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Healing effect of ultrasonic sound wave therapy in case of femoral osteochondritis disecans: A narrative review

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Abstract:

Background: Osteochondritis dissecans is a condition in which a segment of articular cartilage with its underlying subchondral bone gradually separates from the surrounding bone.
Aim: The study's objective is to assess the therapeutic benefits of conservative physiotherapy. In order to determine the persuasiveness of ultrasonic wave treatment's fundamental therapeutic effects, practice-based conservative physical therapy is ultimately required. This assessment demonstrates both the repair of cartilage and the significance of ultrasonic waves in intermittent healing.
Methods: This research included fifty individuals with OCD of the knee. Every patient was a field laborer in their late adult years, with an average age of 45.1 years. During the conservative phase, pulsed-US was administered for an average of 45 days under the same settings as the fracture therapy. For this study, the researcher chose 50 individuals; six of them were not allowed to provide their permission. This study ruined around 44 individuals. Every patient received conservative care. Two groups were used in the study: one group used just conventional methods without ultrasonic wave treatment, while the other group used conventional methods plus ultrasonic wave therapy as an experimental group.
Results: Renotative tissue and cartilaginous repair as well as a healing effect were seen in both groups. Subchondral bone and cartilage findings are indicative of healing. Compared to the control group, the experimental group showed notable changes.
Conclusion: PUS stimulation increased the expression levels and produce healing effects of knee OCD.
Keywords: immunohistochemistry, pulsed ultrasound, osteochondritis dissecans of the femural capitellum, cartilage, ultrasonic wave therapy

1. INTRODUCTION

The German surgeon Franz König (1832–1910) coined the phrase "osteochondritis dissecans," which translates from the Latin phrase "inflammation of bone and cartilage culminating in the production of loose fragments." Osteochondritis dissecans (OCD) is characterized as a focal idiopathic modification of subchondral bone that may cause early osteoarthritis due to fragility and disruption of nearby articular cartilage.(1, 2). In this case, OCD is mostly caused by three potential causes: (1) severe trauma that would cause fragments to break off through direct mechanical impact; (2) less severe trauma that would cause subchondral bone necrosis, which would later cause fragments to separate; and (3) formation of fragments developed without any significant trauma but as a consequence of some (unidentified) foundational lesion.(3) An region of cartilaginous or osteochondral disintegration is evident in osteochondritis dissecans (OCD), osteochondrosis (OC) is the condition itself, and osteochondritis is the inflammatory reaction to it.(4) One of the most well acknowledged causes of OCD is persistent stress, particularly in young athletes (5). The majority of OCD patients (55%–60%) participate in sports on a regular basis. Recurrent cyclical stress through an athlete's joint can cause chondral injury and perhaps vascular damage, which can result in ischemia (6). According to some authors, the development plate of the secondary ossification center, which is located in the epiphysis of an afflicted person merely between the surface cartilage and its sustaining bone, may be repeatedly stressed, leading to OCD lesions. The creation of new bone may then be hampered by damage to the secondary formation plate. Despite being commonly acknowledged, recurrent trauma is not well supported by studies (7, 8). The lack of blood flow was suggested as an underlying cause because of ischemia. It was hypothesized that a reduction in blood flow to the afflicted region would prevent the tissue from efficiently regenerating bone, leading to cell death and the disintegration of the bone from the cartilage (9,10). The capacity to revascularize a partly connected lesion and the occurrence of osteonecrosis in the majority of histological investigations are two examples of supportive data that has been identified by the several writers who have examined the likelihood of lesion growth owing to ischemia (11,12). In the context of mechanical-axis deviation, misalignment of the lower limb makes logical sense since a change in the forces across the joint would put more pressure on particular joint components. Although the degree of valgus/varus remained within acceptable physiological limits, varus alignment was linked to medial condyle lesions and valgus alignment to lateral condyle lesions (13). The usage of an unloading device support may be impacted by increasing loading on the afflicted knee compartment. Adult OCD lesions have also been shown to have a reduced medial tibial slope (14). The majority of people with OCD describe nonspecific knee discomfort as their primary early symptom. Effusion (fluid in the joint), prolonged standing, stair climbing, cross-leg sitting, knee locking on strange surfaces, giving way, muscular atrophy, increased sensitivity, and particular discomfort are other potential signs (15,16). The subchondral involvement of an OCD lesion in the femoral condyle can be seen using radiographs, although their diagnostic sensitivity and specificity have never been assessed. The majority of OCD lesions show up on radiographs as a tiny fragment or a dark, inadequate region located close below the cartilage surface. There may occasionally be a little rip or abrasion on the inner cartilage. A tunnel or notch-view radiograph is the sole way to see many OCD lesions (17). Normal anteroposterior and lateral radiographic images are often inadequate to determine OCD lesions and typically do not illustrate articular cartilage injuries, small lesions, or lesions of the patellofemoral joint (18). up to a condition such as a flexible body is observed in radiograph, the radiographs do not demonstrate whether the underlying cartilage of OCD lesion is solid or uncertain this is critical in determining the appropriate course of intervention. The diagnostic precision of the mixture of radiographs with medical history and physical evaluation has been demonstrated to have sensitivity as well as of preciseness (19). When evaluating the supporting bone structure and cartilage quality of an OCD lesion, which may seem normal on standard radiographs, magnetic resonance imaging is the preferred diagnostic technique. On an MRI, the articular cartilage covering the knee's femur and tibia can be seen as a smooth, gliding surface. Additionally, bone cysts, subarticular high-signal lines, and articular cartilage fissures that may impact prognosis and therapy are more visible with magnetic resonance imaging (20). MRI makes it possible to distinguish between a highly unstable lesion and in situ loosening, as well as to directly visualize loosening and fragment displacement. Furthermore, MRI is helpful in tracking the lesion's revascularization and healing response (27). All

