Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2021 Sep 20; 9(B):1054-1060.
https://doi.org/10.3889/oamjms.2021.7099
eISSN: 1857-9655
Category: *B - Clinical Sciences*
Section: Surgery

OPEN ACCESS

Dynamics of Quality of Life Indicators in Patients with Chronic Synovitis of the Knee Joint after Arthroscopic Laser Double-mode Synovectomy

Alexey Lychagin, Yang Yanbin, Sergey Ivannikov, Stefka Radenska-Lopovok, Roza Yavlieva, Vladimir Surin, Yuliya Goncharuk, Ivan Vyazankin*, Marina Lipina

Department of Traumatology, Orthopaedics and Disaster Surgery, Sechenov First Moscow State Medical University (Sechenov University), Moscow, Russia

Edited by: Ksenija Bogoeva-Kostovska
Citation: Lychagin A, Yanbin Y, Ivannikov S, Radenska-Lopovok S, Yavlieva R, Surin V, Goncharuk Y, Vyazankin I, Lipina M. Dynamics of Quality of Life Indicators in Patients with Chronic Synovitis of the Knee Joint after Arthroscopic Laser Double-mode Synovectomy. OpenAccessMacedJMedSci.2021Sep20;9(B):1054-1060. https://doi.org/10.3889/oamjms.2021.7099
Keywords: Osteoarthritis; Synovitis; Arthroscopic laser synovectomy
***Correspondence:** Ivan Vyazankin, 6-1 Bolshaya Pirogovskaya st., 119991, Moscow, Russia. E-mail: vzvzvzvan@mail.ru
Received: 19-Aug-2021
Revised: 07-Sep-2021
Accepted: 10-Sep-2021

Funding: This research did not receive any financial support
Competing Interests: The authors declare that they have no competing interests.

Abstract

BACKGROUND: The treatment of patients with chronic synovitis of the knee joint is a challenge faced by many doctors all around the world. Treatment of this pathology is often a difficult task.

AIM: The aim of the study was improving the results of treatment of patients with chronic synovitis of the knee joint by applying two wavelengths of radiation.

MATERIALS AND METHODS: Our prospective cohort study consisted of two parts: experimental and clinical. Morphological examination of the synovial membrane and capsule was performed in September and October 2019. The treatment results of 50 patients with chronic synovitis of the knee joint aged 23–67 years with Stage II-IV osteoarthritis according to the Kellgren-Lawrence classification were analyzed. All patients underwent arthroscopic sanation, partial laser synovectomy using LSP-IRE-Polus apparatus, wavelength 0.97 microns in pulse-periodic mode (pulse 100 ms, pause 50 ms) with power 5 W and wavelength 1.56 microns in continuous mode with power 5 W from December 2019 to September 2020. Preoperative, 3, 6, and 12 months post-operative questionnaires were administered using the following scales and questionnaires: visual analog scale (VAS), Leken index, WOMAC, and KOOS.

RESULTS: Mean age (M) was 45.32 ± 131, body mass index 28.63 ± 4.72 kg/m^2, duration of synovitis 2.26 ± 1.91 years. A statistically significant improvement on the VAS, WOMAC, Leken, KOOS scales was noted by the 3rd month of postoperative follow-up. By the 6th month postoperatively, the results had further improved. The achieved results were preserved up to 12 months after surgery ($p < 0.05$).

CONCLUSION: According to the results of our study, which were evaluated using VAS, WOMAC, Leken index, KOOS, we can confirm that arthroscopic laser synovectomy using two working wavelengths allows us to achieve good clinical results and a lasting effect.

Introduction

Osteoarthritis (OA) is one of the most common pathologies of the musculoskeletal system. The high prevalence of OA is a medical, social, and economic problem [1]. Knee joints are most commonly affected by OA, reaching 33.3% of cases, with one in three patients having both knee joints affected [2].

OA is often accompanied by synovitis as a manifestation of the inflammatory response of the joint. Synovitis can be detected at all stages of OA, including the early stages, and its long-term course adversely affects the joint. The treatment of synovitis is an important measure to prevent the progression of degenerative changes in the knee joint [3], [4], [5], [6]. Knee synovitis occurs in 40% of cases of joint problems [7]. It contributes to the progression of cartilage damage, increased pain, and impaired joint function [8].

