Effects of high-intensity laser on gonarthrosis.

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ABSTRACT

Osteoarthrosis of the knee joint, which is also called gonarthrosis, can be classified as primary and secondary. The primary role in primary gonarthrosis is played by heredity, systemic factors, local mechanic problems and chronic overloading; in secondary gonarthrosis, the primary role is played by post-traumatic and post-inflammatory conditions, and, more rarely, conditions following septic arthritis.

The aim of this study was to verify the effectiveness of high intensity laser therapy (HILT) administered by a high-power Nd:YAG laser (HIRO 3.0), in alleviating pain and increasing the range of motion in the affected joint of patients suffering from arthrosis of the knee joint of higher grades. The study comprised 50 patients with diagnosed grade II to III arthrosis. WOMAC questionnaire was applied to evaluate the effect of laser therapy.

INTRODUCTION

Clinical picture of gonarthrosis

A typical symptom of gonarthrosis is pain upon exertion in the affected location. At first it occurs after a major exertion, or as start-up pain at the beginning of the movement. Later there is resting pain which interferes with sleep. Short periods of morning stiffness develop into functional deterioration; the extent of movements in the joint gradually decreases.

Objective findings (through palpation, auscultation) are crepitations and tenderness to palpation. Typical deformities develop, i.e. varosity or valgosity, which are accompanied by varying degrees of flexion contractures in severe cases. The system of ligaments in the location of deformity becomes relaxed. The range of motion is limited to a various degree, later it may lead even to semiankylosis, or even to ankylosis, almost always in a functionally unfavorable position [1].

The bone under the cartilage responds to load by rebuilding its structure (i.e. sclerotization), which leads to the formation of growths (osteophytes). It is a compensatory mechanism, which ultimately limits the mobility of the joint.

Typical characteristics of osteoarthrosis are limited function of certain joints and frequent asymmetry of the process. In the course of the disease, deterioration often comes up in the form of attacks, sometimes without apparent cause, which are subsequently followed by spontaneous remissions.

Pain causing mechanisms in osteoarthrosis

According with the heterogeneity and the different developmental stages of osteoarthrosis in patients, the mechanism of pain development is not always the same. The following conditions are among the causes of pain in osteoarthrosis: synovitis, tension of the joint capsule, periosteal elevations, pain in ligament insertions (enthesopathy) and tendinopathy, muscle hypertonus, increased intraarticular pressure and bone microfractures. According to Pavelka [2]: "The primary location of structural changes in osteoarthritis is hyaline cartilage in the joint, however, the cartilage is aneural and avascular, so it cannot be the primary source of painful stimuli. Pain is caused by secondary changes in other articular tissues – synovial membrane, periosteum, ligament insertions, muscle insertions and the subchondral bone. A relatively frequent source of pain in osteoarthritis is synovitis. Inflammation has often clinical manifestations, which can be used to verify its presence. The joint is usually swollen and results tender to palpation, sometimes even warm. Swelling of the joint may be due both to effusion and thickening of the synovial membrane. If inflammation is present, pain sometimes tends to be present at rest and the quality of the symptom is similar to pain in inflammatory rheumatic diseases. The presence of inflammation can be documented by the presence of exudation. However, cell content in exudation is usually lower than 2000 cell/µl, because the intensity of inflammation is much lower than, e.g., in rheumatoid arthritis. Histological analysis shows that inflammation is present in the synovial membrane, but it is often limited to specific regions, its intensity is lower than in rheumatoid arthritis (RA) and thickening of the synovial membrane is not as extensive as in primarily inflammatory rheumatic diseases. A significant analgesic effect of orally administered NSAIDs or intra-articular glucocorticoids can be also explained by the presence of inflammation.

Bone microfractures in subchondral bone may represent another source of pain. Experimental studies showed changes in the quality of subchondral bone in osteoarthritis and led to several studies which applied drugs showing activity in bone (e.g. risedronate, sodium ranelate) in the effort to achieve both symptomatic and structural effects in osteoarthritis. The results of these

studies have not been positive so far, but some of them have not been finished yet."
Another source of pain, occurring particularly during the night in hip and knee, might be increased intraosseous pressure, which apparently occurs as a result of venous obstruction. Pain can also derive from the joint capsule, due to increased intra-articular pressure caused by intra-articular expansion, if there is an effusion, or synovial hypertrophy, or mechanical problems caused, e.g., by the instability of the joint, which can lead to direct stimulation of mechanoreceptors in the joint capsule, or furthermore, focal ischemia in the joint capsule. However, pain in joints also may be caused by intraarticular periosteum, which may be mechanically irritated by osteophytes. Apart from intra-articular structures, pain may also originate in extraarticular (e.g. periarticular) structures. Such conditions include bursitis, tendonitis, enthesopathy or enthesitis and stretched ligaments. An important source of pain in osteoarthritis may be the muscles, their weakness or dysbalance." [2].
Last but not least, pain is influenced by psychological and social factors.

