

Evaluation of Transcutaneous Electrical Stimulation (TENS), Therapeutic Ultrasound (TU), and Low-Level Laser Therapy (LLLT) Applications for Physical Therapy in Neurological and Orthopedic Disorders in Cats and Dogs; 20 Cases

Aşkın Doğan¹,Sadık Yayla²✉

¹Dicle University, Institute of Health Sciences, Department of Surgery, Diyarbakır, Türkiye
²Dicle University, Faculty of Veterinary Medicine, Department of Surgery, Diyarbakır, Türkiye

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✉Corresponding Author: sadik.yayla@dicle.edu.tr

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ABSTRACT

This study aimed to evaluate the applications of transcutaneous electrical stimulation (TENS), therapeutic ultrasound (TU), and low-level laser therapy (LLLT) for physical therapy and rehabilitation (PTR) in cats and dogs with neurological and orthopedic disorders, and the results obtained from these applications. The study material consisted of 11 cats and 9 dogs (20 cases). Transcutaneous electrical stimulation (TENS), therapeutic ultrasound (TU), and low-level laser therapy (LLLT) were used for PTR in these cases. In the study, 4 (20%) cases had muscular dystrophy, 9 (45%) cases had patellar dislocation or hip joint-related orthopedic problems (1 case of Leg Calve Perthes (5%), 8 cases of hip dislocation and patellar luxation (40%)), while the remaining 7 cases (35%) were neurogenic in origin (6 spinal traumas (30%), 1 radial paralysis (5%)). Only 6 (30%) of the cases included in the study underwent physical therapy alone without any surgical planning. In the other 14 cases (70%), physical therapy was applied after a surgical procedure. While physical therapy resulted in significant improvement in orthopedic problems, complete recovery was not achieved in some neurological cases. Based on the findings from this study regarding the dosages and durations used, the results of this combination are quite satisfactory. We recommend using physical therapy applications consisting of a combination of TENS, TU, and LLLT alone or as a complementary treatment for orthopedic and neurological disorders in cats and dogs.

INTRODUCTION

Physical therapy and rehabilitation (PTR) applications in animals are becoming more widespread every day (Mcgowan and Goff, 2016). Postoperative rehabilitation, which was previously overlooked, has recently started to receive more attention in the veterinary field. PTR applications are becoming even more valuable thanks to the increasing demands due to their ability to accelerate the healing process of patients, contribute to pain management and early mobilization (Marcellin-Little et al., 2015; Sarierler and Ulutürk 2022).

Muscles, joints, tendons, ligaments, and bones that make up the musculoskeletal system are often treated with medical and operative treatments, as well as conservative supportive treatments, in both acute and chronic diseases. These may include heat, light, electricity, and exercise. Physical therapy is a treatment method used to treat diseases or pains that negatively affect the body's motor

functions and to provide rehabilitation for patients (Chuet al., 2022; Ünsaldı, 2024).

Among the treatment methods applied for physical therapy, there are many different or combined applications that show different mechanisms of action and whose effects have also been defined, such as massage, therapeutic exercises, thermal applications, aquatherapy, transcutaneous electrical nerve stimulation (TENS), therapeutic ultrasound, extracorporeal shock wave therapy, low-level laser therapy (LLLT) (Özdinçerler et al., 2013; Vance et al., 2014; Johnson et al., 2022; Sarierler and Ulutürk, 2022).

TENS refers to the stimulation of nerves near the skin's surface with electrical signals (Marcellin-Little et al., 2015; Sarierler and Ulutürk, 2022). These signals use small currents to activate sensory axons without affecting muscle contraction (Özdinçerler et al., 2013; Chuet al., 2022). TENS is an inexpensive and easy self-administered

technique (Vance et al., 2014). The commonly used frequency for TENS in clinical treatment is 1-150 Hz (Johnson et al., 2022). These frequencies have high and low modes. Low-frequency modes provide pulsed currents of 10 Hz or less, while high-frequency TENS is used to describe frequencies greater than 10 Hz (up to 215 Hz at the maximum setting). TENS is generally used in the treatment of pain control, urinary incontinence, and muscle atrophy (Mirza et al., 2019; Johnson et al., 2022).