The treatment of synovitis is determined by both the triggering causes and the duration of the pathological process. In cases where conservative treatment (non-steroidal anti-inflammatory drugs [NSAIDs], glucocorticoids) fails to relieve synovitis, synovectomy is recommended [9]. Synovectomy can be performed using different techniques: chemically-based, radionuclide-based, surgical ("open" and arthroscopic techniques). Each type of synovectomy has its advantages and disadvantages. Chemical synovectomy can damage the articular cartilage. Radionuclide exposure can cause persistent leukopenia and agranulocytosis. Open synovectomy is quite traumatic and often leads to scarring, stiffness, long-term pain, and limited range of motion in the operated joint. Arthroscopic synovectomy is minimally invasive and avoids the complications that arise after an "open" synovectomy. However, it is difficult to perform the operation radically enough to remove all of the affected synovial tissue from the arthroscopic access. For this reason, the recurrence rate is high [10], [11].

Progressive development of laser technology, laser radiation of different wavelengths is widely used in medicine. Laser radiation in surgery is used in dentistry, ophthalmology, gynecology, traumatology, otorhinolaryngology, abdominal and vascular surgery [12]. Radiation from laser diodes with a wavelength of 0.94–0.98 μm penetrates into bio tissues to a depth of about 1 mm and is maximally absorbed in water and hemoglobin. Due to the combination of cutting and coagulation properties of the laser light with a wavelength of 0.97 μm, it is optimal for most surgical interventions. In particular, it is widely used for outpatient and inpatient treatment of various gynecological and anorectal diseases [13].

A widespread use of laser radiation with Er (erbium) - activated fiber laser (radiation with a wavelength of 1.56 μm), which is absorbed in water by an order of magnitude stronger than radiation with a wavelength of 0.97 μm, with similar absorption in the blood. Such radiation has found application in vascular surgery for endovasal laser obliteration. Musaev *et al*. performed endovenous radiofrequency obliteration with puncture laser obliteration (wavelength 1.56 nm), with good results [14]. In traumatology and orthopedics, laser is actively used for bone diseases, including infectious ones with osteoperforation technique [15]. Percutaneous laser decompression for intervertebral disc herniation and facet syndrome is widely used [16]. Shumilin *et al*. performed laser obliteration of hygromas, 1.56 μm wavelength with a quartz fiber diameter of 0.4 mm. The treatment results indicated the effectiveness of the proposed method, which was confirmed by the absence of pain syndrome and a good cosmetic outcome [17].

The studied and applied in practice laser radiation for the treatment of a wide spectrum of pathologies in other directions of medicine allows assuming the possibility of their effective use in traumatology and orthopedics at the treatment of chronic synovitis of a knee joint, applying a combination of arthroscopic laser synovectomy. The morphological picture of the synovial membrane structure in patients with OA is characterized by hyperplasia, sublimating fibrosis, and stromal vascularization. Synovial cells produce pro-inflammatory mediators that attract immune cells, enhance angiogenesis and induce a phenotypic shift in chondrocytes [18]. Since radiation with a wavelength of 1.56 μm is absorbed in water by an order of magnitude stronger than 0.97 μm, it is very effective in cases where it is desirable to carry out heating without carbonization of bio tissues. Sokolov *et al*. showed that using 1.56 μm laser allows using lower radiation power to achieve occlusion [19]. At the same time, two modes are supposed to be used: one of them is aimed at coagulation and the other one is aimed at reduction of the treated surface thickness. Recently, there are two-wavelength devices allowing the use of both modes (0.97 μm and 1.56 μm), changing the effect on bio tissues [13].

Thus, the use of two working wavelengths of exposure to the synovial membrane can lead to good results in the treatment of synovitis.

Materials and Methods

Our prospective cohort study consisted of two parts. The experimental part was performed between September and October 2019. The clinical part of the study was performed from December 2019 to September 2020.