MATERIALS AND METHODS

General therapeutic scheme

The source used was a high power Nd:YAG laser (Hiro 3.0, ASA srl, Arcugnano, Vicenza, Italy). The treatment was divided in three phases:

First phase – manual scanning at higher speed (10 cm/1 s). It was divided into three subphases and characterized by increasing intensity and reduced frequency of the beam.

Second phase – treatment of trigger points. The handpiece was placed statically and directly on the trigger point for a maximum period of 7 seconds.

Third phase - slow scanning, instrument parameters remain the same as in the first phase.

Beyond the treatment on the diseased joint, this protocol also includes the treatment of the surrounding muscles, to address any contractures or secondary problems arising as a consequence of the joint disease. During the treatment, the muscle groups receive about 60% of the total energy supplied, while about 40% of it reaches the diseased area and the region where pain irradiates.

First Phase	Second Phase	Third Phase
Quick scanning	Treatment of trigger points	Slow scanning

Tab I: General Scheme

Parameters of treatment			
Phase	Intensity (mJ/cm^2)	Frequency (Hz)	Scanning speed
First	360 mJ/cm^2	10Hz	Higher
Second	810 mJ/cm^2	25Hz	Static treatment
Third	1780 mJ/cm^2	30Hz	Slow

Tab II: General parameters of treatment

Treatment protocol

Although in the available literature there is no standardized procedure for the application of laser therapy in gonarthrosis, protocols similar to the one reported above have proved to be effective for degenerative chondropathies and gonarthrosis [3,4]. During the first and third phases, the tissues adjacent to the joints and associated muscles were treated. In the second phase, the trigger points were treated. The last step was the treatment of the knee joint by slow scanning in 6 optical windows, which was performed using a DJD head:

- Anteromedial and lateral window – the patient flexing the knee joint up to 90°
- Posteromedial and lateral window – the patient was lying on his stomach, with his knee extended
- Medial and lateral edge of patella – the patient's knee was extended

In each optical window, 500 J were supplied, for a total of 3000 J considering all the treated windows. This treatment phase was performed in contact scanning mode, using an handpiece (mod. DJD - Degenerative Joint Disease, ASA srl, Arcugnano, Vicenza, Italy) specifically designed to minimize the energy loss due to reflection and convey the emission (spot Ø 5 mm) into the intra-articular spaces.
The patients received a series of 10 applications every other day.

Statistical analysis – comparison of WOMAC index before and after the treatment

The effectiveness of the therapy was assessed by WOMAC questionnaire.

Statistical comparison of the answers of a group of respondents before and after the therapy was performed using the paired t-test. It is testing the null hypothesis, which is the agreement of the averages before and after the therapy. An alternative hypothesis is that there are statistically significant differences between the averages, which is assessed at the significance level of 5%. The t-test was computed by Microsoft Excel and the resulting p-value was compared to the significance level of $\alpha = 0.05$ (i.e. 5%). If $p > \alpha$, the null hypothesis remains valid and no significant differences are proved. If $p < \alpha$, then the null hypothesis is rejected in favor of the alternative hypothesis, i.e. that there are statistically significant differences between the average answers of the respondents before and after the therapy, which is proved on the significance level of 5%.

RESULTS

Comparison of WOMAC index before and after the treatment

The full comparison of all individual components of the WOMAC questionnaire, in particular the indexes WOMAC-A, WOMAC-B and WOMAC-C and the summary WOMAC indexes, before and after laser therapy, is presented in Table III.

