Hilterapia® - high intensity laser therapy in the treatment of severe tendon and ligament injuries.

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ABSTRACT

Laser radiation is absorbed in metabolically active chromophores located in tissue and inside the cells. Photothermal interaction at the tissue level is controlled especially by absorption by target molecules. Temperature changes over time depend on the method used to transfer laser energy to the tissues and especially on the duration and energy of the pulses.

The emission of Nd:YAG (neodymium-doped yttrium aluminium garnet) laser has a wavelength of 1064 nm, that is weakly absorbed by natural chromophores of the skin and subcutaneous tissue. That is why it is able to penetrate deeply in the tissues. Pulses with peak power up to 3000 W, with a duration of approx.

90-120 μs, do not cause any damage to cells because the interval between the pulses lasts long enough for heat dissipation, avoiding harmful effects.

This report describes the results of a pilot study on a set of 7 patients affected by severe tendon and ligament injuries. The treatment consisted in two sessions of Hilterapia® per week, with a total number of 12-24 sessions. The purpose of the work was to objectify the effect of Hilterapia® in the treatment of severe tendon and ligament lesions by assessment of thermal parameter changes as recorded by thermovision, structural changes detected by musculoskeletal sonography, degree of pain using Visual Analog Scale (VAS) and musculoskeletal changes before and after the series of Hilterapia® sessions.

The results showed that Hilterapia® promoted normalisation of temperature patterns in most cases, reparation of tendon and ligament structures in all cases, reduction of pain and the improved musculoskeletal condition in all cases.

INTRODUCTION

Laser radiation is absorbed in metabolically active chromophores located in tissues, cells and intracellular organelles, such as mitochondria. The absorption depends on quality and quantity of chromophore molecules present in tissues [1].

Biochemical processes probably play an important role in antinflammatory, antiedema, analgesic, and biostimulating effects associated with laser radiation. An important role is played by the key elements of the cell redox system, such as cytochromes, nicotin coenzymes and flavoproteins, together with additional molecules. Radiation-induced alteration of stereochemical conformation can result in increased cellular energy metabolism with an up to 200% increase of the ATP concentration [2-4].

Photons can be able to optimize the function of the sodium-potassium pump at the level of cellular membranes, increasing protein synthesis and significantly increasing the number of mitosis [1].

Photothermic interaction at the tissue level is controlled by absorption in the target molecules. Temperature changes over time depend on the method used to transfer laser energy to the tissues and especially on the duration and energy of the pulses.

Nd:YAG (neodymium-doped yttrium aluminium garnet) laser emission has a wavelength of 1064 nm, that is weakly absorbed by natural chromophores of skin and subcutaneous tissues, such as melanin, haemoglobin, water, aromatic amino acids, nicotine coenzymes, flavins, and molecules containing tetrapyrol rings. This characteristics allows a deep penetration in the tissues. The use of a pulsed source (frequency 10-30 Hz) with an interval between the pulses that lasts long enough for heat dissipation, allows to transfer to the tissue high energy density (peak power up to 3000 W) preventing thermal damage.

This paper reports about the results of a pilot study aimed to evaluate the efficacy of Hilterapia® in the treatment of severe tendon and ligament injuries. The effect of laser treatment was assessed by thermal parameter changes as recorded by thermovision, structural changes detected by musculoskeletal sonography, degree of pain using Visual Analog Scale (VAS) and musculoskeletal changes before and after the period of therapy.

MATERIALS AND METHOD

Patients

7 patients, 13-63 years old, mean age 45.3 years, 5 male, 2 female, were admitted for treatment in the period 2/5/2011-12/9/2013. They suffered for severe tendon and ligament injuries: ruptured triceps tendon, partial rupture of Achilles tendon (2x), fibrillar degeneration of Achilles tendon, subachillar bursitis and partial abruption of Achilles tendon insertion, partial rupture of medial collateral ligament (MCL), partial rupture of the lateral and medial meniscus and MCL.

Before treatment, the patients were assessed by musculoskeletal examination, thermography, musculoskeletal sonography and VAS.