The microscopic picture of changes occurring in the synovial membrane after knee arthroplasty was assessed. For histological examination, the harvested tissue was divided into 3 parts. One part was left untreated, the other part was treated with 2 wavelengths (0.97 μm wavelength in pulsed-periodic mode (100 ms pulse, 50 ms pause) with 5 W and 1.56 μm wavelength in continuous mode with 5 W for 10 s) and the third fragment was treated with 40 W ablator for 10 s (VAPR® COOLPULSE® 90 Suction Electrode, Depuy Mitek, USA). Three comparison groups were defined: a control group (5 fragments), a post-laser group (5 fragments), and a post-ablation group (5 fragments). Fixation in paraffin was carried out for 2 weeks, and 5 μm thick paraffin blocks were sliced after preparation. Preparations were stained with Van Gieson's picrofuchsin and hematoxylin-eosin. The preparations were examined with an Olympus bx51 microscope (Olympus u-tvo 5 xc-3 digital camera).

Fifty patients with chronic recurrent synovitis of the knee joint aged from 23 to 67 years, with ineffective previous conservative treatment (physiotherapy, NSAIDs) for 6 months before surgery were included in the study.

Before surgery all patients, in addition to clinical examination and standard preoperative preparation, the degree of synovitis was assessed clinically and by magnetic resonance imaging (MRI) of the knee joint. All patients were questioned using the visual analog scale (VAS), WOMAC, Lenken index, and the KOOS (Knee Injury and OA Outcome Score) questionnaire. Postoperative outcomes were assessed with MRI scans and compared with help of VAS, WOMAC, Leken index, and KOOS before surgery, in 3, 6, and 12 months after surgery.

When examining the knee joint, the degree of synovitis was assessed using a 4-point scale [10]: 0 - no swelling; 1 - moderate; 2 - pronounced; 3 - severely pronounced.

Inclusion criteria

The intensity of walking pain >40 mm according to VAS scale at 2 weeks before inclusion; no NSAIDs within 2 weeks before inclusion; ineffectiveness of conservative treatment within 6 months. Inclusion criteria: surgical treatment of gonarthrosis within the previous 6 months; the presence of marked deformity and instability of the knee joint; the presence of serious or unstable somatic diseases (severe liver, cardiovascular, lung or kidney diseases, cancer, and mental illness), decompensated diabetes mellitus.

Patient characteristics by age, sex, body mass index (BMI), etc. are shown in Table 1.

Table 1: Patient characteristics*

Characteristic (n=50)	Score
Age, years	45.3 ± 13.1
Gender	21 (42%)
Male, n (%)	29 (58%)
Female, n (%)	
Body mass index, kg/m^2	28.63 ± 4.72
Side of the lesion, (%)	
Left knee joint	21 (42%)
Right knee joint	29 (58%)
Duration of synovitis, years	2.26 ± 1.91
Radiological stage of	0
osteoarthritis according to	5 (10%)
Kellgren-Lawrence, n (%)	24 (48%)
0	21 (42%)
1	0
2	
3	
4	
ICRS, n (%)	0
0	7 (14%)
1	19 (38%)
2	22 (44%)
3	2 (4%)
4	
Degree of	0
synovitis (pre-operatively,	20 (40%)
clinically) n (%)	23 (46%)
0	7 (14%)
1	
2	
3	
Degree of	0
synovitis (pre-operatively,	10 (20%)
according to magnetic	24 (48%)
resonance imaging) n (%)	16 (32%)
0	
1	
2	
3	

*Except where indicated otherwise, values are the mean±SD. n-number of patients, BMI: Body mass index; ICRS: International cartilage repair society.

In order to relieve recurrent synovitis of the knee joint, all patients underwent arthroscopic sanation, laser partial synovectomy using LSP-IRE-Polus device, 0.97 μm wavelength in pulsed-periodic mode (pulse 100 ms, pause 50 ms), with 5 VT power and 1.56 μm wavelength in continuous mode with 5 VT power. The operations were carried out under combined endotracheal anesthesia. All patients were operated by one surgeon.

All patients included in the study filled out an informed consent beforehand. This study was approved by the local ethics committee of the I.M. Sechenov First Moscow State Medical University (protocol No. 34-20).

Statistical processing was performed using the MedCalc 19.5.2 for Windows statistical data analysis package (MedCalc, Belgium). The information contained in the protocols was manually entered into the computer, followed by software and visual inspection of the data for completeness, acceptable ranges, logical and medical correlations. Normality of the quantitative data distribution was assessed using the Shapiro-Wilk criterion and histogram analysis. Minimum (min) and maximum (max) values, mean (M), and standard deviation from arithmetic mean (σ) were calculated. The mean values in the work were presented in the form of M ± σ. Anacova test was used to compare quantitative indices in dynamics. Differences between the indices were considered statistically significant at the probability level $p < 0.05$.

