Turk J Phys Med Rehab 2024;70(4):517-524
DOI: 10.5606/tftrd.2024.12390
Available online at www.turkishjournalpmr.com

Original Article

The efficacy of interferential current treatment on knee osteoarthritis: A pilot randomized double-blind study comparing the effects of different carrier frequencies

Benil Nesli Ata[1], Berrin Durmaz[2], Ece Çınar[2], Funda Atamaz Calis[2]

[1]Department of Physical Medicine and Rehabilitation, Çiğli Regional Training and Research Hospital, İzmir, Türkiye
[2]Department of Physical Medicine and Rehabilitation, Ege University Faculty of Medicine, İzmir, Türkiye

ABSTRACT

Objectives: This study aimed to investigate the effects of different carrier frequencies of interferential current (IFC) treatment on a Visual Analog Scale (VAS) for pain, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), 10-m walk test, and the amount of paracetamol taken.

Patients and methods: The double-blind, randomized controlled study included 61 patients (16 males, 45 females; mean age: 63.7±9.8 years; range, 50 to 80 years) with knee osteoarthritis who were randomized to three treatment groups: 2,000 Hz, 4,000 Hz, and 8,000 Hz. The study was conducted between February 2019 and October 2019. Subjects received IFC treatment for 20 min five times per week for three weeks. All subjects were prescribed a home exercise program. Patients were evaluated at baseline and at three and seven weeks. The primary outcome was VAS to assess knee pain.

Results: Treatment with IFC yielded significant results in VAS pain, WOMAC pain, and WOMAC function parameters in all three groups, but no significant difference was shown among the three groups. The WOMAC stiffness parameter was found to benefit from the treatment only in the first group, while the 10-m walk test improved for the first and third groups. The number of paracetamol tablets taken differed significantly neither in nor among the treatment groups.

Conclusion: Previous trials have found a significant reduction in knee pain levels and an increase in function with IFC treatment, although there is no consensus on which carrier frequencies and duration to choose for IFC treatment. In this study, we detected significant benefits for all the different carrier frequency groups but were not able to show any to be superior to the others.

Keywords: Interferential current electrotherapy, osteoarthritis of the knee, pain.

Osteoarthritis (OA) remains the most common and well-studied type of joint disorder. It can harm all layers of the moveable joints and is an important cause of disability, decreased independence, social and functional impairment, and reduced quality of life in the elderly population.[1] Significant morbidity has been linked to OA, resulting in disability and decreased quality of life. The increasing prevalence of OA is expected to lead to a growing impact on health care and major challenges for public health systems.[2] Clinically, it may cause pain, stiffness, limitation of movement, crepitation, functional disability, and loss in activities of daily living.[3]

A multidisciplinary treatment approach for managing OA aims to alleviate symptoms, improve functional status, and promote tissue healing to slow down the progression of joint damage.[4] A recent systematic review showed that interferential current (IFC) appears to be the best type of electrotherapy for pain relief in patients with knee OA.[5,6] Although the mechanism of the analgesic effect of IFC is still unknown, it can be explained by gate control theory.[7] Previous studies have found a significant reduction in knee pain levels and an increase in function with IFC treatment for OA of the knee.[8]

Corresponding author: Benil Nesli Ata, MD. İzmir Şehir Hastanesi, Fiziksel Tıp ve Rehabilitasyon Kliniği, 35540 Bayraklı, İzmir, Türkiye.
E-mail: drbenilnesli@gmail.com

Received: August 08, 2023 **Accepted:** January 09, 2024 **Published online:** October 31, 2024

Cite this article as: Ata BN, Durmaz B, Çınar E, Atamaz Calis F. The efficacy of interferential current treatment on knee osteoarthritis: A pilot randomized double-blind study comparing the effects of different carrier frequencies. Turk J Phys Med Rehab 2024;70(4):517-524. doi: 10.5606/tftrd.2024.12390.