Thermography

Thermovision system Fluke Ti32 was used to perform thermovision recordings at 0.05°C resolution. Before each examination, the patient was equilibrated in a darkened room for 15 minutes at a temperature of 23+/-1°C. Thermal recordings were rendered under standard recording conditions, with a perpendicular angle of the thermovision camera with respect to the viewed area, in standard positions and projections. The recorded values were analyzed based on the values of absolute temperature parameters (Tmax, Tmin, Tav, Tmed), where a side difference of 0.5°C and higher was considered significant, as well as on the basis of the assessment of thermal images in each projection [5-11].

Musculoskeletal sonography

Musculoskeletal sonography was performed using the MyLab Gold Esaote ultrasound system with 5-12 MHz resolution, using spatial compounding to increase the image structure resolution [11-15].

Treatment

The patients were subjected to two sessions of Hilterapia® (HIRO 3.0 model, ASA s.r.l., Vicenza, Italy) per week, with a total of 12-24 sessions. The treatment parameter used in the study are reported in Tab. 1

Reduction of Discomfort	Step	Fluence (dose)	Frequency	Energy	Time
Initial Phase (Fast scan)	1	510mJ/cm²	30Hz	166 Joule	
	2	710mJ/cm²	25Hz	166 Joule	
	3	970mJ/cm²	20Hz	166 Joule	
Intermediate Phase (for trigger points if present)	1	360mJ/cm²	15Hz		6 sec
	2	510mJ/cm²	15Hz		6 sec
	3	610mJ/cm²	14Hz		6 sec
	4	360mJ/cm²	16Hz		7 sec
Final Phase (Slow scan)	1	510mJ/cm²	30Hz	166 Joule	
	2	710mJ/cm²	25Hz	166 Joule	
	3	970mJ/cm²	20Hz	166 Joule	
				TOT 1000J	

The efficacy of the therapy was evaluated by assessing the functional changes determined by musculoskeletal examination, thermal parameter changes as recorded by thermovision, structural changes detected by musculoskeletal sonography, degree of pain using VAS following the series of Hilterapia® sessions.

RESULTS

Patient 1

Rupture of the left triceps tendon above the olecranon insertion following a fall in January 2012. Surgery in May 2012. The tendon failed to heal after surgery, repeated surgery was performed in September 2012. Even after this surgery, the tendon was not functional. The patient was examined in our clinic in November 2012. Increased thermal activity 1.8°C in posterior-anterior (PA) view (Fig. 1a), lateral view (Fig. 1b) and medial view (Fig. 1c) was observed on the thermovision focused on the insertion of the triceps tendon above the olecranon. Musculoskeletal sonography was used to find the disrupted fibrillar structure of the tendon (Fig. 1d). At the time of the examination, the degree of pain was 9 on the VAS scale.

The patient was treated using Hilterapia®, 2 sessions per week, for a period of 9 weeks, i.e. a total of 18 applications.

After treatment, the thermal activity was reduced in PA view to 1.0°C (1a), lateral view to 0.5°C (1b), medial view to 0.7°C (1c).

Sonography showed partial restoration of the fibrillar structure (Fig. 1d). The function of the tendon was restored. VAS pain was reduced to 5.

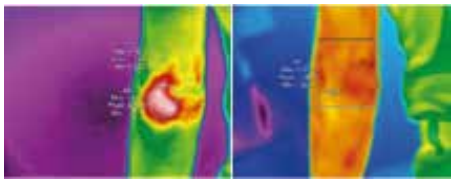

Fig. 1a. Pre- and post-therapy thermogram in PA view.

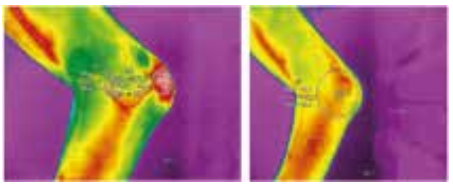

Fig. 1b. Pre- and post-therapy thermogram in lateral view.

