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Nd: YAG Laser Therapy for Gonarthrosis: A Controlled Study Using Thermography and Ultrasound Guidance

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Abstract: ***This study evaluated the clinical efficacy of Nd: YAG laser therapy for treating gonarthrosis through neuromodulation of geniculate nerves, using thermography and ultrasound for precision. Forty patients underwent treatment over a two - week protocol. Results showed substantial pain reduction, improved activity levels, and minimal adverse effects. While patients with comorbidities like diabetes and smoking showed comparatively limited gains, overall results support the therapy's role in non - invasive management of knee osteoarthritis. Continued research is needed to validate long - term effectiveness and generalizability. Background: The behavior of body temperature depends on multiple variables and is quite complex, today it is known that an excess or point of temperature is usually related to an acute process, usually overuse, that is, if for example, one knee is hotter than the opposite, it may indicate increased blood flow, likely due to mechanical overload, repetitive stress, or prior trauma, being overloaded, compensation or even a previous operation or inflammation. On the contrary, a body area that is colder than the contralateral may indicate a lack of activity, a vascular problem, nervous inhibition or protection.1[4] It is generally expected that both limbs exhibit thermal symmetry. When there is a thermal asymmetry, this may indicate that there is some alteration, probably related to decompensations, imbalances, overloads and ultimately injury risks, which may appear even before the person has pain or discomfort. Method: The purpose of this study is to evaluate the efficacy of Nd: YAG laser therapy in reducing pain and improving function in patients with gonarthrosis. The laser was administered at a wavelength of 810 nm and a power of 100 mW at 8 points around the knee for two weeks in 40 patients diagnosed with gonarthrosis who met the inclusion criterio. Findings: Patients decreased their final VAS scores, with changes in daily activity limitations ranging from moderate to normal.27 improved their activities (67.5%) and from moderate to partial (32.5%).38 became sedentary (95%), and 2 had a moderate change in sedentary behavior (5%). Only 2 intensity parameters were high in 19 patients (22.5%) and 21 patients had low parameters (52.5%). Interpretation: Treatment with NdYAG laser together with the support of a thermographic camera is confirmed for patients with grade I, II and III gonarthrosis, reducing pain up to 6 months after the intervention.***

Keywords: Nd: YAG laser, Gonarthrosis, Thermographic imaging, Neuromodulation, Knee osteoarthritis

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1. Introduction

The knee is a complex synovial joint consisting of two subjoints, the patellofemoral and the tibiofemoral, functionally a single joint. Periarticular elements, such as menisci, ligaments, and tendons, contribute to stability. When internal and/or frontal cartilage wear occurs, mechanical pain causes functional impairment and may lead to limping or the need for prosthetic replacement.

Epidemiology

EPISER 2016 reports that 10% of the Spanish population has symptomatic knee osteoarthritis[1]. Prevalence studies based on Kellgren - Lawrence radiological criteria, osteophytes are significant.2 Studies of knee osteoarthritis incidence show variable results according to age and sex; in a 12 - year follow - up of patients aged 45 years, it was 25% in women and 10% in men.3 In a 5 - year follow - up (75 and 79 years), it was shown that 4.5% developed knee osteoarthritis.4 There are other radiological prevalence studies that consider other parameters such as pinching or narrowing of the joint space.5 According to the prevalence criterion used, it varies 25.5% among those ≥ 40 years of age in Mexico.6 In Europe, the prevalence is 13.83% associated with female sex, overweight, and advanced age.7 Knee osteoarthritis is a disease with a worldwide distribution, with little geographic variation. It can be concluded that the prevalence of knee osteoarthritis is high in the general population and increases with age, with a higher incidence in women.

Etiopathogenesis

The etiopathogenesis of osteoarthritis says that it is complex, incurable and degenerative, and it is influenced by both systemic and local factors. The local factors are (8): a) Traumas and fractures in bones close to the knee can cause joint incongruity, with asymmetric load distribution and cause alterations in the cartilage and subchondral bone. b) Obesity is related to the load, presenting an increased risk if the body mass index (BMI) is > 30 kg / m2. c) Epiphyseal deformities, both genetic and acquired, as occurs in the case of osteonecrosis of the femoral condyle (9). d) Alterations in alignment, in genu varum and valgus. e) Paget's disease in the bones of the knee. f) Muscular weakness of the quadriceps extensor apparatus is related to gonarthrosis. g) Proprioceptive impairment occurs in neuropathic arthropathy and is associated with osteoarthritis. The most relevant systemic factors (10): a) Age. b) Genetic factors, in the type

II collagen gene (COL2A1) are related to spondyloepiphyseal dysplasias, producing early osteoarthritis (11). c) Race, in general it is more frequent in the white race (12). d) Nutritional factors, involving vitamins A, C and D as antioxidant agents and regulators of the inflammatory response, influencing the development of the osteoarthritic process (13). e) Occupation and physical activity at work are determining factors, such as frequent hyperflexion in certain professions, as well as certain competitive sports activities (14). f) Chronic diseases such as diabetes mellitus, acromegaly, ochronosis, hypothyroidism, crystal deposition disease, hyperparathyroidism and hemochromatosis are related to a higher prevalence (15).