Results

Morphological characterization of the synovial membrane and capsule

The synovial sheath and capsule of the control group were hypertrophic, areolar, covered by a single layer of synoviocytes (Figure 1A). Subsynovial tissue is represented by thin fibers and a large number of thin-walled vessels. There are clusters of lipocytes (Figure 1B). There are no inflammatory-cell infiltrates. The capsule is moderately sclerosed.

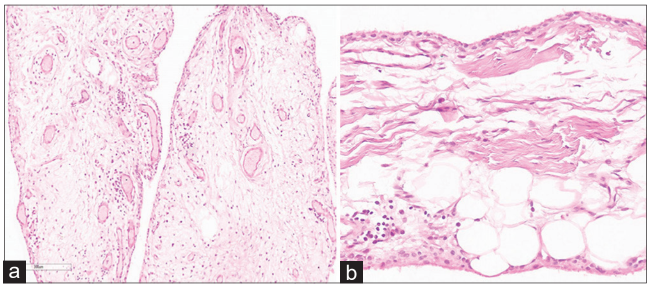

Figure 1: Osteoarthritis. Synovial membrane without any treatment. (A) Severe hypertrophy of villi, ×100. (B) Retained synoviocytes, sclerosis of the subsynovial layer, ×200. Hematoxylin and eosin stains

After exposure with a laser of 2 wavelengths (wavelength 0.97 μ in pulse-periodic mode (pulse 100 ms, pause 50 ms) with power 5 W and wavelength 1.56 μ in continuous mode with power 5 W, 10 s) synovial membrane is hypertrophied, covered with preserved outermost synoviocytes. There is superficial necrosis and sloughing of the covering synoviocytes in a small area. There is edema in the subsynovial tissue (Figure 2A). There are no morphological signs of necrosis and inflammation. Based on picrofuchsin staining, the capsule is moderately sclerosed. There are no morphological signs of damage (Figure 2B).

After an ablation of 40 W for 10 s (VAPR® COOLPULSE® 90 Suction Electrode, Depuy Mitek, USA) the synovial membrane is hypertrophied. The

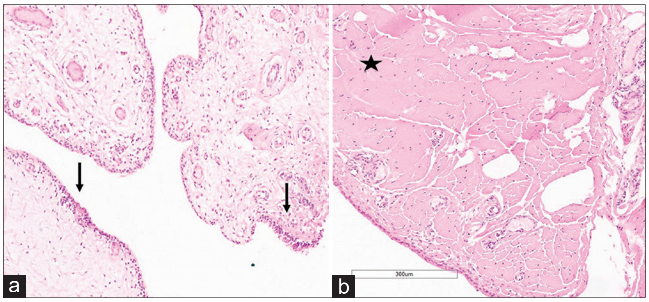

Figure 2: Osteoarthritis. Synovial membrane. Exposure of laser. (A) The expressed edema of subsynovial layer. Focal superficial necrosis of crown synoviocytes (arrow). (B) Sclerosis and hyalinosis (asterisk). Hematoxylin and eosin stains, ×100

covering synoviocytes are necrotic. Tissue detritus can be seen on the surface of the sheath. There is marked edema and foci of coagulation necrosis in the subsynovial tissue. There are no morphological signs of inflammation (Figure 3). The capsule is moderately sclerosed. There are foci of coagulation necrosis in places.

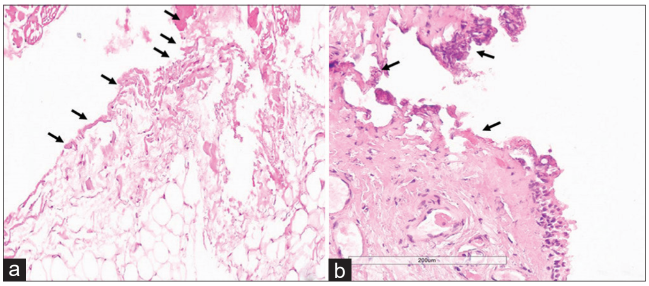

Figure 3: Osteoarthritis. Exposure to ablator mode. (A) membrane. ×100. (B) capsule. ×250. Coagulation necrosis and tissue edema (arrows). Hematoxylin and eosin stains