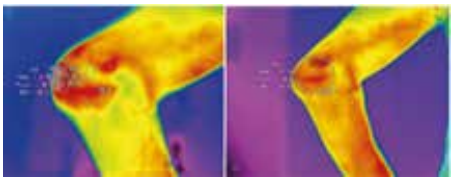

Fig. 1c. Pre- and post-therapy thermogram in medial view.

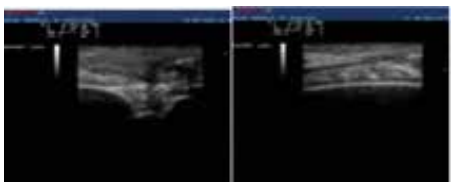

Fig. 1d. Pre- and post-therapy ultrasound.

Patient 2

One year ago, the patient felt pain and had swelling in both Achilles tendons several days after having bicycled up a steep hill. After one month, the pain and swelling in the right Achilles tendon were reduced, but on the left side the pain and swelling persisted. Magnetic Resonance Imaging (MRI) showed the partial rupture of the left Achilles tendon with almost complete granulation - mucoid degeneration.

The patient was examined in our clinic in June 2011. The initial thermogram showed a focus of increased thermal activity + 1.6°C in the left Achilles tendon (Fig. 2a). Initial sonography determined the width of the tendon at the location of the lesion at

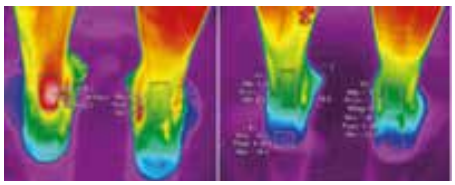

Fig. 2a. Pre- and post-therapy thermogram

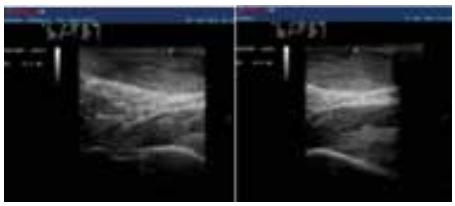

Fig. 2b. Pre- and post-therapy ultrasound.

15.4 mm with mucoid degeneration and hypoechoic longitudinal fissure (Fig. 2b). At the time of examination, the degree of pain was 8 on the VAS scale.

Upon starting the treatment, the patient received Hilterapia®, 2 sessions per week for a period of 12 weeks, with a total number of 24 applications.

After treatment, the thermal activity was reduced to 0.4°C (Fig. 2a). The tendon width was reduced to 14.4 mm, without hypoechoic fissure, partially fibrillarised (Fig. 2b). Tendon function was restored, and the VAS index was reduced to 1.

Patient 3

Pain in the right Achilles tendon dating back to six months before, started playing tennis with shoes that rub excessively at the tendon The patient was examined in our clinic in November 2011. The initial thermogram found a hypothermic area - 0.9°C (3a) above the right Achilles tendon as a result of nociceptive sympathetic efferent activity. Initial sonography determined a tendon width of 8.4 mm with loss of fibrillarity in the upper half (3b). VAS index before therapy was 7.

Upon starting the treatment, the patient received Hilterapia® 2 sessions per week for a period of 8 weeks, with total number of 16 applications. After treatment, the hypothermic area above the right Achilles

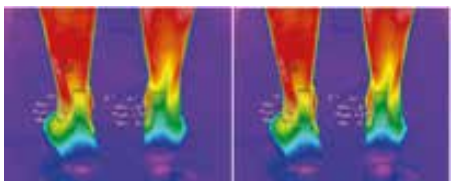

Fig. 3a. Pre- and post-therapy thermogram.

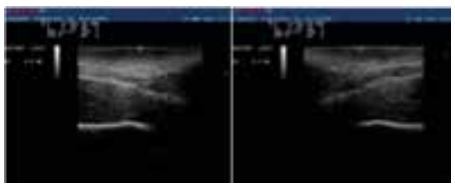

Fig. No. 3b. Pre- and post-therapy ultrasound.

tendon persisted with unchanged intensity - 0.9°C (Fig. 3a). The tendon width on final sonography was 6.6 mm. Fibrillarity was mostly restored (Fig. 3b). Tendon function was restored. VAS pain was reduced to 1.