The pathophysiology of osteoarticular knee pain involves metabolic changes in the articular cartilage, subchondral bone and synovial membrane, causing interactions in the immune system with inflammatory mediators. There are associated neuropathic and central sensitization phenomena that aggravate the clinical picture.[16]

The current treatment of osteoarticular pain has three accepted lines: conservative (physiotherapy, oral NSAIDs, local steroid injection, specific treatment to stop the degenerative process and laser light radiation (phototherapy). The role of neuroinflammation and structural changes are the underlying causes of the chronicity of pain.[17]

Phototherapy is the use of light as a therapeutic medium “it consists of the electronic absorption of laser light without producing heat in the visible to near - infrared spectrum (390 - 1100 nm) ”[7] It corresponds to the 2nd zone of the electromagnetic spectrum: infrared rays; ultraviolet; light amplification by stimulated emission (LASER Light Amplification by Stimulated Emission Radiation).[18]

Lasers use a liquid, solid, or gaseous active medium to emit light when energized by an energy source.1[8] The electromagnetic spectrum is made up of different electromagnetic radiations, based on Bohr's postulates, where the atom emits the radiation and returns to its stationary state.[19]

The laser has four characteristics: a) directionality: concentrated and polarized emitted light. Photons are emitted in a single direction without divergence; b) monochromaticity: emitted light of a single color, formed by photons of the same wavelength. The color depends on the active medium used; c) coherence: Photons vibrate simultaneously in the same plane, allowing concentration in a specific area; d) brilliance: high light density of the laser radiation produced and focused on a surface.2[0] With these characteristics, a light beam is ten times brighter than sunlight.[21]

Laser therapy is a non - invasive technique that promotes tissue restoration, inflammation reduction and pain relief thanks to the photobiomodulatory (PBM) effect of the laser on cells and tissues.2[1] There are several types of lasers and applications with different wavelength, energy density, output power and radiation duration. Cell growth is affected by the photobiomodulatory effect, produced with diode lasers with wavelengths in the red and near - infrared range (630 - 940 nm), deeper penetration is achieved using lasers with wavelengths in the "optical window" (600 - 1100 nm), which also causes an increased cellular - light response.[21] These characteristics make lasers suitable for managing a range of medical conditions and ailments, such as diabetes, osteoarthritis and other dermatological and dental diseases.[22]

Lasers, in their therapeutic use, work by absorption, which occurs primarily at the level of melanin in the skin, hemoglobin in the dermis, and water in both. When the radiation has a wavelength between 350 and 1200 nm, melanin is the pigment that most intervenes in absorption. This depends on: a) factors related to the patient: the skin must be free of both medication and oil secretion; the darker the skin, the greater the absorption at the epidermal level due to a greater presence of melanin; b) factors related to the laser: beam angle, wavelength, and average power. The incidence of the laser beam on the treatment area must be perpendicular.[23]

The visible red wavelength laser (630, 632.8, 650 and 670 nm) presents continuous radiation but penetrates a maximum of about 7 mm from the epidermis. It has analgesic and anti - inflammatory action, and is a tissue regenerator, but its use is limited to superficial processes. The infrared laser has a wavelength of 904 and pulsed emission or 780 and 830 and continuous emission. It reaches about 35 mm deep. Therefore, it can be used for less superficial processes. To avoid the dispersion that it presents (9 to 15o) it is recommended to apply the pointer directly on the area to be treated.[23]

Inside, the various molecular structures, with different refractive indices, vary the path of the beam, causing internal reflections until each of the photons is absorbed. The maximum absorption coefficient is located around 1200 nm in this range where low and medium power lasers emit.[23]

Nd Yag laser has different levels of effect on pain and functional performance for knee osteoarthritis. Its effectiveness is related to higher irradiation, higher frequency and number of sessions. The use of light range that oscillates in 700 - 1000 nm so that the infrared zone has better penetration.2[4] Authors such as Koutenaei et al “used Nd Yag laser in 8 points of the knee joint with 56 joules/session”.[25]