JOCD patients, with the exception of those who have symptomatic loose bodies, should first be evaluated for conservative therapy. Close observation should be used for minimally or completely separate lesions as well as massive lesions. Immobilization with splints should be reduced; the deleterious impacts of immobilization on articular cartilage have been shown (28). The utilization of splints, crutches, and constant non-weight-bearing active range of motion has been recommended (29). The ideal management for OCD is uncertain. Both operative and nonoperative procedures have been explored. Treatment parameters such as skeletal maturity, location of the defect, defect stability, patient symptoms, and surgeon choice may impact treatment choices. Steady lesions in skeletally young patients are typically addressed with 3 to 6 months of nonoperative therapy, comprising activity restriction and unloader bracing (21, 22). In order to encourage revascularization and healing, patients with chronic symptoms are frequently offered surgery, which typically involves transarticular or retroarticular drilling of the afflicted lesion. Even so, this strategy has a high success rate (23). In the treatment of fractures, especially delayed or nonunions, bone stimulation has been used more frequently to speed up bone healing. Exterior bone excitation can be accomplished using a number of approaches, including electric/electromagnetic stimulation, low-intensity pulsed ultrasound (pulsed ultra sonic), and relatively recent advances in extracorporeal shock wave therapy (ESWT) (24,25,26). The cause of this common and complicated illness is still unknown after years of research, and effective therapies are conspicuously lacking. Therefore, a thorough investigation of a safe and effective supplemental strategy for OCD management is urgently needed. Therapeutic ultrasound has been recognized as a non-invasive, safe, and non-carcinogenic technique in the therapy of musculoskeletal disorders since it was first approved by the US Food and Drug Administration (FDA) in 1994 for the treatment of fractures. This method has been shown to increase lymphatic and local circulation, improve metabolism, encourage tissue regeneration and nutritional status, and reduce sensory nerve excitability and stress in the muscles and connective tissues (30). This study sought to ascertain if the conservative treatment of persistent osteochondritis dissecans (OCD) of the knee in adult patients would benefit from the adjuvant use of bone stimulation in terms of healing rate. We postulated that the duration of bone healing would be shortened by pulsed ultrasonic bone stimulation.