Interferential current is a medium-frequency alternative electrical current that is amplitude-modulated in a low-frequency range, which is generated by the superimposition of two electrical currents of medium frequency slightly out of phase.[7,9] Studies have reported that the interference current with a frequency of 100 Hz and a burst length of 10 msec is optimal in terms of both stimulating sensory and motor nerve fibers and analgesic effects.[10] Therefore, interference current at 100 Hz frequency has been used in many studies.[11] On the other hand, in a recent study, it was reported that this alone is not sufficient to provide analgesia, but carrier frequency may also have an important place. Venancio et al.[12] compared the forms of IFC with carrier frequencies of 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 10 kHz. While a frequency of 1 kHz was found to be more effective on pain, the best patient comfort was obtained in 8 kHz and 10 kHz applications. However, there is no consensus on which duration of carrier frequencies to choose for IFC treatment.[12]

By using low carrier frequencies, the number of cycles per burst is reduced, and thus the summation effect is reduced. This causes less nerve stimulation. As the frequency of the carrier current increases, the phase time of the generated current becomes shorter. This causes a neurophysiological branch block in the Aβ fibers, and the analgesic effect decreases.

The resistance that alternating current encounters in the tissue is called impedance. It is theoretically known that as the frequency of the applied carrier current frequency increases, the skin resistance decreases, and the electricity can reach deeper tissues.[12] In our study, we aimed to evaluate the analgesic effect of current obtained at different tissue depths by using different carrier frequencies on knee OA. Hence, we aimed to assess the effects of different carrier frequencies of IFC therapy on the Visual Analog Scale (VAS), the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), the 10-m walk test, and the number of paracetamol tablets taken.

PATIENTS AND METHODS

This double-blind, randomized controlled study was produced from the dissertation of the primary author. Participants were recruited from the physical medicine and rehabilitation inpatient and outpatient clinics of the Ege University Faculty of Medicine between February 2019 and October 2019. A written informed consent was obtained from each patient. The study protocol was approved by the Ege University Faculty of Medicine Ethics Committee (date: 16.05.2016, no: 16-4.1/54). The study was conducted in accordance with the principles of the Declaration of Helsinki. Eligible volunteers were diagnosed with knee OA diagnosed according to American College of Rheumatology criteria, radiologically confirmed with a Kellgren-Lawrence grade of 2 or 3.[13] The patients had to be symptomatic with at least 4-cm severity of pain on VAS for at least six months. Sixty-six patients initially enrolled in the study. During the study period, a total of two patients discontinued the treatment, three patients did not come for the last control. A total of five patients were excluded from the study. At the end of the study, a total of 61 patients (16 males, 45 females; mean age: 63.7±9.8 years; range, 50 to 80 years) were evaluated. The reasons for dropout were not enough time to attend last follow up (n=3) and health problems not related to knee pain (n=2). A flowchart of the patient enrollment in the study is shown in Figure 1.

The primary outcome was an improvement in 100-mm visual VAS to assess the level of knee pain. The patients were asked to assess their pain levels between 0 (no pain) and 100 (severe pain). The VAS also measured the patients' satisfaction with their treatment process, with 0 reflecting extremely dissatisfied and 100 reflecting extremely satisfied. The WOMAC is commonly used in the evaluation of the effect of OA. It is a questionnaire that is self-administered, consisting of 24 items, and divided into three subscales: function, stiffness, and pain.

Patients with symptomatic Stage II and higher OA in adjacent joints of the lower extremity were excluded to rule out the confounding effect of coexisting difficulty in ambulation. Patients were also excluded if they had received intraarticular corticosteroid or chondroprotective injections in the previous six months, had undergone previous major surgery, such as joint replacement, had severe cardiovascular disease, or had a cardiac pacemaker. The other exclusion criteria included a diagnosis of septic arthritis, cancer, a neurological disease that could affect walking, inflammatory arthritis, and poor general health status that would interfere with the functional evaluations during the study.