It is recommended to take into account the following considerations during laser application: a) protect both the patient and the therapist with protective glasses that only allow 5% of the radiation to pass through. Even if glasses are worn, the laser beam should not be looked directly at; b) avoid mirrors, tiles, or other objects that allow uncontrolled reflections; c) cover metal tables with sheets or try to use wooden or upholstered ones; d) matte paint is recommended in the rooms and lighting that induces miosis of the pupil to reduce the penetrability of the reflected beams.[26]

Nd Yag laser thermography is a technique for measuring surface temperature graphically. With thermographic cameras, not only can the temperature value be measured punctually, but also, and more importantly, the distribution of the object under study can be observed.2[7] It is a non - invasive measurement technique and warns of areas of the body where there is hyperthermia produced by different types of injuries.

Lately, thermography is an increasingly used technique for detecting certain types of tumors, circulatory problems, joint problems, muscle problems, etc.[28]

In any case, as stated above, it all depends on many factors, and knowing whether there is pain, where it has been, and for how long is key to using thermography. Laser efficacy depends on four factors: wavelength, treatment duration, dose, and application sites. The high prevalence of osteoarthritis and its impact on quality of life highlights the importance of identifying the appropriate approach to its treatment.[28]

2. Materials and Method

Forty patients referred by orthopedists at the EUROLASER MEDICAL CENTER clinic with a diagnosis of gonarthrosis were included.31 patients were female (77.5%) and 9 were male (22.5%). Inclusion criteria were: obesity, alignment disorders (genu varum and valgus), proprioceptive impairment in the joint, occupation, physical activity, and diabetes mellitus; knee classification criteria were Kellgren - Lawrence based on imaging studies (Table 1).

Table 1: Radiological classification of Kellgren - Lawrence osteoarthritis.[29]

Grado 0	Normalidad
Grado 1	Dudoso estrechamiento del espacio articular. Posible osteofitosis.
Grado 2	Posible estrechamiento del espacio articular. Osteofitosis.
Grado 3	Estrechamiento evidente del espacio articular. Osteofitosis moderada múltiple. Esclerosis subcondral. Posible deformidad de los extremos óseos.
Grado 4	Marcado estrechamiento del espacio articular. Abundantes osteofitos. Importante esclerosis subcondral. Deformidad de los extremos óseos

Criteria used for precision diagnosis and for the development of research studies by the American College of Rheumatology.[30]

A pain questionnaire was carried out based on the Chronic Pain grade Questionnaire (CPQ).[31] (Figure 1) and the Visual Analogue Scale (VAS) (Figure 2) to determine the degree of pain before and after starting treatment.[32] Factors such as sedentary lifestyle, smoking, physical limitation and degree of satisfaction were added to the classification.

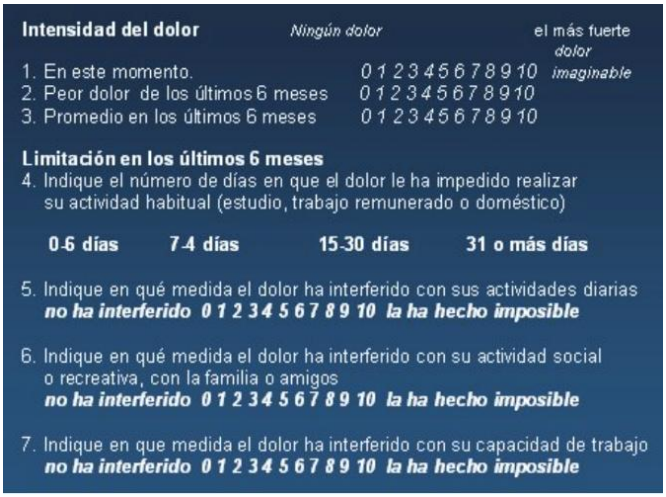

Figure 1: CPQ (Chronic pain Grade Questionnaire), abbreviated version.[31]

