

Acupuncture in the Management of Knee Osteoarthritis

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Abstract. Knee osteoarthritis (KOA) is a leading cause of global disability, with over 370 million patients worldwide, and its prevalence continues to rise amid aging populations. Current treatments such as nonsteroidal anti-inflammatory drugs (NSAIDs) and surgery are often limited by side effects, high costs, and variable efficacy. Acupuncture has re-emerged as a safe, nonpharmacological intervention with multimodal mechanisms and potential synergistic benefits. This review summarizes evidence supporting acupuncture's efficacy in alleviating pain and improving function in KOA, primarily through anti-inflammatory, neuromodulatory, and cartilage-protective pathways. Clinical studies demonstrate significant improvements in scales such as Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Visual Analog Scale (VAS), with sustained effects and fewer adverse events compared to conventional treatments. Furthermore, the integration of acupuncture with established therapies, such as hyaluronic acid injections and physical rehabilitation, has shown enhanced therapeutic outcomes. However, heterogeneity in study designs and unclear mechanistic nuances remain challenges. This review aims to evaluate the clinical value, safety, and integrative potential of acupuncture in KOA management, while advocating for more large-scale trials and biomarker-guided strategies.

Keywords: Acupuncture; knee osteoarthritis; pain management; integrative medicine.

1. Introduction

Knee osteoarthritis (KOA) represents a major contributor to the global burden of disease. According to 2021 statistics, the number of individuals affected by KOA worldwide has exceeded 370 million, with its prevalence continuing to rise. Research indicates that age is a significant risk factor for the onset of KOA; the risk increases progressively after the age of 30 and peaks around 80 years. Against the backdrop of a globally aging population, KOA is expected to further exacerbate public health challenges [1]. The principal cause of knee osteoarthritis (KOA) is the gradual wear and destruction of articular cartilage in the knee itself. This erosion ultimately leads to the direct contact of bone on bone, causing inflammation and pain [2]. KOA characteristically progresses gradually over time with increased symptoms of knee pain, stiffness, and swelling. These changes make it difficult to move the joint adequately and interfere with daily living activities. In late stages the knee may lose virtually all of its function.

Typical management of KOA relies on a combination of drug treatment, physical therapy, exercise programs, and in advanced cases, joint arthroplasty. Doctors frequently prescribe opioid analgesics, such as codeine or tramadol, on a short-term basis, to relieve pain. However, their long-term use in the treatment of KOA raises questions relative to side effects such as nausea and vomiting, as well as possible dependence. Nondrug alternatives such as physical therapy, supervised exercise, and joint arthroplasty are frequently utilized in the alleviation of symptoms and in the delay of the advancement of the disease. However, conservative rehabilitation invariably requires quite a considerable expenditure of time before results are seen and the slow improvement in a condition in which pain is the most frequent symptom frequently leads to a lack of patient compliance. Although arthroplasty is of benefit in extreme cases, the operation per se entails many dangers, as well as a heavy financial burden on the patient [3].

Acupuncture has become better recognized as a significant nonpharmacological treatment for KOA in recent years. Acupuncture is thought to relieve pain and improve knee function via many biological pathways, including the effects on gene-related signals, modulation of the body's own pain-

relieving substances, and adjustment of signaling in the central nervous system [4]. Acupuncture has demonstrated favorable clinical outcomes with a well-established safety profile, minimal adverse effects, and low treatment cost. Consequently, it is increasingly regarded as a valuable adjunct or alternative to conventional therapeutic modalities. Nevertheless, patient responses to acupuncture remain variable, and its precise mechanisms of action are not yet fully elucidated. Further high-quality clinical trials are required to substantiate its efficacy and clarify the underlying biological pathways. The aim of this review is to provide a systematic overview of the clinical applications and mechanistic foundations of acupuncture in the treatment of knee osteoarthritis, analyzing its therapeutic efficacy and safety, exploring its integration with other treatment strategies, and outlining future directions within the context of precision rehabilitation and evidence-based medicine.

