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RESEARCH ARTICLE

The Effects of Pulsed Electromagnetic Field in the Treatment of Osteoarthritis in Dogs: Clinical Study

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ABSTRACT

In this study the effects of pulsed electromagnetic field (PEMF) on pain relief and functional capacity of dogs with osteoarthritis (OA) were investigated, and compared with firocoxib. Patients were randomly assigned to two groups: twenty-five client-owned dogs were treated with PEMF once a day for 20 sessions, and fifteen dogs (control group) were treated with 5 mg/kg of firocoxib once daily for 20 days. Blinded clinical examination and owner's assessment were recorded before and after the therapy, as well as 4 and 12 months later. Data collections were statistically compared before and after treatments and between groups. Both groups showed decreased clinical signs of OA during the treatment. Compared with baseline, these improvements were statistically significant ($P<0.01$) during the therapies. Differences were recorded during observation time spans following the end of treatments. In the PEMF group the effects were sustained until the end of the study, whereas in the control group the progress tended to return to baseline values after the end of therapy. The beneficial effects of PEMF on pain relief and functional capacity make it a potential treatment modality for canine osteoarthritis compared to traditional pharmacological therapy, in absence of adverse effects and in favour of the quality of life.

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INTRODUCTION

The impact of chronic pain and inflammation on the quality of life and on disability has been well documented (Wiseman-Orr *et al.,* 2006). Osteoarthritis (OA) is the most common cause of chronic pain in both young and elderly dogs. OA is a chronic degenerative disease characterized by the destruction of the articular cartilage, which leads to capsular inflammation, synovitis, production of marginal osteophytes and subchondral sclerosis (Johnston and Budsberg, 1997). Lameness, joint pain and stiffness are main clinical symptoms in canine OA, although chronic pain is also assessed by behavioral changes (Wiseman-Orr *et al.,* 2006).

The goals of OA treatments are to relieve pain, to control inflammation, to maintain function and range of motion (ROM), and to increase functional capacity. There are various medical treatments (non-steroidal anti-inflammatory drugs –NSAID-, analgesics, nutraceuticals, functional food, physical therapy), up to surgical methods (Sanderson *et al.,* 2009). Although effective, some of these treatments may lead to adverse effects. Consequently, alternative treatment choices (electromagnetic field therapy for one) are needed. The effectiveness of pulsed electromagnetic field (PEMF) therapy has been well demonstrated by several experimental and clinical studies (Pipitone and Scott, 2001; Fini *et al.,* 2008; Ongaro *et al.,* 2011), and the PEMF therapy is widely used in human medicine (Markov, 2007; Ryang *et al.,* 2012). As far as could be ascertained, only a few physical therapies for canine OA have been reported (Scardino *et al*., 1998; Shafford *et al.,* 2002; Canapp, 2007). PEMF employs low frequency non-ionized athermic and time-varying electromagnetic fields. PEMF activates biological processes including an increase in erythrocyte membrane potential, tissue oxygenation, vascular vasodilatation and pain relief without heating (Pipitone and Scott, 2001).

The present study focused to evaluate the effects of pulsed electromagnetic field on pain relief and functional

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capacity of dogs with OA. To collect further data on the effectiveness of PEMF, a study comparing PEMF to the frequently used firocoxib (an approved NSAID for OA) was carried out.

MATERIALS AND METHODS

Study design: The present study was a single-center, prospective, observational, randomized clinical trial. The dogs were assigned to 2 groups viz., group 1 (PEMF group) and group 2 (firocoxib-control group). Owners of the dog of group 1 were informed about the study and received a detailed written description about the clinical survey as well as about the physical and therapeutic characteristics of PEMF and of the employed medical device (Medithera Medical-Vet; ConsForm; Pordenone, Italy). Owners signed a written informed consent, stating also their obligation to bring their own dogs to the veterinary hospital at least 3 times per week, for a total of 20 sessions. In group 2, the patients received firocoxib (Previcox; Merial), 5 mg/kg once daily per 20 days.

Owners of both groups agreed to bring their dogs for re-checkup at mid-therapy, at the end of therapy, and at 4 and 12 months after the conclusion of treatment. Moreover, owners were asked not to give any analgesic drugs, or other medications, nor to change their dogs' dietary and environmental habits, and to report any health problems which might occur during the study period.