The effects of therapeutic ultrasound are considered non-thermal and typically a combination of cavitation, acoustic flow, and micromassage. Ultrasound waves interacting with tissue cause a local increase in blood flow and a temporary increase in the elongation of collagenous structures such as tendons, ligaments, and joint capsules. It creates a mild inflammatory reaction, reducing pain and muscle spasm in joint contractions (Cotler et al., 2015; Mirza et al., 2019; Gölgeli and Yanmaz, 2023; Ünsaldı, 2024).

LLLT, commonly referred to as photobiology or biostimulation, is a non-invasive light source therapy that does not emit heat, sound, or vibration. It is believed to accelerate connective tissue repair by affecting the function of connective tissue cells (fibroblasts) and to act as an anti-inflammatory agent. Lasers with different wavelengths ranging from 632 to 904 nm are commonly used in the treatment of musculoskeletal disorders. Wavelengths between 660 nm and 905 nm have the ability to penetrate the skin and soft/hard tissues. This light has a good effect on pain, inflammation, and tissue repair. The effect of LLLT is photochemical, not thermal, and its positive effects on pain, inflammation, and tissue repair are known (Bockstahler, 2006; Anders et al., 2015; Yayla et al., 2026).

This study aimed to evaluate transcutaneous electrical stimulation (TENS), therapeutic ultrasound (TU), and low-level laser therapy (LLLT) applications for physical therapy in cats and dogs for neurological and orthopedic disorders.

MATERIALS AND METHODS

This study was conducted on 11 cats and 9 dogs (20 cases) with physiotherapy indications at the Surgical Clinics of the Animal Hospital, Faculty of Veterinary Medicine, Dicle University. The owners of the animals included in the study were informed about the study and their written consent was obtained through patient consent forms. Furthermore, ethical approval for the study was obtained from the Dicle University Local Ethics Committee for Animal Experiments, with protocol number 2024/05 dated 26/12/2024.

In this study, TENS, TU, and LLLT applications were performed using the "M1890 CHATTANOOGA Intellect VET Combo Physical Therapy Unit." This unit contains TENS, TU, and LLLT modules and can be easily controlled from a single panel.

TENS application: All patients received TENS once daily for 1200 seconds for the first three days, using a premode waveform, continuous cycle, 80/150 Hz frequency, and 1.3 mA. On subsequent days, the treatment was continued at 1.5 mA and increased to 1.8 mA until the patient responded. Additionally, TENS electrodes were placed at the beginning and end points of the affected muscle. In patients with spinal cord trauma, they were placed on the right and left sides of the affected area.

TU therapy was administered once daily using the TU probe located on the device (Intellect Vet; 1 MHz, continuous mode, SATA intensity 1.5 W, exposure time:

900 seconds; Chattanooga Group Inc., Chattanooga, TN, USA). The intensity was increased to 1.8 W during the second week and then to 2.0 W for 3 or 4 weeks (in patients requiring continued treatment).

For LLLT applications, a GaAs (gallium arsenide) laser device was set to continuous mode with $\lambda=905 \mu\text{m}$, 10,000 Hz, 25 mW, and a peak power of 25 W. The monodiode laser probe (MLA1/25) was held perpendicular to the skin and applied at close range once daily. Laser treatment was calculated according to the formula (power/beam area) X time = J/cm² and applied transcutaneously for 180 seconds daily for 3 or 4 weeks with regional scanning movements at 9 J/cm². In addition, all patients were advised to perform passive exercises, massage, and hot hydrotherapy. In addition to physical therapy lasting 3 or 4 weeks, none of the patients in the study received additional supplements such as muscle relaxants or analgesics.

Generally, when working on a specific muscle group (such as cases 1, 2, and 5), TENS electrodes were placed at the origin and insertion points of the affected muscle groups, while the TU and LLLT probes were applied to the area with circular movements. In spinal diseases or after spinal surgery (cases 3, 4, 6, 8, 10, and 20), TENS electrodes were placed bi-directionally, while the TU and LLLT probes were held perpendicular to the skin and applied to the area with circular movements. If a metal implant was present, the application was performed starting more caudally, without applying to the implant itself. In cases involving the hip joint (cases 12, 15, 16, 17, 19) or cases with local inflammation (case 14), application was performed only to the affected area (Figure 1 and 2).