The patients were grouped into Groups 1, 2, and 3, according to their order of admission. Randomization scheme was created by a web-based randomization generator.[14] Patients were then

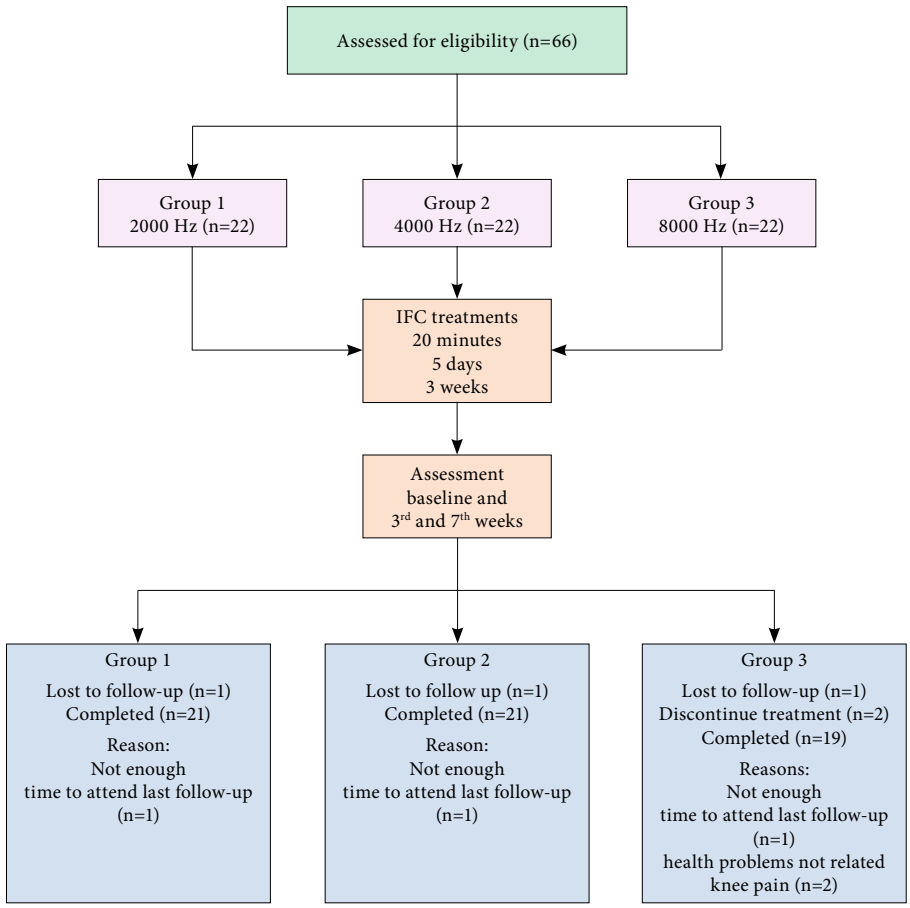

Figure 1. Study flowchart.
IFC: Interferential current.

forwarded to the coinvestigator, who would administer the IFC treatment. The pretreatment and posttreatment evaluations of the patients were made by the coordinator researcher, who was blinded to the groups. In the study, patients and the evaluator were blinded to the treatment groups.

Interferential current, Sonopuls 692 Combination Therapy Device (Enraf-Nonius, Rotterdam, the Netherlands), was applied for 20 min a day, five days a week, for three weeks with a carrier current of 2,000 Hz in Group 1, 4,000 Hz in Group 2, and 8,000 Hz in Group 3. The amplitude-modified current frequency was set to 100 Hz in all groups. Before the application, the patient was seated in a comfortable position, and both knees were treated with self-adhesive silicon electrodes measuring 5×5 cm. The current intensity was increased until a tingling sensation was felt under the electrodes without causing pain. No complications were recorded as a result of the treatments that were applied.

An exercise program was given to all groups.[15] The exercises were recommended every day for both knees, with three sets of 10 repetitions per day. Subjects were strongly recommended to continue exercising regularly at home. All patients also received a complete set of premade exercise brochures showing the exercises to ensure that the training program would be carried out properly.

Subjects' age, sex, educational status, comorbidities, and the number of paracetamol tablets used were questioned and recorded in the case evaluation form. Clinical assessments were made at baseline and at three and seven weeks. The physician who assessed the treatment outcomes was blinded to the patient's group of treatment.