Inclusion criteria: Only dogs that had had lameness for at least 4 weeks were chosen for this study. It was also required a radiographic evidence of OA in one or more joints, supported by a complete clinical examination, in order to confirm OA as the cause of lameness.

Exclusion criteria were: systemic diseases, infectious arthritis, neurologic disease or orthopedic disease different from OA. Dogs that had been treated with NSAID in the last 2 weeks, or with corticosteroids or opioids during the 4 weeks prior to evaluation, were excluded too. And also pregnant patients were not enrolled.

Medical device: Pulsed electromagnetic field treatment was delivered by an electromagnetic device using a quantum resonance system. This system delivers double sawtooth waveform of weak intensity and various low frequencies. Dogs were laid on a pulsated electromagnetic field mat (Fig. 1) and treatment was applied on the whole body at a cyclic frequency of 3-22-250-500 Hz and intensity of 0.75 μT for 10 minutes, followed by a small pad was employed on the affected joint(s) at a cyclic frequency of 0.3-1.5-3 Hz and intensity of 0.75 μT for 8 minutes, 3 to 6 times per week for a total of 20 sessions.

Data collection and statistical analysis: The effectiveness of the treatments was assessed by the clinician as the change in three main variables. Lameness, pain elicited upon palpation and ROM were evaluated, on the basis of an orthopedic examination, at the beginning of the therapy (T0), at mid-therapy (T10), and at the end of the therapy (T20). Then symptoms were re-evaluated at 4 and 12 months after the end of treatment (T4 mo and T12 mo). Group 2 assessments at T12 mo were not performed and the period of study was terminated 4 months after the end of therapy.

At each time point, lameness was scored on a basis scale of 0 to 4 (none to extreme), presence or absence of pain on manipulation was recorded as yes/no, and ROM was measured by goniometer and compared with contralateral joint and scored as decreased/normal (Table 1). Radiographic exams were taken at the beginning and at the end of the treatment, and scoring of the OA signs was based on a scale from 0 to 4 (normal to severe). At each point of observation, owners were submitted a questionnaire to measure the effects of chronic pain on the health-related quality of life of their dogs on the basis of behavioral changes (Wiseman-Orr *et al.*, 2006).

Table 1: Scoring system for the clinical sign and owner's evaluation

Variables	Score	Definition
Lameness	0	none
	1	slight: slightly altered movement, function preserved
	2	mild: altered movement, function preserved
	3	moderate: altered movement, function impaired
	4	extreme: altered movement, function lost
Pain on palpation	Yes	presence of reaction to palpation or passive movement
	No	absence of reaction to palpation or passive movement
Range of motion	Decreased	less than controlateral joint
	Normal	the same range as controlateral joint
Radiographic OA	0	normal
	1	slight: soft-tissue swelling only
	2	mild: early osteophytes, roughening along joint capsule margins
	3	moderate: obvious osteophytes and subchondral sclerosis
	4	severe: large osteophytes, loss of joint space, severe subchondral sclerosis
Chronic pain assessment	0 to 10	Activity
	0 to 10	Mobility
	0 to 10	Agility
	0 to 10	Appetite
	0 to 10	Sociability
	0 to 10	Posture
	0 to 10	facial expression
	0 to 10	Vocalizing
	0 to 10	Curiosity
	0 to 10	Aggression
	0 to 10	Obedience
	0 to 10	Attention
Owner' satisfaction	0 to 10	high satisfaction to dissatisfaction

The questionnaire consisted of 12 behavioral-items, which were considered signs of chronic pain. A visual analogue scale from 0 to 10 was used, in which 0 indicated the absence of any behavioral changes and 10 the presence of extreme behavior modified. At the end of therapy and after the treatment, owners recorded their own opinions about therapy stating their level of satisfaction on a scale of 0 to 10 (high satisfaction to dissatisfaction).

To avoid interobserver variation errors, at each time point, orthopedic and radiographic assessments were performed by the same clinician who was not aware of the

Fig. 1: A patient lying on a pulsed electromagnetic field mat.