The study consisted of clinical cases, predominantly orthopedic and neurological. There was no control group. Within the scope of the study, criteria such as treatment duration, faster recovery, and a more comfortable postoperative period were interpreted solely based on observation and previous experiences. On the other hand, in conditions such as muscular dystrophy, recovery was assessed by observing the increase in muscle mass and the clinical use of the affected extremity. Similarly, a more comfortable postoperative period was interpreted based on the patient's general condition and indicators such as appetite, willingness to walk or cheerfulness, liveliness, response to environmental stimuli, and communication. All these observations were made by the same person (first author).

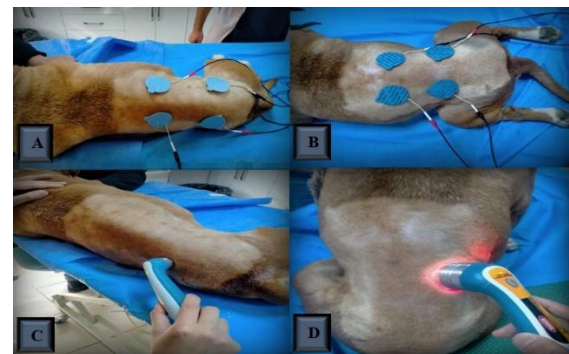


Figure 1. Case 4: Male dog with spondylitis (15-day-old case). After determining the treatment protocol, A, B: bidirectional TENS (20 min 1.3 MA), C: TU (20 min 2 w/cm²), and D: LLLT (3 doses at 50 sec intervals) were applied.

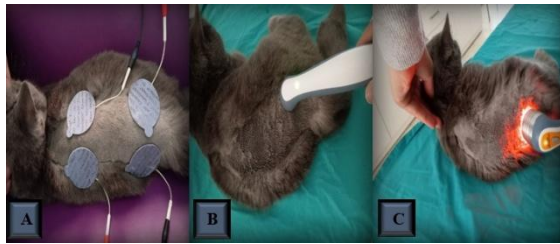


Figure 2. Case 6; improvement was observed in a cat with spinal trauma after 10 sessions of physical therapy protocol: TENS (A), TU (B), LLLT (C).

RESULTS

The distribution of cases evaluated in this study was 55% cats and 45% dogs. When the cases were evaluated among themselves, the average age of the cats was calculated as 18.90 months, and that of the dogs as 31.77 months. Six of the cats were male and five were female, and all of the dogs

were male (Table 1). Of these cases, 4 cases (20%) had muscular dystrophy, 9 cases (45%) had patellar dislocation or hip joint-related orthopedic problems (1 case Leg Calve Perthes (5%), 8 cases hip dislocation (40%), while the remaining 7 cases (35%) were determined to be of neurogenic origin (6 spinal trauma (30%), 1 radial paralysis (5%).

It was determined that only 6 of the cases included in the study (30%) received physiotherapy alone without surgical planning. In the other 14 cases (70%), physiotherapy was applied after a surgical procedure for therapeutic purposes.

During the physical therapy applications, patients expressed their satisfaction, stating that they allowed the applications without resistance from the second session onwards, and that they were more comfortable at home with their owners. Other findings from the study are summarized in Table 2.

Table 1. Patient data including type, race, gender, age, weight

Case No	Type	Race	Gender	Age	Body weight (kg)
1	Cat	Tabby	Male	6 month	3
2	Dog	Anatolian shepherd	Male	7 month	35
3	Cat	Tabby	Female	1 year	4.5
4	Dog	Crossbreed	Male	1.5 year	26
5	Dog	Belgian Shepherd	Male	2 year	25
6	Cat	Scottish	Female	6 month	1.5
7	Dog	German Shepherd	Male	3 year	25
8	Cat	British Shorthair	Male	3 year	5
9	Dog	Japanese spits	Male	4 year	27
10	Cat	British Shorthair	Male	1 year	4
11	Dog	German Shepherd	Male	2 year	35
12	Dog	Poodle	Male	9 month	15
13	Cat	Tabby	Female	4 month	1.5
14	Cat	Tabby	Male	3 year	4.5
15	Cat	Tabby	Male	2 year	3.5
16	Cat	Turkish Van	Male	3 year	4
17	Cat	Tabby	Male	1 year	2
18	Dog	Malinois	Male	4 year	25
19	Dog	German Shepherd	Male	6 year	35
20	Cat	British Shorthair	Female	2 year	4