2. MATERIAL AND METHODS

Between September 2024 and February 2026, 50 male and female patients between the ages of 35 and 50 who mostly complained of discomfort in the medial femoral condyle of their knees were included in an interventional trial at the Advanced Neurology and Neurosurgery Hospital in Jaipur, Rajasthan. Twenty men and twenty-four women participated in this study; the other six people declined to participate. The Medical Ethical Committee gave its approval to the trial. They were diagnosed with OCD based on clinical examination and radiography of x-rays and MRIs; 10 of these individuals were removed from the study because of time restrictions. A random selection procedure was used to divide the study's participants into two groups. Groups A (N = 22) and B (N = 22) consist of patients, respectively. Group B is regarded as the controlled group, whereas Group A is the experimental group. Group A participants received medicine in addition to pulsed ultrasonic wave treatment and traditional physiotherapy (cryotherapy, knee supporter, isometric strengthening exercises, IFT for knee). Eventually, group B participants received medication in addition to conventional physiotherapy. The main fundamental structures of inclusion include a history of severe trauma, jumping from a height, sprinting on an unusual surface, falling while kicking, etc. Every participant had radiological conformity that was consistent with OCD; X-ray and MRI results showed a tiny articulation shifted on cartilage that appeared to be a scratch mark on the articular capsule; any degeneration, fracture, or ligament damage to the knee was excluded.

Participants: The study included fifty patients from A N S Hospital. Participants had to meet pre-established OCD diagnostic criteria. The eligible subjects, who ranged in age from 35 to 50, were diagnosed with OCD using the following diagnostic criteria: 1. Knee pain on standing, 2. Effusion on knee, 3. Painful stair climbing, 4. Clicking sound on knee extension, 5. MRI shows the small fragment on articular surface, 6. Somehow a small scratch seen in the radiological presentation. Every participant experienced a 45-day intervention. On days 0 and 45 following the intervention, pre and post data on pain and balance-coordination were gathered. Data collection was followed by data analysis for a comparison study.

Randomization: Simple randomization techniques were used to assign participants using cheat chat. An impartial individual in charge of the allocation process requested participants to select cheaters from a container in consecutive numerical order. Each cheat was accompanied by a designation letter that assigned the individual to either the experimental group (EXPR) or the control group (CONT). Without revealing to the participants which was the experimental group, this randomization procedure ensured an equitable distribution among the three comparable treatment groups. The result assessments were carried out by a researcher who was not involved in delivering the treatments and who was blind to group assignment. The goal of the treatments prevented the medical therapist from being anonymised, even if they were not involved in the evaluation or data processing.

3. Interventions

Control group: The participants received conventional medical care. At the beginning of each session of the selected physiotherapy program, a cold pack was applied to the injured capsule area and knee for ten minutes. After that, the knee was exposed to interferential current for 20 minutes at conventional settings (typically 70 µs pulse length and 100 Hz frequency). Additionally, participants underwent therapeutic exercises such as isometric knee strengthening, which focused on improving knee range of motion through posture correction. It was advised to complete 10 repetitions of these workouts three times a day. The intervention lasted for 45 days.

Experimental group: These patients received the identical physiotherapy regimen as the control group at each treatment session, plus an additional 15 minutes of ultrasound treatment for the afflicted knee, typically at a pulsed intensity of 1.5 W/cm². These innovative techniques offer a novel therapeutic approach meant to enhance cartilage regeneration, raise awareness, and aid in the recovery of OCD sufferers. The duration of the intervention was forty-five days.

Outcome measures

NPRS: Adult pain intensity is measured in a single dimension using the Numerical Pain Rating Scale (NPRS). The baseline values of the 11-numeric point scale range from "0" to "10," which denotes one extreme of discomfort, such "no pain" (31).