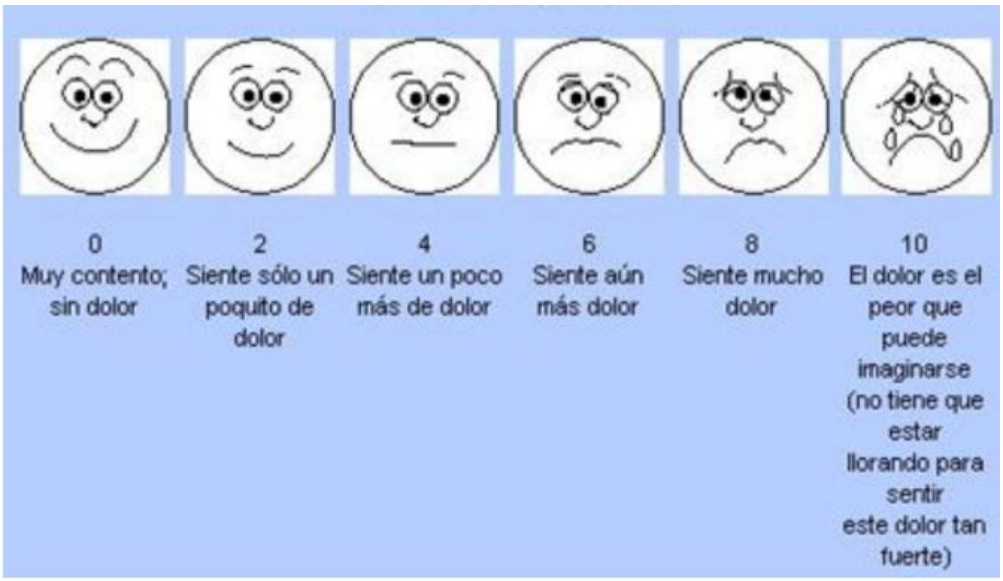

Figure 2: Visual Analog Scale. For measuring pain intensity.[32]

The treatment used ultrasound with a high - frequency linear probe to locate the geniculate arteries, assessing their length and depth. The areas for laser firing were marked; a FLIR T530, 24* thermographic camera; and Thermohuman software to assess the thermal degree and achieve neuromodulation temperature (>45 and <60 degrees Celsius); as neuromodulation, the FOTONA 1064 Neodymium YAG Laser with an R31 handpiece and 6 mm aperture were used. Parameters were calculated according to the artery depths.

Forty volunteer patients diagnosed by orthopedic physicians were included, ruling out intra - articular lesions resolved by surgery or arthroscopy. Geniculate artery marking with white ink was used, assessing the depth of each artery to set the NdYAG laser parameters, which fluctuated from: fluence 80 - 100 J/cm2, width 20 - 25 ms, aperture 6 - 8 mm, frequency 1.0 Hz, performing 6 shots in each area to be neuromodulated with 4 cycles. Thermal control based on thermography with a FLIR T530 camera was maintained until reaching above 45 degrees and less than 60 degrees Celsius. Each patient received six treatment sessions at 14 - day intervals. Follow - up was every month for the first 6 months and subsequently every 6 months for 18 months.

Table 2: Control of each patient with NdYAG Laser parameters

	EDAD	GENERO	IMC	Eva inicio	EVA final	limitacion de actividades diarias I/F	SEDENTARISMO I/F	TABAQUIMSO/ DM	Parametros usados de Laser
paciente 1	36	m	sobrepeso	9 puntos	1 punto	M/N	CS/SS	NA	80/20/6/1
paciente 2	65	f	obesidad	9 puntos	3 puntos	M/P	CS/SS	NA	80/20/6/1
paciente 3	45	f	obesidad	9 puntos	3 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 4	43	f	obesidad	8 puntos	3 puntos	M/P	CS/SS	1/0	80/20/6/1
paciente 5	66	f	obesidad	8 puntos	3 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 6	70	f	obesidad	8 puntos	2 puntos	M/P	CS/SS	1/0	80/20/6/1
paciente 7	72	f	obesidad	9 puntos	3 puntos	M/N	CS/SS	1/0	100/25/8/1
paciente 8	51	f	sobrepeso	9 puntos	1 punto	M/P	CS/SS	NA	100/25/8/1
paciente 9	72	f	normal	9 puntos	1 punto	M/N	CS/SS	1/0	80/20/6/1
paciente 10	73	f	sobrepeso	7 puntos	3 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 11	68	f	sobrepeso	9 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 12	44	m	sobrepeso	10 puntos	2 puntos	M/N	CS/MS	NA	100/25/8/1
paciente 13	68	m	obesidad	9 puntos	2 puntos	M/P	CS/SS	NA	100/25/8/1
paciente 14	65	m	obesidad	9 puntos	3 puntos	M/P	CS/SS	1/0	100/25/8/1
paciente 15	78	f	normal	9 puntos	3 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 16	54	f	obesidad	8 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 17	54	m	obesidad	9 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 18	71	m	sobrepeso	10 puntos	5 puntos	M/P	CS/SS	1--1	100/25/8/1
paciente 19	80	f	sobrepeso	9 puntos	3 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 20	63	f	sobrepeso	9 puntos	3 puntos	M/P	CS/SS	NA	100/25/8/1
paciente 21	63	f	sobrepeso	8 puntos	3 puntos	M/N	CS/SS	1--1	80/20/6/1
paciente 22	65	f	sobrepeso	9 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 23	62	m	sobrepeso	9 puntos	2 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 24	59	f	obesidad	9 puntos	4 puntos	M/P	CS/SS	1--1	100/25/8/1
paciente 25	58	f	sobrepeso	8 puntos	3 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 26	73	m	normal	9 puntos	3 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 27	78	f	sobrepeso	9 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 28	79	f	sobrepeso	9 puntos	3 puntos	M/P	CS/SS	NA	80/20/6/1
paciente 29	51	m	sobrepeso	9 puntos	3 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 30	55	f	obesidad	9 puntos	3 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 31	50	f	obesidad	9 puntos	2 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 32	50	f	normal	9 puntos	1 punto	M/P	CS/SS	NA	100/25/8/1
paciente 33	81	f	sobrepeso	9 puntos	1 punto	M/P	CS/MS	NA	100/25/8/1
paciente 34	75	f	sobrepeso	9 puntos	3 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 35	66	f	normal	9 puntos	3 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 36	59	f	obesidad	8 puntos	3 puntos	M/P	CS/SS	1--1	80/20/6/1
paciente 37	69	f	obesidad	9 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 38	74	f	sobrepeso	9 puntos	2 puntos	M/N	CS/SS	NA	80/20/6/1
paciente 39	78	f	normal	9 puntos	2 puntos	M/N	CS/SS	NA	100/25/8/1
paciente 40	70	f	sobrepeso	9 puntos	3 puntos	M/N	CS/SS	NA	100/25/8/1