The 10-m walk test was measured with a stopwatch. The 10-meter walk test was used to evaluate the

gait. In this test, the subject was asked to walk at their normal pace in a premeasured 10-m corridor (if using a walking aid, it was carried out with it). The timer was started when the person's foot was at the starting line and ended when they crossed the finish line. Two measurements were made at each visit, averaged, and recorded in meters per second.[16]

The subjects were asked to discontinue any medical treatment with nonsteroidal anti-inflammatory drugs for the study period. If the patient required additional analgesics due to knee pain, paracetamol use was permitted with the condition that they noted every paracetamol tablet intake on the study form. At each clinic visit, the study report form was evaluated, and paracetamol intake was recorded in tablets/week.

In addition to clinical assessments, patients were evaluated using VAS pain scale, WOMAC pain, WOMAC stiffness, and WOMAC function scale.[17]

Statistical analysis

All statistical analyses were carried out with IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). A power analysis was performed to calculate the sample size of the study. The calculated minimum number of patients was determined as 15 for each group, with a power of 80% and an effect size of 0.4 according to VAS results from previous studies.[18] The normal distribution of continuous data was evaluated with the Shapiro-Wilk test. Variation of demographic data were evaluated with the chi-square test, and continuous numerical data that showed a normal distribution were evaluated with one-way analysis of variance (ANOVA). Intergroup comparisons were evaluated with one-way ANOVA for data showing a normal distribution, and the Kruskal-Wallis test was used for continuous data with nonnormal distribution and for ordinal data. For the comparison of intragroup and intergroup changes, data showing normal distribution were evaluated with the repeated measures ANOVA. Intragroup changes over time were examined for the data that showed no interaction between time and groups. If in-group variation was detected, Dunn's test was used for pairwise comparisons. Friedman test was carried out for intragroup comparisons for data that did not show normal distribution and for ordinal data (10-m walk test, paracetamol use, WOMAC subgroups, and VAS pain). Wilcoxon test was used for pairwise comparisons of within-group measurements in cases where significant changes were detected. The Kruskal-Wallis test was used in independent groups to evaluate whether there was a difference between the groups in terms of changes that occurred over time. A p-value <0.05 was considered statistically significant.

RESULTS

The demographic and disease characteristics of the patients are shown in Table 1. There was no significant difference in the demographic data between the groups before treatment. No side effects were observed in any of the patients during the study.

TABLE 1
Demographic and clinical characteristics of patients

	Group 1 (n=21)			Group 2 (n=21)			Group 3 (n=19)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	p
Age (year)			64.5±10.3			62.1±8.9			64.7±10.4	NS
Sex										NS
Male	3	14.3		6	28.6		7	36.8		
Female	18	85.7		15	71.4		12	63.2		
Body mass index (kg/m^2)			29.4±5.1			29.6±4.5			29.4±4.7	NS
Comorbidities										NS
Coronary artery disease	4	19		1	19		1	5		
Diabetes mellitus	4	19		4	19		11	58		
Hyperlipidemia	1	4		1	4		0	0		
Hypertension	13	62		13	62		8	42		
None	6	29		8	38		4	21		
Others	3	14		3	14		1	5		
Thyroid dysfunction	0	0		1	4		3	16		

SD: Standard deviation; NS: Not significant; Nominal data Chi-square test, numerical data one-way ANOVA test.