Lysholm Knee Score: LKS is a patient-reported outcome measure (PROM) intended to assess functional impairment and knee discomfort. Although it was first created in 1982 to treat patients with ligament injuries, namely anterior cruciate ligament (ACL) injuries, it is currently often utilized for meniscal injuries, cartilage lesions, such as osteochondritis dissecans, and other knee conditions (32).

Statistical analysis

Age differences between groups were evaluated using an unpaired t-test. To confirm a normal data distribution, we assessed variance homogeneity both within and between groups using the t-test. Since our data displayed indications of a normal distribution, we employed parametric statistical analysis to examine the impact of the treatment on NPRS and LKS ratings. An a priori statistical analysis was performed using JASP: vs.16.0. The sample size was determined using the NPRS-measured pain intensity result. Statistical significance was established at $p < 0.05$ with an alpha level of NPRS and LKS standard deviations that demonstrate minimal variability.

4. RESULT

Descriptive Statistics

	sex (A)	sex (B)	age (A)	age (B)	NPRS day0(A)	NPRS day45(A)	LKS day0(A)	LKS day45(A)	NPRS day0(B)	NPRS day45(B)	LKS day0(B)	LKS day45(B)
Valid	22	22	22	22	22	22	22	22	22	22	22	22
Missing	0	0	0	0	0	0	0	0	0	0	0	0
Mean			42.545	41.727	6.318	3.136	57.864	81.045	5.909	3.045	60.455	79.000
Std. Error of Mean			0.997	1.007	0.153	0.119	0.998	0.961	0.160	0.154	0.892	0.730
Std. Deviation			4.677	4.723	0.716	0.560	4.683	4.509	0.750	0.722	4.183	3.423
Variance			21.879	22.303	0.513	0.314	21.933	20.331	0.563	0.522	17.498	11.714
Shapiro-Wilk			0.910	0.927	0.779	0.733	0.966	0.969	0.813	0.813	0.959	0.954
P-value of Shapiro-Wilk			0.046	0.105	2.406e -4	5.275e -5	0.611	0.682	7.973e -4	8.110e -4	0.467	0.370

Descriptive Statistics

	sex (A)	sex (B)	age (A)	age (B)	NPRS day0(A)	NPRS day45(A)	LKS day0(A)	LKS day45(A)	NPRS day0(B)	NPRS day45(B)	LKS day0(B)	LKS day45(B)
Range			14.000	15.000	2.000	2.000	16.000	19.000	2.000	2.000	15.000	14.000
Minimum			36.000	35.000	5.000	2.000	50.000	70.000	5.000	2.000	54.000	70.000
Maximum			50.000	50.000	7.000	4.000	66.000	89.000	7.000	4.000	69.000	84.000

Note. Not all values are available for *Nominal Text* variables

Paired Samples T-Test

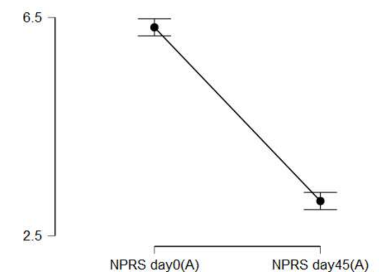
									95% CI for Cohen's d	
Measure 1		Measure 2	t	df	p	Mean Difference	SE Difference	Cohen's d	Lower	Upper
age (A)	-	age (B)	0.994	21	0.332	0.818	0.823	0.212	-0.213	0.632
NPRS day0(A)	-	NPRS day45(A)	29.784	21	0.0015	3.182	0.107	6.350	4.394	8.240
LKS day0(A)	-	LKS day45(A)	17.942	21	0.025	-23.182	1.292	-3.825	-5.041	-2.597
NPRS day0(B)	-	NPRS day45(B)	21.000	21	0.041	2.864	0.136	4.477	3.064	5.879
LKS day0(B)	-	LKS day45(B)	20.795	21	0.018	-18.545	0.892	-4.433	-5.823	-3.033
NPRS day45(A)	-	NPRS day45(B)	0.526	21	0.042	0.091	0.173	0.112	-0.308	0.530
LKS day45(A)	-	LKS day45(B)	4.031	21	0.034	2.045	0.507	0.859	0.361	1.343

Note. Student's t-test.