Table 2. Clinical status of the cases

Case No	Diagnosis	Clinical status	Developments or clinical findings related to the case
1	Muscular atrophy	Due to surgery on the femur, the cat was unable to use its leg, resulting in muscle atrophy and lameness. No surgery other than physical therapy was performed for treatment.	Regarding lameness, the leg was functionally usable. There was no lameness, but it could not be said that a complete recovery had occurred. This improvement was achieved after 3 weeks of TENS, TU, and LLLT treatment.
2	Delayed movement after femoral osteosynthesis	The dog was unable to use its leg due to a femur operation. No surgery other than physical therapy was performed for treatment.	The patient's treatment was not completed because they were not brought in regularly for TENS, TU, and LLLT treatments for 3 days.
3	Spinal trauma	Prior to physical therapy, dorsal laminectomy and vertebral stabilization were performed. Physical therapy applications were performed regularly starting 24 hours after the operation.	The patient started weight-bearing after 4 weeks of TENS, TU, and LLLT therapy.
4	Discospondylitis	No surgery other than physical therapy was performed for the treatment.	The patient, who was completely paraplegic on the first day of arrival at the clinic, started walking by the end of the second session. The treatment consisted of 2 weeks of TENS, TU and LLLT applications.

Table 2. (continued)

Case No	Diagnosis	Clinical status	Developments or clinical findings related to the case
5	Muscular atrophy	No surgery other than physical therapy was performed for the treatment.	Three weeks of TENS, TU, and LLLT therapy significantly prevent muscle atrophy, as the developmental gap between the two arms was observed to have decreased compared to baseline.
6	Spinal trauma	Dorsal laminectomy was performed prior to physical therapy. Physical therapy applications were performed regularly 24 hours after the operation.	Despite the challenges of home care following the application of TENS, TU, and LLLT treatments, the patient weight-bearing on the 45 th day.
7	Patellar luxation	A combination of tibial tuberosity transposition, extracapsular stabilization, and trochlear sulcoplasty was performed, and physical therapy was applied in the postoperative period.	Within a short period of time, approximately one week, the patient functionally recovered as a result of TU and LLLT treatment, and no relapse was observed during the following 6 months.
8	Spinal trauma	Physical therapy was performed after hemilaminectomy.	The patient could not be contacted after 1 week of TENS, TU, and LLLT treatment.
9	Patellar luxation and subluxation of the coxofemoral joint	A combination of tibial tuberosity transposition, extracapsular stabilization, and trochlear sulcoplasty was performed, and physical therapy was applied in the postoperative period. Physical therapy was applied without any surgery on the hip joint.	Functional recovery occurred within a short time, approximately one week, following TU and LLLT application, and no recurrence was observed during the 6-month follow-up period. The hip joint became tighter, and the subluxation corrected.
10	Spinal trauma	Physical therapy was performed after laminectomy and vertebral stabilization.	After 3 weeks of TENS, TU, and LLLT treatment, the patient showed functional improvement, and no relapse was observed during the 6-month follow-up period.
11	Patellar luxation and aseptic arthritis	A combination of extracapsular stabilization and trochlear sulcoplasty was performed, and physical therapy was applied in the postoperative period.	Within a short period of time, approximately one week, the patient functionally recovered as a result of TU and LLLT treatment, and no relapse was observed during the following 6 months.
12	Legg calve perthes (LCP)	Physical therapy was applied after excision arthroplasty.	No complications were observed in the surgical area, and the patient was able to walk functionally from the third day onwards.
13	Radial paralysis	Physical therapy was planned without any surgical procedure.	Complete recovery was not achieved after 3 weeks of TU, LLLT treatment. Even though it started using its paw, it couldn't fully put weight on it.
14	Pain control after multiple fracture surgery	After stabilizing multiple fractures with intramedullary nailing and plate osteosynthesis, physical therapy was applied.	Three weeks of TU and LLLT treatment prevented the development of local edema, increased limb mobility, and contributed to both muscle growth and bone healing.
15	Hip dislocation	Physical therapy was applied after excision arthroplasty.	With TU and LLLT application, he walked functionally without limping on the 3 rd postoperative day. Since the time interval between trauma and surgical intervention is not precisely known in these cases, rapid recovery may be attributed to the pain reduction achieved through surgery. However, in such situations requiring surgery, physical therapy can be considered as an additional supplementary support to the surgical plan.
16	Hip dislocation	Physical therapy was applied after excision arthroplasty.	With TU and LLLT application, he walked functionally without limping on the 3 rd postoperative day. Since the time interval between trauma and surgical intervention is not precisely known in these cases, rapid recovery may be attributed to the pain reduction achieved through surgery. However, in such situations requiring surgery, physical therapy can be considered as an additional supplementary support to the surgical plan.