TABLE 2
Intragroup and intergroup comparison of clinical parameters over time

	Group 1 (n=21)		Group 2 (n=21)		Group 3 (n=19)		Intergroup comparison of change over time
	Median	Min-Max	Median	Min-Max	Median	Min-Max	*p*
VAS pain							
At baseline	6	4-8	6	4-8	6	4-10	
3rd week	3	0-8	4	2-6	3	2-9	
7th week	3	0-8	4	1-8	4	0-8	
p^{α} within-group comparison	<0.001**		<0.001**		<0.001**		
0-3rd week change	3	–2-7	2	–2/4	2	–1/6	0.209$^{\beta}$
0-7th week change	3	–3-7	2	–2/4	2	–3/7	0.163$^{\beta}$
WOMAC pain							
At baseline	9	4-14	6	1-18	8	2-14	
3rd week	4	0-15	5	0-10	4	0-13	
7th week	5	0-12	6	0-14	4	0-12	
p^{α} within-group comparison	0.001**		0.009**		0.036*		
0-3rd week change	4	–4-11	1	–2-10	3	–4-12	0.134$^{\beta}$
0-7th week change	4	–4-9	1	–5-15	4	–5-13	0.123$^{\beta}$
WOMAC function							
At baseline	30	3-43	22	5-52	21	10-50	
3rd week	19	3-36	18	2-35	14	1-40	
7th week	21	2-32	17	3-33	10	2-40	
p^{α} within-group comparison	0.004**		0.014*		0.018*		
0-3rd week change	8	–16-33	6	–7-22	10	–15-38	0.212$^{\beta}$
0-7th week change	9	–16-35	6	–7-21	11	–15-48	0.651$^{\beta}$
WOMAC function							
At baseline	3.0	0-6	1.0	0-7	2.0	0-6	
3rd week	1.0	0-6	3.0	0-4	0.0	0-5	
7th week	1.0	0-4	2.0	0-4	1.0	0-4	
p^{α} within-group comparison	0.005*		0.083		0.003*		
0-3rd week change	1	–3-4	0	–3-3	1	0-5	0.003*$^{\beta}$
0-7th week change	1	–2-6	0	–3-5	2	–2-6	0.116$^{\beta}$
WOMAC function							
At baseline	11.8	7-26	9.2	7.5-15.5	10.4	8.5-20	
3rd week	10.0	7-21	9.2	7-20	10.0	7.7-13.4	
7th week	9.7	7-21	9.0	7.1-20	9.7	7.7-12.7	
p^{α} within-group comparison	0.003**		0.912		0.58		
0-3rd week change	0.4	–2.2-5	0	–4.5-3.3	0	–2.5-10	0.188$^{\beta}$
0-7th week change	0.9	–1.1-5	0	–4.5-3	0.3	–1.2-9.6	0.045*$^{\beta}$
WOMAC function							
At baseline	2.0	0-14	0	0-14	0	0-14	
3rd week	0	0-14	0	0-7	0	0-10	
7th week	0	0-14	0	0-14	0	0-7	
p^{α} within-group comparison	0.375		0.239		0.823		
0-3rd week change	0	–7-13	0	–14-7	0	–14-7	0.845$^{\beta}$
0-7th week change	0	–7-13	0	–14-7	0	–14-4	0.994$^{\beta}$

VAS: Visual analog scale; WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index; p^{α} Within-group comparison, Friedman test; β Intergroup comparison of change over time, Kruskal Wallis test.

In the intragroup comparison of the VAS parameter, which was the primary outcome of our study, significant improvement was observed in all three groups ($p^a<0.001$, Table 2). The decrease in the VAS parameter was significant between baseline and three ($p^\beta=0.209$) and seven ($p^\beta=0.163$) weeks. There was no significant change in parameters between three and seven weeks. No superiority was found between the groups in terms of VAS decrease. The results were the same for WOMAC pain and WOMAC function parameters (Table 2).

The change in WOMAC stiffness parameter within the group over time was evaluated with the Friedman test. Difference was significant in Groups 1 and 3 ($p^\alpha=0.005$ and $p^\alpha=0.003$, respectively). In Group 1, a significant improvement was observed in the stiffness parameter compared to the baseline in the evaluation at the end of the seventh week. In Group 3, the improvement in the stiffness parameter was observed only at the three-week control. There was no significant change in WOMAC stiffness parameter with treatment in Group 2. While evaluating the WOMAC stiffness parameter between the groups, Dunn's test was applied for the parameters with a significant difference in the Kruskal-Wallis test in the independent groups. Significant difference was found between Groups 1 and 2 when comparing baseline and three weeks ($p\beta=0.003$).

In the within-group evaluation, significant improvement was observed in the 10-m walk test in Group 1 ($p^\alpha=0.003$, Table 2). There was a significant difference between the baseline and seven weeks. While the change between baseline and three weeks was not significant in the analysis between groups, the change between baseline and seven weeks was significant between the groups ($p^\beta=0.045$*).