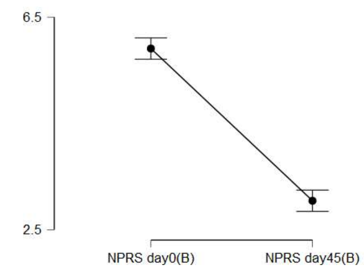
***from the above analytical study the interventions of group-a placed a better outcome compared than group-b, however the ‘p’ shows significance changes. The reminding effects of ultrasound wave having an better healing effect in person suffering from OCD ***

Descriptives Plots

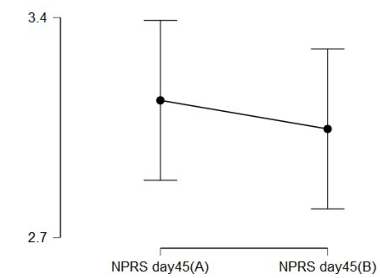
NPRS day0(A) - NPRS day45(A)



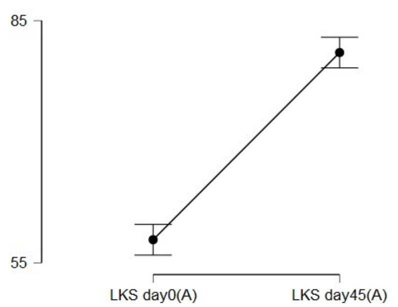
NPRS day0(B) - NPRS day45(B)



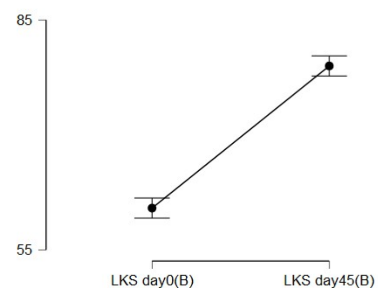
NPRS day45(A) - NPRS day45(B)



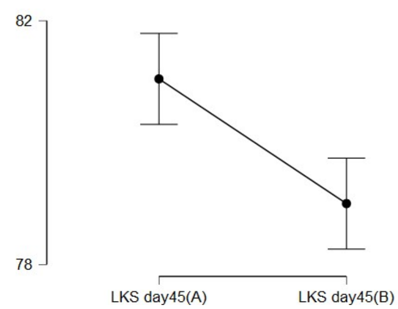
LKS day0(A) - LKS day45(A)



LKS day0(B) - LKS day45(B)



LKS day45(A) - LKS day45(B)



5. DISCISSION

Thermal and non-thermal processes are the main ways that pulsed ultrasonic works. Periodic mechanical sound waves produced by pulsed ultrasonic penetrate tissues and cells, causing vibration and collisions (33). It modifies cellular metabolism, speeds up tissue healing processes, and lessens cellular ischemia and hypoxia by producing small thermal effects and significant non-thermal effects inside the targeted tissue, eventually improving tissue nutrition and encouraging tissue repair (34). In both in vivo and ex vivo settings, a mild temperature of 0.5°C following a 10-minute exposure indicates that pulsed ultrasound has little thermal impact. Researchers have focused a lot of emphasis on cavitation and mechanical effects, which are the main non-thermal modes of action for pulsed ultrasonic.