2. Mechanisms of Acupuncture in the Treatment of Knee Osteoarthritis

2.1. Fundamental Mechanisms of Acupuncture

Pain is one of the main clinical signs of KOA, which is closely linked to centralization. Acupuncture reduces pain by regulating the nervous system through the modulation of brain derived neurotrophic factor (BDNF) and its signaling pathways. In neuropathic pain, BDNF contributes to the initial sensitization of the pain pathways and the long-term release of BDNF at a sufficiently high level can lead to maladaptive plasticity and unfavorable effects. Acupuncture relieves central sensitization and inflammation, thereby relieving pain by inhibiting the overactivation of the BDNF/TrkB signaling pathway. Likewise, acupuncture inhibits the activation of microglia and thus reduces excessive release of BDNF. It is to be noted that acupuncture has a dualistic regulatory property, in other neurologic diseases acupuncture promotes neural repair and functional recovery by activating the BDNF signaling pathways [5]. They reflect the fact that the neuroprotective role of acupuncture is disease state dependent and adaptable in different pathological situations. Acupuncture has immunoregulatory effects as well by regulating macrophage polarization. In allergic diseases, acupuncture promotes the transition of macrophages from pro-inflammatory (M1) to anti-inflammatory (M2) phenotype and reduces the secretions of pro-inflammatory cytokines from macrophages e.g. IL-6 and increases the anti-inflammatory factors such as IL-10, thus containing the inflammatory amplification. This process amplifies the interaction between the immune system and the neuroendocrine system through modulation of sympathetic nerve activity and the hypothalamic-pituitary-adrenal (HPA) axis, allowing acupuncture to modulate the function of immune cells and decrease response to allergens [6]. Acupuncture increases local (improved perfusion), and therefore, improved metabolic regulation of soft tissues. Acupuncture has been shown to enhance local perfusion by increasing blood flow to ischemic areas via stimulation of vasodilators (e.g., nitric oxide), thereby decreasing nerve injury, resulting in improvement in functional recovery [7]. Acupuncture also excites cytoskeletal remodeling in subcutaneous fibroblasts, aiding in the remodeling of the extracellular matrix and improving the mechanical properties and reparative ability of soft tissues. Acupuncture also increases the functionality of the mitochondria in cells, allowing for mitochondrial biogenesis to increase while inhibiting the effects of excessive mitophagy which would impair energy homeostasis in the cell, allowing for improved repair of soft tissues [8].

2.2. Therapeutic Effects of Acupuncture on Knee Osteoarthritis

Acupuncture also shows unique effects on joint protection in KOA beyond its general actions as an analgesic and modulator of immunity. The clear anti-inflammatory effects of acupuncture in the management of KOA involve the inhibition of the release of local pro-inflammatory mediators such as IL-6, which breaks the cycle of inflammation, decreases the degree of chondrocyte apoptosis and facilitates the proliferation of these cells. At the same time, it increases the level of anti-inflammatory mediators such as IL-10, which regulates the immune responses in relation to the production of both the pro-inflammatory and anti-inflammatory mediators.

Regarding cartilage protection, traditional acupuncture helps maintain the dynamic stability of chondrocyte numbers, while warm needling and electroacupuncture further downregulate the activity of various matrix metalloproteinases (MMPs), inhibit cartilage matrix degradation, and enhance the synthesis of collagen and proteoglycans, thereby slowing degenerative changes in joint structure. Through this series of regulatory actions, acupuncture demonstrates unique structural protective values distinct from pharmacological approaches.

Furthermore, acupuncture improves the joint microenvironment through mechanisms involving mechanical balance and sustained stimulation. Sustained stimulation not only helps release soft tissue adhesions and reduce abnormal tension but also restores medial-lateral mechanical symmetry and increases joint space. It concurrently reduces the level of inflammatory factors in the synovial fluid and alleviates synovial hyperplasia, thereby creating a low-inflammatory, low-stress, and metabolically favorable environment for cartilage repair [9]. This optimized microenvironment supports the repair and regeneration of chondrocytes, ultimately slowing the progression of KOA.