The number of paracetamol tablets taken did not significantly differ in both intra- and intergroup comparisons.

DISCUSSION

In our study, in which we investigated the effects of different carrier frequencies on pain and function parameters, we found that IFC therapy created significant improvement in all groups. Although IFC therapy is a frequently preferred physical therapy modality in knee OA, the number of studies investigating the effects of different carrier frequencies on the analgesic effect and other functional parameters is limited in the literature.

In our study, only Group 1 showed a significant improvement in 10-m walk time compared to baseline. There was no significant change in other groups. The 10-m walk test may be affected by the general health status of the patients, chronic diseases, aerobic capacity, stiffness level during the test, balance status, and the drugs they use.[19] The fact that only Group 1 showed a significant change in the 10-m walk test in our study can be explained by the fact that Group 1 had a longer walking time than the other groups, although it was not statistically significant in the first evaluation before the treatment. Finally, this statistically significant difference may not be clinically important.

In our study, the lack of decrease in the amount of paracetamol used may be because the patients had mid to advanced OA. In addition, since paracetamol has a more tolerable side effect profile than other nonsteroidal anti-inflammatory drugs, the patients may have continued to use pain relievers during the study period for other painful conditions other than knee OA.

Fuentes et al.[5] compared the effectiveness of two amplitude-modified currents of 0 Hz and 100 Hz created with a carrier current of 4 kHz. It has been determined that both currents had similar efficacy on pain. The authors stated that the main effective part of IFC on pain may be the carrier current. The frequency of the carrier current can change the phase time and skin impedance of the generated current.

The importance of carrier current frequency for the efficacy of IFC therapy has not been adequately studied. For example, Nelson[2] used cyclic carrier frequencies of 0-10 Hz, 0-100 Hz, 90-100 Hz, and a fixed frequency of 100 Hz for musculoskeletal pain. Shafshak et al.[20] used a cyclic protocol of 20-50 Hz in patients with OA. Quirk et al.[21] used a protocol of 0-100 Hz in knee OA with a cyclic frequency of 10 min, followed by a fixed frequency of 130 Hz for 5 min.

In a recent study, it was reported that the input current also may have an important role in the analgesic effect.[5] For example, an IFC feature with a frequency of 100 Hz and a burst length of 10 msec, consisting of two currents of 1,000 Hz and 1,100 Hz, and a current of 100 Hz and 10 msec burst length, consisting of two currents of 10,000 Hz and 10,100 Hz, were found to have different efficacy.[5] In this study, it has been reported that better analgesia is provided with 1 kHz input currents than 8 kHz

and 10 kHz currents. However, this research is not a clinical study but an experimental study, and it is important to confirm such results in clinical studies.

Venancio et al.[12] compared the forms of IFC with carrier frequencies of 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 10 kHz. While 1 kHz frequency was found to be more effective on pain, the best patient comfort was obtained in 8 kHz and 10 kHz applications. In this study, which was similar to our point of view, there was a significant improvement in pain in all three groups compared to baseline in providing analgesia in patients with knee OA, and no superiority was found among the groups. Our study differs from the mentioned study regarding this result. Although the study conducted by Venancio et al. was on healthy volunteers, our study is the first study to be conducted on real patients with knee OA.

Interferential current therapy has been found to be effective on knee OA.[22] A multicenter study conducted by Atamaz et al.[22] investigated the effects of transcutaneous electrical nerve stimulation, shortwave diathermy, and IFC treatment in knee OA in a double-blind, randomized controlled study. Six groups of 203 patients were formed for each physical therapy modality to be compared with a sham application. Patients were evaluated in terms of VAS, 15-m walk distance, WOMAC OA scores, and paracetamol use. In all intervention groups, a significant decrease was observed in the use of paracetamol compared to the sham-administered patients. In addition, improvements were found in all parameters of the patients, except for the stiffness score of the WOMAC OA index. In the study, although a significant improvement was observed in all groups, the use of physical therapy agents was recommended because it significantly decreased the use of paracetamol. In our study, the WOMAC stiffness score improved significantly in Group 1 and Group 3, and no change was observed in the stiffness score in Group 2. Stiffness was evaluated with only two questions, and since the data did not show a normal distribution statistically, nonparametric analyses were used. Although the sample size of our study was determined by power analysis, more patients may need to be recruited to evaluate the stiffness parameter. Finally, the sensation of stiffness may be related to the level of joint degeneration, BMI, and other accompanying factors, as well as pain. Therefore, the change in the stiffness parameter after treatment may not differ as significantly as the pain parameter.