Patient 4

The patient fell from a ladder 3 weeks before the examination in our clinic, in May 2011. Since the fall, the patient felt pain in the left Achilles tendon and in the posterior aspect of the foot. During the examination an extensive haematoma was present and the patient had pain when walking. Upon examination the patient was proposed a surgical intervention which he refused.

Increased thermal activity was found on initial thermovision examination above the insertion of the left Achilles tendon + 0.9°C (4a). Sonography determined a 70% rupture of the Achilles tendon. Only the surface part was compact (4b.). VAS pain level was 9.

Upon starting the treatment, the patient received Hilterapia® 2 or 3 sessions x per week for a period of 9 weeks, with a total number of 20 applications.

After treatment the increased thermal activity above the Achilles tendon persisted at an unchanged intensity + 0.9°C (4a). On sonography, we observed the restored continuity of the tendon. Fibrillarity was not fully restored (4b). The function of the tendon was restored. VAS pain level was 3.

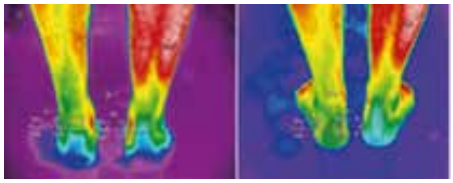

Fig. 4a. Pre- and post-therapy thermogram.

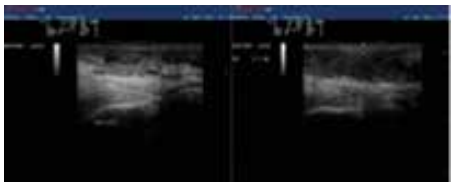

Fig. 4b. Pre- and post-therapy ultrasound.

Patient 5

The patient was examined in our clinic in May 2012. He complained of pain in both Achilles tendons and under the heel following exercise

Before treatment, plantar (5a) and dorsal (5b) thermograms showed a thermal increase of + 0.4°C in the heel area. Pre-treatment sonography (5c) was used to determine the fluid collection in the subachilleal bursa and a small abruption on calcaneus. VAS pain was at 7. The patient was put under treatment. Hilterapia® was applied 2 sessions per week, for 8 weeks, with a total of 16 applications.

After treatment, the thermal activity in the plantar and dorsal aspects was reduced to + 0.1°C. The function of the tendon was restored. VAS pain was reduced to 0.

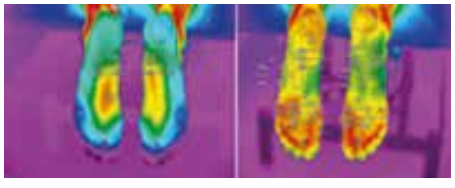

Fig. 5a. Pre- and post-therapy plantar thermogram.

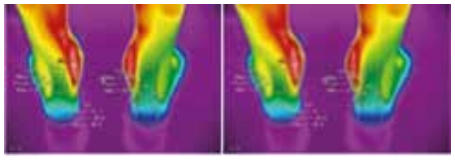

Fig. 5b. Initial and final dorsal thermogram.

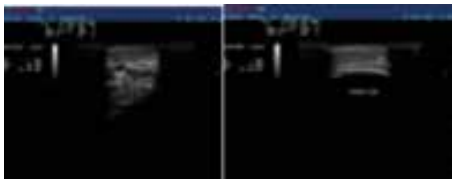

Fig. 5c. Pre- and post-therapy ultrasound.

Patient 6

At judo practice, the patient hooked his right foot with the opponent; he then had the feeling of cracking in the knee. When the patient was examined (November 2013) the pain was localized in the knee, with swelling and limited motion.

Pre-treatment assessment by thermovision demonstrated significant hyperthermia at the right medial condyle of the femur + 2.1°C, lateral femoral condyle and right tibia + 1.6°C (6a).