Cavitation effects of P-US: The ultrasonic cavitation phenomena mainly refers to a sequence of dynamic processes in which tiny gas-core bubbles of cavitation undergo a typical expansion and fall apart in accordance with acoustic pressure created by ultrasonic waves present in the liquid medium. This occurrence manifests in two different appearances: steady state and temporary cavitation. Temporary cavitation, which is typically utilized in the treatment of cancer and funeral care (35), is defined as the unstable oscillation of bubbles that expand to 2–3 times their resonance size before rapidly collapsing, releasing significant energy resulting in cell injury and rapid tissue loss. Both types of cavitation constitute fundamental mechanisms that contribute to ultrasound's biological effects on targeted tissues. Nonetheless, the preservation of a stable cavitation impact appears to be more efficient in achieving beneficial effects in ultrasound treatment.

Mechanical effects of P-US: The two primary mechanical impacts are the improvement of mass transfer and acoustic flow. Acoustic flow, which may be classified into macroscopic and microscopic flows, is the circulation that takes place around a liquid when a cavitation bubble vibrates. The significant movement of a fluid in line with the propagation of an ultrasonic wave within a liquid is referred to as macroscopic flow. In contrast, tiny vortices that develop at the oscillation point are what define microscopic flows. Moreover, macroscopic fluxes have a somewhat less mechanical influence than tiny flows. Cavitation results in microscopic fluxes, which can affect protein synthesis, diffusion ion rates, membrane permeability, and cell secretion processes (36). Maintaining steady cavitation and acoustic fluxes is essential when using non-thermal effects in pulsed ultrasonic applications. One important aspect of pulsed ultrasonic's non-thermal effects is improving mass transfer. By boosting mass transfer and response speeds, ultrasound significantly contributes to the fluid medium's increased mobility. This effect, which primarily affects the cell membrane, cytosol, and border layers, is most apparent in cells and tissues treated with pulsed ultrasonic. Bubble oscillation produces micro-flows in the surrounding sound field that direct reagents toward cells or enzyme active sites, facilitating the release of biological materials into the medium and producing observable biological effects (37).

Effects of P-US on cartilage repair: One of the main pathological characteristics of OCD is articular cartilage degeneration, which is crucial to the diagnosis of OCD. The equilibrium of chondrocytes can be upset by a variety of physiological events, including trauma, mechanical forces, and load carrying, which can reduce cartilage production and articular cartilage's ability to withstand stress, eventually resulting in damage. Because cartilage tissue is sensitive to mechanical stimuli, chondrocyte proliferation and differentiation may be impacted by pulsed ultrasonic. According to studies, pulsed ultrasonic can influence the elevated production of TGF-ß and transmit sustained wave energy, which encourages the growth of bovine chondrocytes and the upregulation of cartilage-related markers like MMP-1 and Col I (38). Furthermore, studies have shown that the CCN protein family 2 may contribute to the proliferation and differentiation of traumatized osteoblasts and articular cartilage, thereby promoting the regeneration of damaged articular cartilage.

PUS and tissue engineering: In the field of regenerative medicine, stem cells and tissue engineering techniques are important research topics, especially when it comes to regeneration. It is possible to produce cartilage tissue that closely mimics natural hyaline cartilage by combining stem cells with tissue engineering methods. Scaffolds, growth factors, and seed cells are crucial elements in artificial cartilage tissue creation. With an emphasis on these crucial components, this paper offers a thorough examination of the use of pulsed ultrasonic in cartilage tissue engineering.

6. CONCLUSION

The results of this study indicate that the treatment of osteochondritis dissecans of the knee is more successful when therapeutic ultrasound is added to a traditional physiotherapy program that includes interferential therapy, cryotherapy, and isometric strengthening exercises. Individuals who received therapeutic ultrasound showed more gains in range of motion, muscular strength, knee function, pain reduction, and overall functional performance. For patients with stable osteochondritis dissecans of the knee, therapeutic ultrasonography may therefore be a useful addition to conservative physiotherapy. To validate these results and assess their long-term clinical importance, more multicenter trials with bigger sample numbers and long-term follow-up are advised.

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