Component of WOMAC questionnaire	Average before the therapy	Average after the therapy	p-value	Relative decrease (before/after)	Absolute difference (before/after)
1	2.24	1.72	0.000	77%	0.52
2	3.02	2.22	0.000	74%	0.80
3	3.48	2.38	0.000	68%	1.10
4	2.02	1.72	0.000	85%	0.30
5	2.34	1.94	0.000	83%	0.40
6	3.78	2.68	0.000	71%	1.10
7	2.88	2.28	0.000	79%	0.60
8	3.30	2.44	0.000	74%	0.86
9	3.38	2.50	0.000	74%	0.88
10	2.82	2.12	0.000	75%	0.70
11	2.22	1.74	0.000	78%	0.48
12	3.12	2.40	0.000	77%	0.72
13	2.08	1.76	0.000	85%	0.32
14	2.60	2.06	0.000	79%	0.54
15	2.56	2.04	0.000	80%	0.52
16	2.50	1.96	0.000	78%	0.54
17	2.68	2.00	0.000	75%	0.68
18	2.34	1.86	0.000	79%	0.48
19	1.64	1.42	0.002	87%	0.22
20	3.10	2.22	0.000	72%	0.88
21	1.72	1.38	0.000	80%	0.34
22	2.10	1.62	0.000	77%	0.48
23	3.46	2.48	0.000	72%	0.98
24	2.56	1.94	0.000	76%	0.62
WOMAC-A	13.10	9.98	0.000	76%	3.12
WOMAC-B	6.66	4.96	0.000	74%	1.70
WOMAC-C	44.18	33.94	0.000	77%	10.24
WOMAC	63.94	48.88	0.000	76%	15.06

Table III: Comparison of average values before and after the high-intensity laser therapy

The averages reported in Table III are arithmetic averages of the respondents' answers to each question or component of the WOMAC questionnaire.

The column "p-value" shows the results of the t-test. It can be observed that in all cases the resulting value $p < \alpha$. This means that all individual components of the WOMAC questionnaire, including the partial indexes WOMAC-A, WOMAC-B, WOMAC-C, and even the summary WOMAC index, showed statistically significant differences between the average answers of patients before and after the therapy on the significance level of 5 % (and even 1%).

In summary: using the t-test it was proved that with a probability of 99%, the high-intensity laser therapy significantly reduced pain, stiffness and problems with normal daily activities.

The column "relative decrease" shows the proportion of average answers before and after treatment expressed as percentages. E.g. in question No. 6, this proportion is 71%, which means that after treatment the respondents rated the feeling of joint stiffness after awakening in the morning at 71% of the initial stiffness prior to therapy, that is an improvement of 29%.

The column "absolute difference" is computed as the average difference between the values before and after the therapy. In question No. 6 mentioned above, there was an improvement by 1.1 points.

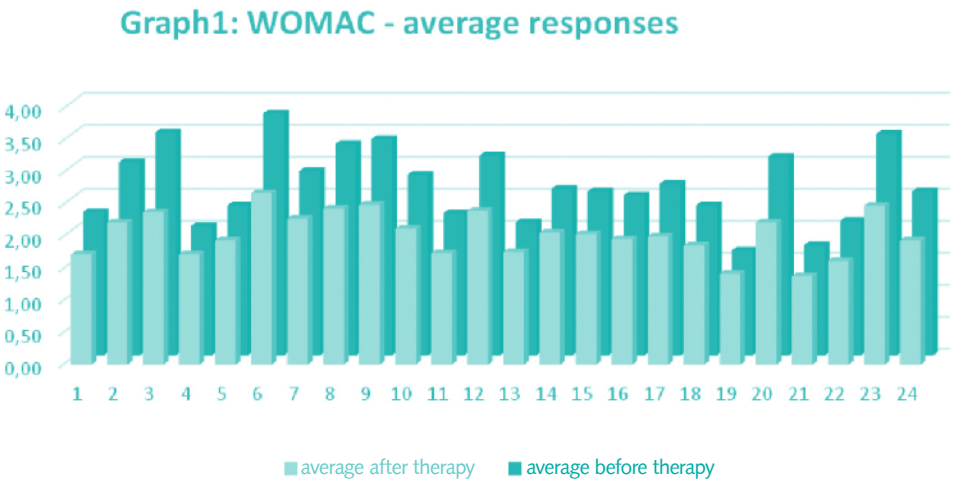

Fig.1 Results of WOMAC questionnaire

The best results (the greatest difference when comparing the state before and after the therapy) were found in questions 3 (pain at night in bed), 6 (joint stiffness after awakening in the morning) and 23 (performing heavy housework).
Nevertheless, the alleviation of pain and joint stiffness is noticeable also in all other components of the WOMAC questionnaire, which is very clear in Fig 1.

Conclusion from the statistical analysis of data

The assessment of each of the individual components of the WOMAC questionnaire, i.e. in partial indexes WOMAC-A, WOMAC-B, WOMAC-C, and even the summary WOMAC index, showed statistically significant differences between the average answers of patients with gonarthrosis before and after the therapy with a high-intensity NIR Nd:YAG laser on the significance level of 5 % (and even 1 %).
After the HILT, there was a statistically significant decrease in the WOMAC, WOMAC-A, WOMAC-B, WOMAC-C indexes of the respective components.
Using the t-test it was proved that, with a probability of 99%, HILT significantly reduced pain, stiffness and problems with normal daily activities.
The summary WOMAC index on average decreased by 24%.