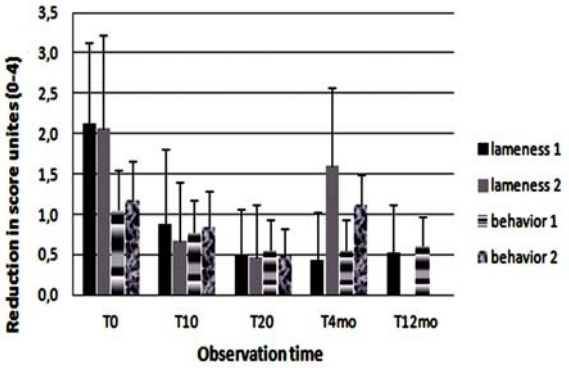

Fig. 2: Change from baseline to different time points in both groups. Lameness score is given by clinician evaluation. Behavior score indicates chronic pain and it is achieved by owner assessment. In each groups (1 and 2) the trends are similar between clinician and owner evaluations.

therapy. Interval data were given as mean±SD. The data recorded 0-10 were re-elaborated and scored in a 0-4 scale. For determining the variation before, during and after treatment for all groups, the paired *t* tests were used. To compare the difference between groups at each point time, the Student's *t*-Test was applied.

For analyzing nominal values before and after treatment for all groups, the McNemar's test was used, and for comparing values between groups the Fisher's exact test was used. The level of significance for interval data analyses was $P<0.01$, and for nominal data the values of $P<0.05$ were considered significant.

RESULTS

A total of 40 dogs were enrolled into the study and only the most severely affected joints were investigated. The dogs in group 1 (n=25) received PEMF therapy, and in group 2, patients received (n=15) firocoxib. The two groups of dogs were similar in terms of their general characteristics and the nature of their disease (Table 2).

In the PEMF group, four dogs were lost during the study: 2 old dogs died before T4mo time point due to unrelated causes, and the owners of other 2 dogs were not available for the clinical evaluation at T12mo. Five of 15 (33.3%) dogs in control group had needed NSAID administration after the end of therapy because of worsening lameness, therefore, they were excluded at T4mo of the study. Both therapies decreased clinical signs of OA during the treatment. Differences were recorded during observation time spans following the end of therapies.

In group 1, the percentage of dogs with lameness that improved by at least one grade was 84% at T10 and 92% at T20, and the improvement –in both percentage and in score values- was stable until at T12mo (Table 3, Fig 2). Whereas in group 2, the progress recorded at T10 (80%) and T20 (93.3%), showed a reduction (30%) at T4mo. Besides, lameness scores of group 2 trended toward a return to the baseline values after the end of therapy. Compared with the baseline, these improvements were statistically significant ($P<0.01$) in both groups at all time points, except for group 2 where the score was not significant ($P=0.07$) at T4mo. The differences of lameness scores between the groups were at all times not significant ($P>0.01$), but significant at T4mo ($P=0.000$).

Likewise trends were recorded in the changes of pain on palpation in both groups during the treatment. In PEMF group the reduction of percentage of dogs with pain was significant ($P<0.05$) at each observation, whereas in firocoxib group the percentage increased (40%) at a value not significant ($P=0.479$) at the end of study.

In all dogs ROM values at T0 had decreased. The improvements of the ROM were noticed in only a few dogs (Table 3) and these improvements were not significant

Table 2: Demographic data collected at baseline

Characteristic	Group 1 (PEMF)	Group 2 (Firocoxib)
Number of dogs evaluated (n)	25	15
Bodyweight (Kg)		
Mean±SD	25.98±12.7	24.7±14.4
Range	5.0-50.0	5.5-48.0
Age (yr)		
Mean±SD	6.4±3.4	7.1±3.6
Range	1yr-13yr 11mo	1yr 1 mo-14yr
Sex		
Female entire	6	4
Female spayed	7	4
Male entire	10	5
Male castrated	2	2
Most severely affected joint		
Shoulder	2	1
Elbow	9	5
Carpus	2	0
Hip	4	3
Stifle	8	6
Osteoarthritis subtype		
Primary degenerative joint disease	2	1
Traumatic pathogenesis	10	6
Joint dysplasia	13	8
Radiographic grade of OA		
Grade 0	0	0
Grade 1	3	1
Grade 2	7	4
Grade 3	6	4
Grade 4	9	6
Lenght of therapy	20 sessions	20 days
Mean (days)±SD	23.28±3.61	
Dogs evaluated at each time point (n)		
T0	25	15
T10	25	15
T20	25	15
T4mo	23	10
T12mo	21	0