Pre-treatment sonography showed rupture of the deep layer of the medial collateral ligament (MCL) in the area over the medial femoral condyle and hypoechoic effusion in the suprapatellar recess (6c). The degree of pain was 8 on the VAS scale.

The patient was treated with Hilterapia® for a period of 6 weeks, with a total number of 12 applications (2 sessions/week).

After treatment, the final thermovision assessment demonstrated a reduction of temperature to 1.1 °C over the right medial femoral condyle, to + 0.7°C as regards lateral femoral condyle and right tibia (6a).

Post-trestment ultrasound showed reduced hypoechoic effusion in the suprapatellar recess, narrowing of the deep layer of MCL (1 mm) over the medial joint gap, echo-architecture was restored (6d). The function was partially restored. VAS pain was reduced to 4.

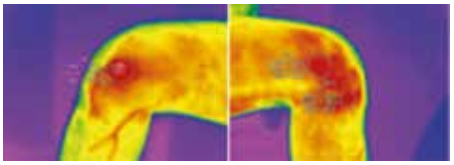

Fig. 6a. Pre-treatment medial and lateral thermogram.

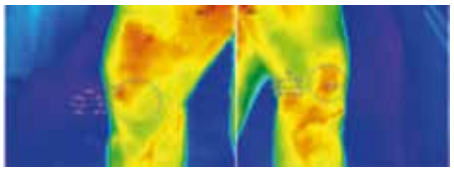

Fig. 6b. Post-treatment medial and lateral thermogram.

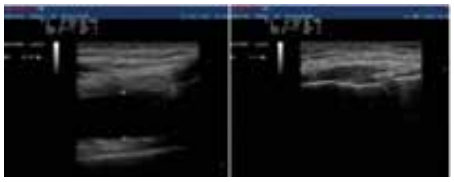

Fig. 6c. Pre-treatment sonographs.

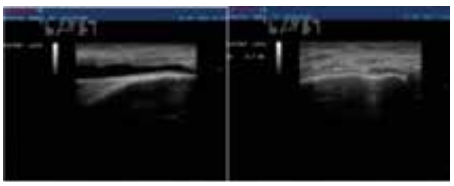

Fig. 6d. Post-treatment sonographs.

Patient 7

The patient first felt pain in the right knee and then fell down. She was transported in the regional hospital. MRI was performed, finding a vertical lesion of the posterior horn of the medial meniscus (MM), unstable vertical rupture of the body of lateral meniscus (LM), grade III, oblique lesion of the MM, grade III, posterior lesion of the anterior horn of LM, partial to subtotal rupture of the anterior cruciate ligament (ACL), hypergranulation of the posterior collateral ligament (PCL), ventral shifting of the tibial condyle with respect to femur by 7 mm, subcortical to cortical fracture in the dorsal aspect of the lateral

condyle of tibia without dislocation, elongation of patellar ligament.
The patient was examined in our clinic in in 2013. Initial thermograms showed foci with increased temperature in the AP view on the right side of the knee + 2.1°C and in lateral view, always on the right side + 1.7 °C (Fig. 7a). Initial sonography found longitudinal lesion of the medial collateral ligament (MCL), subcutaneous lesion in the adipose layer above lateral collateral ligament (LCL) (Fig. 7c). VAS scale before treatment was 8. The patient was treated with Hilterapia® for a period of 6 weeks, with a total number of 12 applications. After treatment,

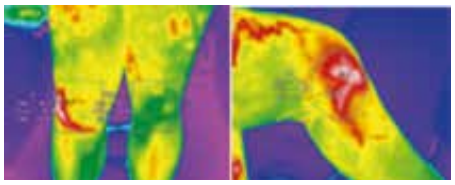

Fig. 7a. Pre-treatment thermograms, anterior and lateral.

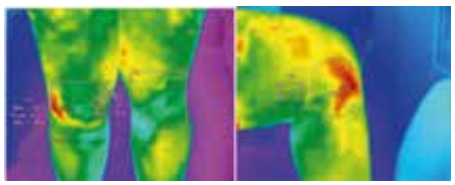

Fig. 7b. Post-treatment thermograms, anterior and lateral.