Table 2. (continued)

Case No	Diagnosis	Clinical status	Developments or clinical findings related to the case
17	Hip dislocation	Physical therapy was applied after excision arthroplasty.	With TU and LLLT application, he walked functionally without limping on the 3 rd postoperative day. Since the time interval between trauma and surgical intervention is not precisely known in these cases, rapid recovery may be attributed to the pain reduction achieved through surgery. However, in such situations requiring surgery, physical therapy can be considered as an additional supplementary support to the surgical plan.
18	Regional atrophy due to lameness originating from the elbow.	Physical therapy was planned without any surgical procedure.	After three weeks of TENS, TU, and LLLT treatment, atrophy in the treated area stopped, and muscular development was achieved. Information was obtained indicating an increase in the dog's capacity during exercise and training.
19	Hip dislocation	Physical therapy was applied after excision arthroplasty.	With TU and LLLT application, he walked functionally without limping on the 3 rd postoperative day.
20	Spinal trauma	Physical therapy was performed after laminectomy.	After 4 weeks of TENS, TU, and LLLT therapy, the child started walking on day 25.

DISCUSSION AND CONCLUSION

In veterinary practice, FTR applications have become quite popular recently and are sometimes used as a treatment alone, and sometimes as a secondary application supporting surgical treatment (Bockstahler, 2006). In our study, cats or dogs with indications for FTR applications were included in the study and the results were evaluated. It can be used in many different conditions, from acute and chronic injuries to various musculoskeletal or nervous system diseases (Martorell et al., 2006; Sarierler and Ulutürk, 2022). In our study, the use of physical therapy for orthopedic and neurological disorders was discussed. Among these, muscle atrophy developing in animals that have undergone faulty orthopedic interventions or been kept immobile for a long time was noteworthy. In addition, patellar dislocation and hip-related orthopedic diseases also occupied a significant place. Almost all of our patients with neurological disorders had spinal trauma, and the main cause was trauma. Physical therapy applications can be used alone for therapeutic purposes or to support a treatment (Wiputhanuphongs et al., 2015; Henea et al., 2023). In our cases, physical therapy and rehabilitation (PTR) applications (TENS, TU, LLLT, respectively) were used alone for muscle atrophy, while in spinal trauma patients, PTR was applied following laminectomy and vertebral stabilization surgery. In cases of patellar dislocation and hip dislocation, PTR was continued to support treatment while orthopedic surgery for the dislocation was planned. This approach aims to shorten treatment time, accelerate recovery, make the postoperative period more comfortable, and contribute to pain control. All of these are expected effects of TENS, TU, and LLLT. Due to the limited number of cases for each disease or the lack of a control group in our study, it is extremely difficult to explain the specific mechanism of action of PTR for each disease; however, it is possible to interpret these effects based on the known effects of TENS, TU, and LLLT. Therefore, whether PTR is planned alone or in conjunction with surgery depends on many factors, primarily the disease, the patient's condition, and the physician's preference.

Physical rehabilitation should be started as soon as possible (Sarierler and Ulutürk, 2022). In this study, if surgery was not planned when the cases were brought in, physical rehabilitation applications were started immediately. If surgery was planned, physical rehabilitation applications were started the day after the surgery to accelerate recovery. Physical rehabilitation applications should be considered important for early mobilization and muscle development, especially since mobilization is important for the health of regional muscles and tendons after many orthopedic surgeries and complete immobilization is not always a desirable situation.

Although physical therapy applications were not widely known in veterinary practice initially, they have found new application areas in veterinary medicine thanks to the successful results obtained in humans. Postoperative rehabilitation, in particular, has gained importance recently due to its contribution to accelerating the healing process, early mobilization, and pain management (Wright, 2021; Sarierler and Ulutürk, 2022). In our study, the aim of postoperative rehabilitation was to accelerate the healing process in patients, enable early mobilization, and support pain management, and in this sense, most of the cases included in the study expressed great satisfaction by the owners by the end of the second day. The absence of a control group in this study and the unstandardized distribution of patients from different disease groups were limitations in providing a complete picture of the results. However, it can be said that the authors' experience was somewhat better than expected.