Table 3: Effectiveness variables at baseline (T0) and at T10, T20, T4mo, T12mo of the study

Parameters	T0 (start of therapy)		T10 (mid-therapy)		T20 (end of therapy)		T4 months		T12 months (end of study)
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1 (PEMF) (n=23)	Group 2 (Firocoxib) (n=10)	Group 1 (PEMF) (n=21)
Score	2.12±1.01	2.07±1.16	0.88±0.93	0.67±0.72	0.48±0.59	0.47±0.64	0.43±0.59	1.60±0.97	0.52±0.60
Lameness Score/Grade									
LG 0	0 (0)	0 (0)	10 (40)	7 (46.6)	14 (56)	9 (60)	14 (60.9)	1 (10)	11 (52.4)
LG 1	8 (32)	6 (40)	10 (40)	6 (40)	10 (40)	5 (33.3)	8 (3.8)	4 (40)	9 (42.8)
LG 2	9 (36)	5 (33.3)	3 (12)	2 (13.3)	1 (4)	1 (6.7)	1 (4.3)	3 (30)	1 (4.8)
LG 3	5 (20)	1 (6.7)	2 (8)	0 (0)	0 (0)	0 (0)	0 (0)	2 (20)	0 (0)
LG 4	3 (12)	3 (20)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lameness (dogs improved at least 1°)			21 (84)	12 (80)	23 (92)	14 (93.3)	23 (100)	3 (30)	20 (95.2)
Pain upon manipulation	19 (76)	12 (80)	5 (20)	3 (20)	2 (8)	1 (6.7)	2 (8.7)	4 (40)	2 (9.5)
ROM decreased	25 (100)	15 (100)	22 (88)	13 (86.7)	21 (84)	12 (20)	18 (78.3)	8 (80)	18 (85.7)
Radiographic signs of OA	2.84±1.07	3.00±1.00			2.80±1.12	2.93±1.10			
Owner's questionnaire	1.06±0.49	1.17±0.49	0.79±0.39	0.84±0.45	0.56±0.37	0.49±0.33	0.56±0.38	1.12±0.37	0.61±0.35
Owners' satisfaction					0.18±0.28	0.29±0.35	0.23±0.32	2.28±1.41	0.23±0.32

Group 1 (PEMF) and Group 2 (Firocoxib) comprised of n=25 and n=15 at T0, T10 and T20, respectively. Mean±SD; LG=Lameness; Group 2 was not evaluated at 12 months; Figures in parenthesis indicate percentage.

(P>0.05) in the two groups as well as between the groups. The radiographic signs of OA were scored in all dogs at baseline T0 and they were not significantly (P>0.01) improved at T20. The owners' evaluations of their dogs' behavior by the questionnaires showed similar progress in both groups with *P* values statistically significant during the therapy compared with their baseline. In group 1 the behavioral improvement recorded was less than P=0.01 at the end of the study; in contrast, in group 2 the chronic pain assessment became not significant (P>0.01) at T4mo (Fig. 2).

Owners' satisfaction was scored very close to high satisfaction in PEMF group during the study, whereas the score moved toward dissatisfaction in firocoxib group at T4mo. At this time point the difference of satisfaction between the groups was significantly (P=0.000) in favor of group 1. No adverse effects were recorded during both treatments.

DISCUSSION

Basically, in this study, we investigated the effects of PEMF on the functional capacity of dogs with OA by lameness assessment and other clinical variables, and the benefits on chronic pain evaluated by the dog owner's questionnaire. Likewise evaluations were carried out in a control group treated with firocoxib, and the differences were estimated. The results of this study indicate that the effectiveness of PEMF was not lesser if compared with firocoxib, and it was sustained over time only with PEMF therapy.