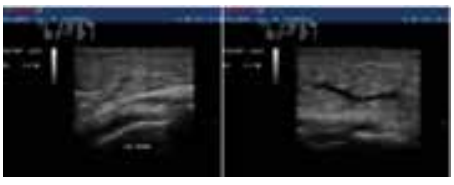

Fig. 7c. Pre-treatment sonographs.

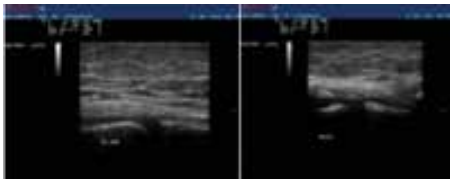

Fig. 7d. Post-treatment sonographs.

the thermovision assessment showed a reduction of temperature to + 0.7°C in PA view on the right part of the knee and to + 0.8°C in the right lateral view (Fig. 7b). Final sonography showed normalisation of the echo-structure of the medial collateral ligament (MCL) and lateral subdermal layer (Fig. 7d). The function was restored. VAS pain was reduced to 2.

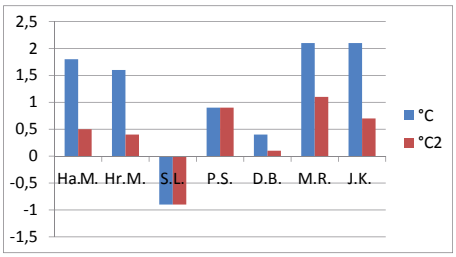

Fig 8. Effect of Hilterapia® on the thermal parameters.

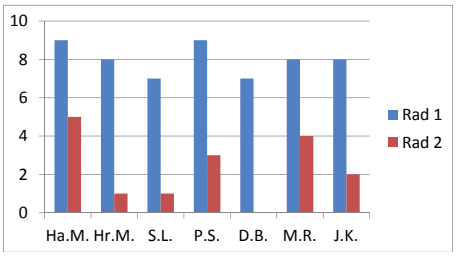

Fig. 9. Effect of Hilterapia® on pain.

DISCUSSION

Thermography is a diagnostic technique widely used and accepted. In our clinic, we have been performing the thermovision assessment of locomotory apparatus for research and clinical purposes for 29 years. Over this period, we performed and analysed more than 34,000 thermovision recordings of various parts of the locomotory apparatus. By thermography, we have repeatedly objectified the effectiveness of different physical and rehabilitation therapy options [16-29]. Over the last 10 years, we have complemented the thermovision examinations with ultrasound examinations. This provides us with information on the pathophysiology of pain as well as on the structural damage. Since 2010, we have had the opportunity to use Hilterapia®, an advanced system of NIR laser therapy. Over this time, we have used this system on more than 500 patients with different injuries to soft tissues of the locomotor apparatus. The effectiveness of this therapy has been objectified by clinical examination, VAS assessment, and by the use of imaging methods (X-Ray, MRI, Ultrasound, Thermography). Vervainioti, while observing patients with low back pain, found greater effectiveness in the improvement of pain symptoms and support of healing with simultaneous use of HILT, compared to the only standard physical therapy approach [30]. Viliani supported the importance of laser therapy and laser-puncture in the management of arthropathies and musculoskeletal problems in haemophiliac patients [31]. To evaluate the effectiveness of Hilterapia® in our study, we chose severe ligament and tendon lesions, many of which would be indicated for surgical repair, and in some of them even repeated surgery failed to restore the structural functionality. The objective was to assess the possibility to use Hilterapia® as an alternative therapy to surgical repair for several types of damage to the soft tissues of the locomotor system. In agreement with the findings of other [30,31] the results of the present study demonstrated the efficacy of Hilterapia® in the management of musculoskeletal diseases.

CONCLUSION

In the presented cases of severe tendon and ligament lesions we observed the effectiveness of Hilterapia®

- in reducing temperature alteration and, in most cases, normalising the temperature patterns
- promoting repair in tendon and ligament structures in all cases
- reducing pain in all cases
- favouring restoration of the function in all cases.

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