In recent years, many different physical therapy methods have become an integral part of postoperative rehabilitation, in addition to being conservative treatment for animals with orthopedic and neurological disorders. In spinal cord injuries and neurological injuries, physical therapy can be used to help improve and protect muscle elasticity, joint mobility, and the nervous system (Grecu et al., 2018; Hyytiäinen et al., 2022; Sarierler and Ulutürk, 2022). Our cases consisted of animals with orthopedic and neurological disorders, and the application of physical

therapy, mostly in the form of conservative treatment, was among the important findings in postoperative rehabilitation. Furthermore, physical therapy and rehabilitation (FTR) can be beneficial in spinal cord injuries or neurological disorders, helping to improve muscle elasticity, joint mobility, and the nervous system.

In veterinary practice, electrotherapy methods generally use electrical current to affect nerves, muscles, bones, or other tissues. TENS is one type of electrotherapy and can be used as part of the rehabilitation process or as a standalone treatment (Okur and Okumuş, 2022). TENS can be applied to many different muscles and can be easily applied to the medial or lateral side of a joint or inflamed area. When it needs to be applied to the spine, electrodes can be placed to the right and left of the affected area, and also cranially and caudally to the affected area (Sarıerler and Ulutürk, 2022). In the cases included in our study, the placement of TENS electrodes was based on previously reported author recommendations. The effectiveness of this approach on treatment or its relationship to dose was not evaluated, but it is considered to offer an advantage based on the reference of previous studies.

One of the FTR applications is TU, which has two main features. The first is its anti-inflammatory property. This property consists of high-frequency vibrations that create cavitation, increase cell permeability, and thus support cell communication between joint membranes (Arioli et al., 2008; Cheng et al., 2014). The second important feature of TU is that it reduces pain by decreasing the nerve conduction velocity of C fibers through stable cavitation. In addition, when used in continuous mode, TU can increase intratissue temperature. Therefore, the important benefits of the thermal effects of ultrasound are the reduction of muscle fiber activity and consequently the reduction of muscle spasms and pain (Arioli et al., 2008; Yanmaz et al., 2021). We believe that TU is largely effective in cases, especially in terms of its effect on muscles and its ability to provide pain control. However, of course, the regional effects of TU could not be specifically determined in this study due to many limiting factors. Nevertheless, clinically, TU may be beneficial in situations where it is indicated due to the lack of defined effects and side effects.

LLLT has been used in many clinical applications since the 1980s. The main therapeutic advantages of LLLT are to enhance tissue repair, reduce inflammation, edema, and pain (Pallotta et al., 2012; Okur and Okumuş, 2022). It can be used to stimulate cell function. Laser photons are thought to be absorbed by chromophores in cells, such as cytochrome C oxidase located in mitochondria. Changes in cytochrome C oxidase activity lead to increased production of adenosine triphosphate, the main source of cellular energy, and consequently to normalization of metabolism (Aimbire et al., 2006; Pallotta et al., 2012; Alves et al., 2013; Hentschke et al., 2013; Cheng et al., 2014). In our study, LLLT was the final stage of the treatment plan. Energy metabolism is undoubtedly very important in a healthy muscle or joint structure or tissue. We also believe that if inflammation occurs in a muscle, this condition should quickly return to normal and be sustainable. Therefore, the application of LLLT aimed to alleviate local inflammation, edema, and pain, and to regulate energy metabolism in muscle and joint structures. We planned the LLLT application as a complement to TENS and TU applications.

The results obtained at the doses and durations used in this study were quite satisfactory, and it was observed that physical therapy applications consisting of a combination

of TENS, TU, and LLLT can be used alone or as a complementary treatment for orthopedic and neurological disorders in cats and dogs. Furthermore, we believe that further studies using different doses and durations will lead to the widespread use of physical therapy in veterinary clinical practice.

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Ethical Declaration

The owners of the animals included in the study were informed about the study and their written consent was obtained through patient consent forms. Furthermore, ethical approval for the study was obtained from the Dicle University Local Ethics Committee for Animal Experiments, with protocol number 2024/05 dated 26/12/2024.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authorship Contributions

Concept: A.D., S.Y., Design: A.D., S.Y., Data Collection or Processing: A.D., S.Y., Analysis or Interpretation: A.D., S.Y., Literature Search: A.D., S.Y., Writing: SY.

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