DISCUSSION

The main objective of this work was to evaluate the effectiveness of HILT in gonarthrosis.
Etiology of gonarthrosis is a result of a complex interaction of interrelated biological, mechanical and biochemical factors. Effects of these factors result in impaired integrity and gradual loss of the cartilage. The final effect is joint destruction [5].
Osteoarthrosis of the knee joint (gonarthrosis) significantly reduces the quality of life. A typical clinical picture of gonarthrosis includes pain upon exertion, localized at the site of pathology, later also pain at rest and at night.
The patients included in the present study were selected based on pre-diagnosed grade II - III gonarthrosis. In order to assess the effectiveness of therapy, WOMAC questionnaire was chosen, which contains components dealing with pain, stiffness, and finally with problems in activities of daily living.
The study resulted in the following findings:

- An analgesic effect of a high-intensity laser was observed after the first application.
- Pain at rest and at night alleviated soon.
- None of the patients noticed any side effect of the HILT.

The aim of the present study was to test three hypotheses:
Hypothesis 1: Application of HILT has a positive effect on the mobility of the knee joint affected with arthrosis.
In the component related to stiffness after awakening in the morning, the resulting proportion is 71%. It means that, after the therapy, the respondents
assessed the feeling of joint stiffness after awakening in the morning at 71% of the stiffness before therapy, with an improvement of 29%. In this component, the improvement was 1.1 points.
Hypothesis 2: Application of HILT alleviates pain caused by gonarthrosis.
Alleviation of pain and reduction of joint stiffness can be observed in all components of the WOMAC questionnaire.
Hypothesis 3: The effect of the therapy has a positive influence on the quality of life and functional self-sufficiency.
The assessment of each of the individual components of the WOMAC questionnaire, i.e. partial indexes WOMAC-A, WOMAC-B, WOMAC-C, and even the summary WOMAC index, showed statistically significant differences between the average answers of patients before and after the therapy, with significant improvements in the quality of life
Therefore, according to the results obtained, the three hypotheses are verified.
The effectiveness of HILT in the treatment of musculoskeletal disorders was confirmed by various studies [6,13]. Buda et al. [14] investigating the effects of HILT in the treatment of patellar tendinopathy in sportsmen, demonstrated that patients who were treated with HILT showed accelerated recovery.
The findings here presented are in agreement with those obtained by other authors. Valent [4] demonstrated improvements in the function of the knee

joint in 74% of the patients and 66% of the patients reported alleviation of pain. Viliani [3] found that HILT was effective in treating pain and functional disorders related to gonarthrosis. A remarkable statistically significant improvement was found after the treatment and no side effects were observed.

The advantages of laser therapy are simple application, relatively low operating costs and easy device operation.

The results of this study demonstrate the positive effect of HILT on gonarthrosis and confirm hypotheses and objectives of this research.

CONCLUSIONS

The data obtained in this research clearly state a positive effect of HILT on the symptoms of osteoarthrosis. The conclusion of this research is that a therapy using this method could contribute to an improvement in availability and extend the healthcare options in this area

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APPENDIX

Likert scaling

Likert scaling is a method used to determine the level of agreement or disagreement with a statement with which the respondents are confronted in a survey. Likert scale, which was created in 1932, represents one of the most reliable techniques in the measurement of opinions. As this is an one-dimensional method, the essence of the problem investigated should be limited to one issue. In order to make it possible to identify the respondent on the scale, it is necessary not only to polarize the scale in an appropriate manner, but, of course, also to formulate the confronting statements in an appropriate, not misleading manner.

WOMAC algofunctional index

One of the most frequently used algofunctional indexes for gonarthrosis is the WOMAC index (Western Ontario and MacMaster Universities Osteoarthritis Index). The WOMAC index consists of three parts [15]:

WOMAC-A: 5 questions concerning various types of pain

WOMAC-B: 2 questions concerning the stiffness of knee joints

WOMAC-C: 17 questions concerning the activities of daily living

The WOMAC questionnaire evaluates pain, stiffness, functional disorders and summary index of algofunctional disability. Quantitative assessment of answers is divided into categorical, which is determined using a Likert scale, and continuous, which is determined using an analogue scale. WOMAC is the most frequently used tool for the assessment of algofunctional disability in gonarthrosis in Czech clinical studies [15].