Results of quality of life and knee function score

The mean age of the patients was 45.3 ± 13.1 years (23–67 years), as shown in Table 1. Of 50 patients, there were 29 females (58%) and 21 males (42%). BMI was 28.63 ± 4.72 kg/m^2 and the duration of synovitis was 2.26 ± 1.91 years. Patients with stage 3 radiological knee OA according to Kellgren-Lawrence – 21 (42%), grade 3 intraarticular changes according to ICRS – 22 (44%), grade 2 synovitis (clinically) and according to MRI - 23 (46%), 24 (48%), respectively, pre--dominated. There were no infectious and thromboembolic complications after surgical treatment.

The assessment of the results showed a statistically significant reduction in pain in the post-operative period according to the VAS scale. VAS before surgery was 51.2 ± 16.62. In 3 months after surgery VAS intensity was 18.54 ± 9.52, $p < 0.0001$. By 6 months post-operatively the pain intensity decreased to 10.22 ± 9.98 ($p < 0.0001$) and achieved in 12 months post-operatively - 10.4 ± 9.48, $p < 0.0001$ (Figure 4).

The WOMAC and Leken scales also showed a similar positive trend (Figures 5 and 6). WOMAC

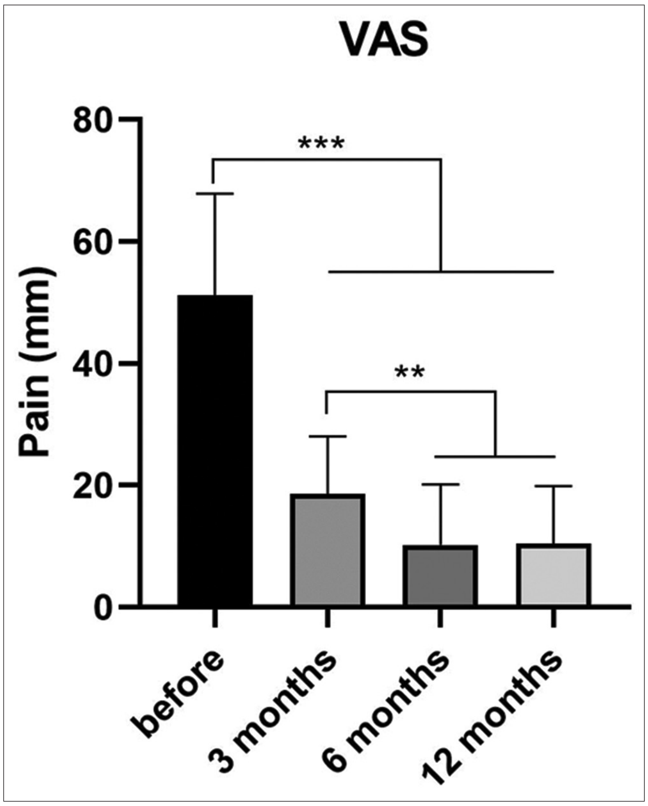

*Figure 4: Dynamics of mean visual analogue scale (mm) in patients, **:p < 0.01; ***: p < 0.001*

pre-operative score was 65.54 ± 16.5 and improved to 41.82 ± 7 ($p < 0.0001$) in 3 months after surgery. By 6 months post-operatively, the trend of improvement had continued, with a score of 38.22 ± 6.39 ($p < 0.0001$)