Note: *M/N (minimal/Nil), M/P (minimal/partial), CS/SS (with sedentary lifestyle/without sedentary lifestyle), MS (medium sedentary lifestyle), NA (not applicable).

3. Results

Table 2 shows the NdYAG laser parameters of each patient. Average age 63 years, gender 9 men and 31 women, BMI 19 patients overweight (47.5%), 6 with normal weight (15%), 15 patients with obesity (37.5%). The average VAS at baseline, 2 patients with 10 points at the beginning (5%), 30 patients with 9 points (75%), 7 patients with 8 points (20%), 1 patient with 7 points (2.5%). Final VAS 5 patients with 1 point (12.5%), 13 patients with 2 points (32.5%), 20 patients with 3 points (50%), 1 patient with 4 points (2.5%), 1 patient with 5 points (2.5%). Limitations of daily activities at baseline and at the end were measured by their usual occupational capacity (daily habits); Changes in daily activity limitations from moderate to normal, 27 patients improved their activities (67.5%), and from moderate to partial (32.5%). Sedentary

lifestyle was measured as initial sedentary lifestyle and no sedentary lifestyle at the end, 38 patients stopped sedentary lifestyle (95%), and 2 patients had a moderate change in sedentary lifestyle (5%). Among the patients, 10% had diabetes and 22.5% were smokers, both of which influenced treatment outcomes. There were only 2 laser intensity parameters with high parameters 19 patients (22.5%) and 21 patients with low parameters (52.5%).

4. Conclusions

Ultrasound - guided Nd: YAG laser therapy, supported by thermographic monitoring, offers promising results for managing grade I–III gonarthrosis. It significantly reduces pain and enhances patient functionality with minimal side effects. Patients with diabetes and smoking experienced limited benefits from the laser; however, they experienced symptomatic improvement. No analgesic was administered during treatment, so laser treatment for knee pain is statistically and clinically recommended. However, further trials are essential to confirm its widespread applicability.

5. Discussion

This study addresses the need for effective, noninvasive therapies for early - stage gonarthrosis, providing a novel approach using thermography - guided laser treatment. Patients in the sample diagnosed with gonarthrosis who underwent NdYAG laser treatment using the aforementioned protocol showed clinical improvement and pain reduction, consistent with the findings of Dr. Graeme Ewan Glass[24], who reported the effectiveness of low - density lasers in relation to higher irradiation, greater frequency, and greater number of sessions. In the present study, 6 sessions were performed every 14 days, and follow - up was performed monthly for the first 6 months and then every 6 months for 18 months.

Patients with diabetes and smoking were found to have limited beneficial effects from laser therapy, like what Dr. Mohd Azzuan Ahmad reported in his study[15], which found that these chronic diseases are risk factors for knee osteoarthritis, limiting its treatment. However, in the sample studied, they showed symptomatic improvement. No analgesic was added during treatment, so statistically and clinically, laser treatment is recommended for knee pain, and a decrease in the CPQ and VAS scales was evident. However, further studies are recommended and the other three accepted treatment lines described by Dr. Viktor Shtroblia[17] should not be excluded until more evidence is available worldwide.

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