As the effectiveness of IFC therapy has been proven by many studies, we did not include a sham IFC group in our study for ethical reasons. In a review of nonpharmacological and nonsurgical treatment methods for knee OA in 2019, IFC therapy was found to be the modality with the most significant improvement in pain in patients with knee OA compared to the control group. General use is recommended as 100 Hz, 20 min, three to five days a week, for a total of four weeks.[23] Our treatment protocol was similar to the programs recommended in the literature, and a total of 15 sessions of IFC treatment were administered every day to the patients.

There are some limitations to our study. A sham group was not included, and other locomotor system diseases that may cause paracetamol use have not been excluded. In addition, exercise compliance was not questioned. In addition, studies with larger sample sizes and longer follow-up periods are needed to evaluate the long-term effects.

In conclusion, the patients were checked not only at the end of the treatment (three weeks) but also four weeks after the end of the treatment, and the mid-term persistence of the positive effects was evaluated. As a result, although the effect of IFC applications with different carrier currents on stiffness is not clear, their analgesic effect has been shown to be significant in all groups. Furthermore, IFC is an easily tolerated and safe treatment method in the treatment of knee OA. We hope that this study will help pave the way for designing further randomized controlled studies regarding the effects of IFC therapy on wider populations with longer follow-up periods.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, data collection and/or processing: B.N.A., B.D.; Design: B.N.A., B.D., F.A.C. Control/supervision, literature review, critical review: B.N.A., E.C., F.A.C.; Analysis and/or interpretation, materials: B.N.A., B.D., E.C.; Writing the article: B.N.A., E.C.; References and fundings: B. D., E.C.; Other: E.C.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Ferreira RM, Torres RT, Duarte JA, Gonçalves RS. Non-pharmacological and non-surgical interventions for knee osteoarthritis: A systematic review and meta-analysis. Acta Reumatol Port 2019;44:173-217.
2. Nelson AE. Osteoarthritis year in review 2017: Clinical. Osteoarthritis Cartilage 2018;26:319-25. doi: 10.1016/j.joca.2017.11.014.
3. Lewek MD, Rudolph KS, Snyder-Mackler L. Quadriceps femoris muscle weakness and activation failure in patients with symptomatic knee osteoarthritis. J Orthop Res 2004;22:110-5. doi: 10.1016/S0736-0266(03)00154-2.
4. Tubach F, Ravaud P, Baron G, Falissard B, Logeart I, Bellamy N, et al. Evaluation of clinically relevant changes in patient reported outcomes in knee and hip osteoarthritis: The minimal clinically important improvement. Ann Rheum Dis 2005;64:29-33. doi: 10.1136/ard.2004.022905.
5. Fuentes JP, Armijo Olivo S, Magee DJ, Gross DP. Effectiveness of interferential current therapy in the management of musculoskeletal pain: A systematic review and meta-analysis. Phys Ther 2010;90:1219-38. doi: 10.2522/ptj.20090335.
6. Novak S, Guerron G, Zou Z, Cheung G, Berteau JP. New guidelines for electrical stimulation parameters in adult patients with knee osteoarthritis based on a systematic review of the current literature. Am J Phys Med Rehabil 2020;99:682-8. doi: 10.1097/PHM.0000000000001409.
7. Johnson MI, Tabasam G. An investigation into the analgesic effects of different frequencies of the amplitude-modulated wave of interferential current therapy on cold-induced pain in normal subjects. Arch Phys Med Rehabil 2003;84:1387-94. doi: 10.1016/s0003-9993(03)00151-5.