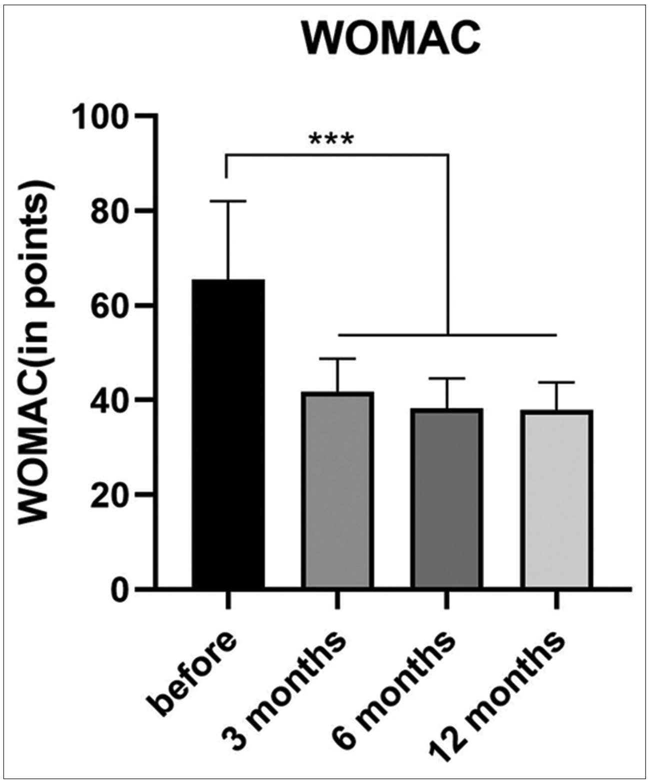

*Figure 5: Dynamics of average WOMAC scores in patients (in points), ***: p < 0.001*

and stabilized at an average value of 37.92 ± 5.9 ($p > 0.05$) in 12 months after surgical treatment.

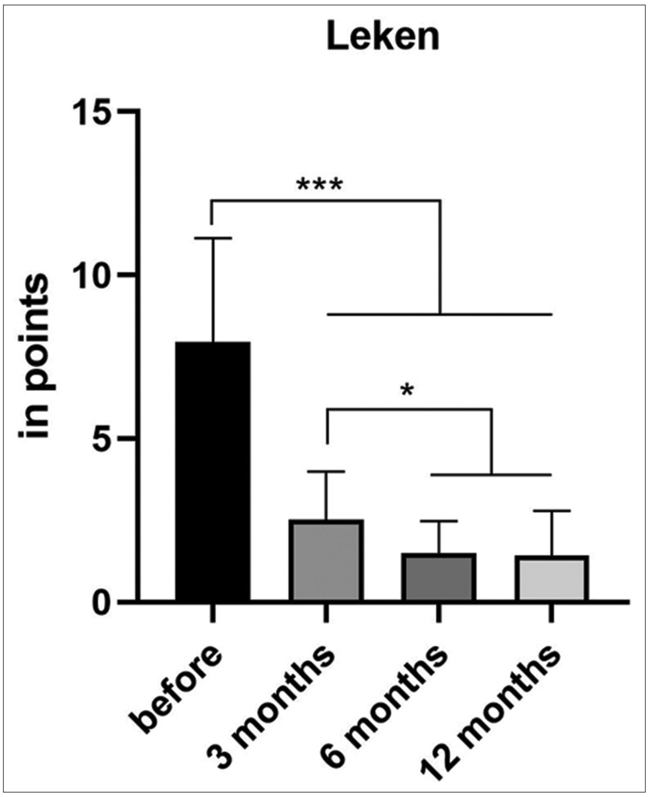

*Figure 6: Dynamics of the average total indices according to the lenken index, (in points), *:p < 0.05; ***:p < 0.001*

In an analysis of the Leken's index score, 70% improvement was also achieved by 3 months post-operatively and by 6 months by 80% ($p < 0.05$). This index was maintained by 12 months after surgery.

The results of treatment were also determined on the basis of the KOOS questionnaire. The mean score on the KOOS final index score on admission was 44.64 ± 15, at 3 months postoperatively it had improved by 70% pre-operatively to 77.44 ± 8.51 ($p < 0.05$), indicating good outcome. At 6 months, the mean score had increased by a further 4.18 points to 81.62 ± 6.88 ($p < 0.05$). At 12 months, there was no further significant improvement, but the score had stabilized at "excellent" (Figure 7). The greatest improvement could be observed in sporting activity and quality of

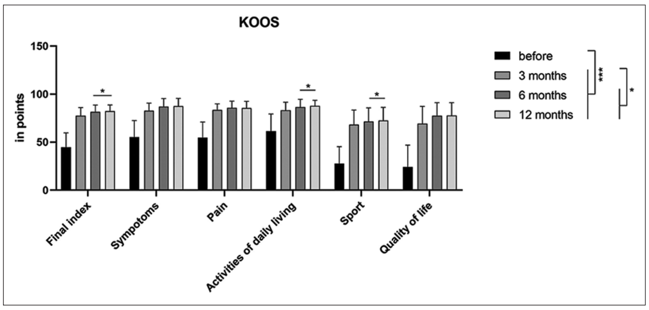

*Figure 7: Comparative assessment of the dynamics of the knee joint function by KOOS subscale scores (in points), *: p < 0.05; ***: p < 0.001.*

life, with patients reporting a 2.7-fold and 2.8-fold increase in these indices by 3 months post-operatively, respectively. There was a 1.7-fold improvement in pain scores and activity scores ($p < 0.001$). Another positive aspect is that the positive results of minimally invasive treatment can be maintained for up to 12 months after surgery in cases of long-standing synovitis.

