain relief to the inhibition of nociceptive C-fibers through the stimulation of different A-fibers, depending on the amplitude of the stimulation at the segmental level of the spinal cord [18]. Another mechanism of action is the activation of efferent inhibition pathways from subcortical cerebral structures [18]. The release of endorphins through electrical stimulation plays an additional important role in relieving pain through TENS [18]. However, when used in a high-frequency range, as in our study, TENS

reduces pain by interfering with the transmission of nociceptive input at the level of the spinal cord through the activation of ɣ-opioid and $GABA_A$ receptors, subsequently reducing the input of pain through the ascending spinothalamic tract. In addition, the stimuli may activate ɣ-opioid receptors on the periaqueductal gray matter and posterior horn of the medulla, reducing the release of glutamate [24].

Lan et al. [25] investigated the use of TENS on acupoints in the production of some analgesic effect in the postoperative period after total hip arthroplasty (THA) in elderly patients. The use of TENS was compared to the acupuncture and placebo groups. Six acupoints were used (bilateral P6, L14; ST36, GB31 ipsilateral to the surgery site). A frequency of 2/100Hz (alternating stimulation at 2Hz and 100Hz every 3 seconds) was defined, and intensity according to patient tolerance. The application was done 30 minutes before the surgical procedure and two, four, 20 and 44 hours after surgery, each lasting 30 minutes. There were no differences between the two stimulation groups in the reduction of the pain threshold, but the acupuncture group showed a significant reduction in the administration of Fentanyl, and this led to a significant decrease in side effects such as nausea, vomiting and dizziness.

5. CONCLUSION

Transcutaneous electrical nerve stimulation, used uninterruptedly during the immediate postoperative period following proximal femoral fractures, significantly reduced pain threshold and drug intake. However, further studies are needed to confirm these findings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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