8. Gundog M, Atamaz F, Kanyilmaz S, Kirazli Y, Celepoglu G. Interferential current therapy in patients with knee osteoarthritis: Comparison of the effectiveness of different amplitude-modulated frequencies. Am J Phys Med Rehabil 2012;91:107-13. doi: 10.1097/PHM.0b013e3182328687.
9. Palmer ST, Martin DJ, Steedman WM, Ravey J. Alteration of interferential current and transcutaneous electrical nerve stimulation frequency: Effects on nerve excitation. Arch Phys Med Rehabil 1999;80:1065-71. doi: 10.1016/s0003-9993(99)90062-x.
10. Ward AR, Chuen WL. Lowering of sensory, motor, and pain-tolerance thresholds with burst duration using kilohertz-frequency alternating current electric stimulation: Part II. Arch Phys Med Rehabil 2009;90:1619-27. doi: 10.1016/j.apmr.2009.02.022.
11. Johnson MI, Tabasam G. A single-blind investigation into the hypoalgesic effects of different swing patterns of interferential currents on cold-induced pain in healthy volunteers. Arch Phys Med Rehabil 2003;84:350-7. doi: 10.1053/apmr.2003.50005.
12. Venancio RC, Pelegrini S, Gomes DQ, Nakano EY, Liebano RE. Effects of carrier frequency of interferential current on pressure pain threshold and sensory comfort in humans. Arch Phys Med Rehabil 2013;94:95-102. doi: 10.1016/j.apmr.2012.08.204.
13. Kohn MD, Sassoon AA, Fernando ND. Classifications in brief: Kellgren-lawrence classification of osteoarthritis. Clin Orthop Relat Res 2016;474:1886-93. doi: 10.1007/s11999-016-4732-4.
14. Research Randomizer [Internet]. [cited 2022 Dec 22]. Available at: https://randomizer.org/
15. Basedow M, Williams H, Shanahan EM, Runciman WB, Esterman A. Australian GP management of osteoarthritis following the release of the RACGP guideline for the non-surgical management of hip and knee osteoarthritis. BMC Res Notes 2015;8:536. doi: 10.1186/s13104-015-1531-z.
16. Shubert TE, McCulloch K, Hartman M, Giuliani CA. The effect of an exercise-based balance intervention on physical and cognitive performance for older adults: A pilot study. J Geriatr Phys Ther 2010;33:157-64.
17. Tüzün EH, Eker L, Aytar A, Daşkapan A, Bayramoğlu M. Acceptability, reliability, validity and responsiveness of the Turkish version of WOMAC osteoarthritis index. Osteoarthritis Cartilage 2005;13:28-33. doi: 10.1016/j.joca.2004.10.010.
18. Kelly AM. The minimum clinically significant difference in visual analogue scale pain score does not differ with severity of pain. Emerg Med J 2001;18:205-7. doi: 10.1136/emj.18.3.205.
19. Kim HJ, Park I, Lee HJ, Lee O. The reliability and validity of gait speed with different walking pace and distances against general health, physical function, and chronic disease in aged adults. J Exerc Nutrition Biochem 2016;20:46-50. doi: 10.20463/jenb.2016.09.20.3.7.
20. Shafshak TS, el-Sheshai AM, Soltan HE. Personality traits in the mechanisms of interferential therapy for osteoarthritic knee pain. Arch Phys Med Rehabil 1991;72:579-81.
21. Quirk AS, Newman RJ, Newman KJ. An evaluation of interferential therapy, shortwave diathermy and exercise in the treatment of osteoarthrosis of the knee. Physiotherapy 1985;71:55-7.
22. Atamaz FC, Durmaz B, Baydar M, Demircioglu OY, Iyiyapici A, Kuran B, et al. Comparison of the efficacy of transcutaneous electrical nerve stimulation, interferential currents, and shortwave diathermy in knee osteoarthritis: A double-blind, randomized, controlled, multicenter study. Arch Phys Med Rehabil 2012;93:748-56. doi: 10.1016/j.apmr.2011.11.037.
23. Ferreira RM, Torres RT, Duarte JA, Gonçalves RS. Non-pharmacological and non-surgical interventions for knee osteoarthritis: A systematic review and meta-analysis. Acta Reumatol Port 2019;44:173-217.