More results of quality of life assessments and knee joint function are presented in Table 2.

Table 2: Results of quality of life and knee function score*

Score	Before surgery	3 months	6 months	12 months
Visual analog scale (мм)	51.2 ± 16.62	18.54 ± 9.52	10.22 ± 9.98	10.4 ± 9.48
WOMAC (in points)	65.54 ± 16.5	41.82 ± 7	38.22 ± 6.39	37.92 ± 5.9
Leken index (in points)	7.95 ± 3.18	2.53 ± 1.47	1.5 ± 0.98	1.43 ± 1.37
KOOS (in points)	44.64 ± 15	77.44 ± 8.51	81.62 ± 6.88	82.16 ± 6.51

*Except where indicated otherwise, values are the mean±SD.

Discussion

According to our hypothesis, confirmed by the results of the study, the use of laser arthroscopic synovectomy helps in the treatment of chronic knee synovitis. According to the world literature, there are many methods for the treatment of this disease, but there have been no studies on the use of laser synovectomy with two wavelengths.

Synovitis can be detected at all stages of OA, including early stages. Synovial cells produce pro-inflammatory mediators that attract immune cells, enhance angiogenesis and induce a phenotypic shift in chondrocytes [18]. It contributes to the progression of cartilage damage, increased pain, and impaired joint function [8]. In clinical practice, various methods of treating synovitis in OA are used. Chondroprotectors and NSAIDs are aimed at reducing inflammation and restoring cartilage. When conservative treatment of persistent recurrent synovitis is ineffective, synovial sheath removal - synovectomy - is relevant [9]. Both positive and negative aspects of this type of surgery have been described, and the search for optimal combinations is still relevant [10].

Progressive development of laser technologies enables their widespread use in clinical practice. The combination of cutting and coagulation properties can be achieved by laser radiation with a wavelength of 0.97 μm [13] and 1.56 μm, which is important especially in the aquatic environment.

Radiation with a wavelength of 1.56 μm has found application in vascular surgery for endovasal laser obliteration. Musaev *et al*. performed endovenous radiofrequency obliteration with puncture laser obliteration, with good results [14]. In traumatology and orthopedics, Sahakyan used laser for bone diseases, including infectious ones with osteoperforation technique [15]. Percutaneous laser decompression for intervertebral disc herniation and facet syndrome is widely used [16]. The treatment results indicated the effectiveness of the proposed method. We hypothesized that the use of two working wavelengths of exposure to the synovial membrane can lead to good results in the treatment of synovitis.

Illustrations of the histomorphological damage to the synovial membrane structure and capsule made it possible to understand the nature of the structural abnormalities occurring after surgical treatment. Comparison of the morphological results revealed that the use of laser with 2 wavelengths (0.97 μm and 1.56 μm) leads only to superficial changes. Necrosis of the covering synoviocytes and swelling of the subsynovial tissue develop. The application of 40 W ablation damages not only the covering synoviocytes but also the subsynovial layer. Coagulation necrosis develops. In addition, foci of coagulation necrosis develop in the capsule.

Our clinic study and the results show that after arthroscopic laser synovectomy using a combination of 2 wavelengths, the results were achieved in terms of pain and quality of life, as well as synovial fluid volume in the operated joint, are maintained for 1 year after surgery.

In order to reliably assess the effectiveness of the chosen method of surgical treatment of chronic synovitis, it is necessary to continue working on a larger sample of patients and analyze the long-term results.

Conclusions

Arthroscopic laser synovectomy using two working wavelengths of exposure to the synovial membrane made it possible to achieve significant positive dynamics in the treatment of recurrent synovitis in OA. According to the results obtained, the use of our technique allows us to achieve good clinical results and a lasting effect.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

All patients who took part in the study gave their informed consent prior to their inclusion in the study

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