The majority of dogs improved in lameness and pain values compared with their baseline, and this improvement was already obvious at mid-therapy. The benefits were maintained stable between the end of therapy and the end of the study, without using any anti-inflammatory drugs. In the group treated with firocoxib the effects recorded were similar during the therapy, whereas they tended to return toward baseline values through the post-treatment phase of the study. In group 2 the period of observation was completed at four months because the symptoms reappeared and the dogs needed to further treatment. Lameness is the most prominent sign of limb pain with OA. The improvement of these two variables was that we expected through the anti-inflammatory action of therapies. Pain elicited upon palpation is variable. Many dogs with known osteoarthrosis of a joint will not react to palpation (Gordon *et al.*, 2003). Consequently, as we had had some difficulty to evaluate the pain score in a 0-4 scale, it was graded with nominal values. Further, no high percentage of improvement of ROM was recorded. We suppose that causes of stiffness, such as muscle spasm and contracture, capsular contraction and pain elicited to movement, may get better thanks to anti-inflammatory and analgesic effects of both treatments. In contrast, a mechanical block from osteophytes, recorded on x-ray films, could be the reason of the lack of significant reduction of stiffness.

According to other authors, there is not relationship between functional capacity of dogs with OA and radiographic evidence of disease (Gordon *et al.*, 2003). At the beginning of the study, X-ray evaluation was performed in order to confirm OA diagnosis and achieve a classification. It must be noted that immunohistochemistry trials on guinea pigs showed that PEMF treatment preserves the morphology of articular cartilage and retards the development of osteoarthritic lesions (Fini *et al.*, 2008). In contrast, in the present study the radiograph signs of OA were not decreased (P>0.01) probably because 20 sessions were not enough to observe any X-ray changes of bone and cartilage.

In our opinion the evaluation of pain elicited upon palpation is not as accurate as the assessment of behavioral disturbances associated with both acute and chronic pain in dogs.

With chronic pain, it was suggested that changes in behavior may be so gradual that they are apparent only to someone very familiar with the animal. Thus in this study, the measurement of chronic pain was obtained by the owners' questionnaire (Wiseman-Orr *et al.*, 2006). In both groups, the results of questionnaires indicated that the decrease of pain during treatments impacted positively on dogs health-related quality of life. This progress was sustained over time only with PEMF therapy.

Overall, as a consequence of the differences in sustainability of therapy effects, the differences between the groups at the end of observation were in favor of dogs treated with PEMF. It is well accepted that the cellular membrane is a primary target of the magnetic field action. It is assumed that, due to its interaction with the

membrane channels, PEMF alters the transport of ions, such as sodium, and causes a consequent modification of the membrane potential. This process induces the fall of transduction signals which stimulate the synthesis of growing factors, important for bone and cartilage formation (Markov, 2007). PEMF chondroprotective action is both direct, by means of homeostasis and articular metabolism modulation, and indirect due to its anti-inflammatory properties. Some trials demonstrated that PEMF increases chondrocytes proliferation and extracellular matrix components synthesis, and reduces OA progression (Fini *et al.*, 2008).

PEMF anti-inflammatory properties are mediated by an agonist activity on adenosin receptors as well as by an inhibition of prostaglandin synthesis (Varani *et al.*, 2008). PEMF analgesic effect could either be the result of a direct effect on the brain waves, or a consequence of its capacity to affect the endogenous and exogenous opioids system (Thomas *et al.*, 2007).

We suppose that the effectiveness of PEMF on OA joint for a medium-long time would be due to the main action of electromagnetic waves on cells membrane, and consequent adjustment of the membrane potential of any pathologic cells.

Firocoxib has been used to treat OA in dogs for the last few years. It has been recognized highly effective, safe, and adequate for the control of the pain and inflammation associated with OA (Autefage *et al.*, 2011). Firocoxib proprieties are related to the inhibition of prostaglandin synthesis, through the inhibition of cyclo-oxygenases. It is well known that the effects of NSAID are limited for a short-medium time after the end of treatment.

The limitations of the study includes: this report was not an experimental trial, but was performed capturing clinical practice and there was no reason why it should influence the outcomes. The design lacked a placebo group, therefore further studies could be interesting to compare treated and untreated groups. The dogs enrolled in the study had a clinical history of lameness for 4 weeks, some improvement in both treatment groups might be attributable to the natural course of the disease. Again, the sample size was limited and the scoring system had not been scientifically validated before the trial and some outcomes measurements are subjective.

Conclusion: In conclusion, given that there is no standard treatment procedure suitable for all kinds of musculoskeletal diseases, the present study proves that PEMF is a non-invasive remedy, free of adverse effect, easy to employ, and useful for controlling pain and inflammation associated with osteoarthritis for medium-long time, compared with NSAID therapy. Further studies are warranted to standardize dosage and treatment duration in OA and other orthopedic disorders.

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