3. Clinical Evidence for Acupuncture in the Treatment of Knee Osteoarthritis

3.1. Clinical Efficacy of Acupuncture

Acupuncture can effectively reduce pain scores in patients with KOA. In recent years, multiple randomized controlled trials (RCTs) have provided robust evidence supporting the analgesic effect of acupuncture in KOA. A three-arm randomized controlled trial enrolling 455 patients with KOA demonstrated a significant and sustained reduction in pain following six weeks of acupuncture. The primary outcome, assessed using the J-MAP scale, declined from a baseline mean of approximately 4.4 to 3.1-3.3 after treatment and remained stable at 3.2-3.4 at the three-month follow-up. The mean reduction of 1.0-1.2 points surpassed the minimal clinically important difference (MCID) of 0.5, indicating a clinically meaningful improvement maintained over time. Consistent trends were observed in secondary pain measures. The WOMAC-Pain subscale (0-100) decreased from 44-45 to 28.1-28.9 at six weeks, sustaining a 13-14-point improvement at three months, corresponding to a moderate effect size and outperforming the waitlist control group ($p = 0.0002$). Similarly, the VAS score declined from 57-59 mm to approximately 29-33 mm, reflecting a mean reduction exceeding 27 mm, which is well above the MCID threshold of 15 mm. Collectively, these findings indicate that acupuncture provides clinically relevant and durable analgesia in KOA, positioning it as a promising nonpharmacological intervention for pain management [10]. Acupuncture also demonstrates significant efficacy in improving functional mobility in patients with KOA. A meta-analysis of 11 randomized controlled trials including 2,408 participants assessed functional outcomes using the WOMAC function subscale, where higher scores reflect poorer joint performance, and compared true acupuncture with sham procedures involving non-meridian, non-acupoint, or superficial needling. The results showed that the acupuncture group had significantly better functional scores than the sham group after treatment ($p = 0.0007$), indicating clinically meaningful functional improvement. Subgroup analysis suggested that the most significant functional benefits were observed with treatment durations of 6-13 weeks, and patients with a BMI of 25-29.9 benefited more than those with a BMI ≥ 30 , implying that weight management may enhance the efficacy of acupuncture. In conclusion, current evidence supports acupuncture as an effective intervention for improving function in KOA patients, particularly when applied over medium-to-short terms and combined with weight control [11].

3.2. Safety and Adverse Effects of Acupuncture

Acupuncture demonstrates a favorable safety profile in the treatment of KOA, with most adverse events being mild and self-limiting; serious adverse events are extremely rare. The most common acupuncture-related adverse event is mild local bruising, which generally occurs in less than 8% of cases and is significantly less frequent than in NSAID control groups. In a high-dose acupuncture study, 22 cases of mild bruising were observed in the real acupuncture group compared with 17 cases

in the sham group [12]. Mild subcutaneous bleeding or transient dizziness was reported in five cases after treatment, accounting for approximately 5% of participants, and all events resolved spontaneously without serious complications [13]. In general, the adverse reactions to acupuncture treatment for KOA are mild and transient and the safety record is significantly better than for conventional pharmacological treatment, thus it is appropriate to recommend it as a safe and effective clinical procedure. The acceptable safety profile also makes acupuncture the ideal treatment of choice for KOA particularly for those individuals who are anxious about drug dependency or those with a high surgical risk.

4. Integration of Acupuncture with Other Therapeutic Approaches

When treating KOA in a clinical setting, therapeutical efficacies of those therapies and their safety features seem to conflict with each other when single methods are used. The integration of acupuncture with conventional therapies has been shown to enhance overall treatment efficacy while reducing adverse effects associated with either approach when used alone. Current mainstream interventions for knee osteoarthritis include oral nonsteroidal anti-inflammatory drugs (NSAIDs) and intra-articular injections of hyaluronic acid. However, when these treatments are applied in isolation or over prolonged periods, their limitations become evident, including gastrointestinal side effects, local inflammation, and diminishing long-term benefits. Long-continued NSAID-men, for instance, experience gastric mucosal lesions, together with local pain or inflammatory reactions when injecting hyaluronic agents. Studies show that adjunctive use of acupuncture can significantly reduce these adverse effects. In a study made by Lin et al., it showed that when patients taking NSAIDs were offered this adjunctive treatment, a number of them needing additional protective agents for the gastric mucosa decreased from 28% to 7% within 8 weeks after the start of acupuncture treatment [14]. Likewise, the study by Shi et al., showed that after 12 weeks of treatment with acupuncture added to hyaluronic-acid injections, the patients experienced gastrointestinal discomfort in only 4% of cases as compared with as much in 21% of cases, where hyaluronic-acid injections only were applied [15].

Beyond improving safety-features also the combination of acupuncture and conventional therapy show a synergistic effect, when clinical symptoms shall be alleviated. Lin et al. found that after 8 weeks of combined acupuncture and medication, WOMAC pain and function scores decreased by an additional 32% and 29%, respectively, compared to medication alone [13]. Likewise, a trial by Wang et al. showed that after 12 weeks of electroacupuncture combined with hyaluronic acid injection, the reduction in total WOMAC score was 1.5 times greater than that achieved with hyaluronic acid alone [16]. These findings suggest that acupuncture, as an adjunctive therapy, can be effectively integrated with existing conventional treatments to improve overall efficacy while enhancing safety.

5. Future Perspectives

5.1. Towards Personalized and Precision Acupuncture Therapy

Developing tailored acupuncture protocols based on individual patient characteristics, such as age, disease duration, constitution, pain profile, and functional impairment, represents a key pathway to enhancing therapeutic efficacy. Future research should build upon the traditional framework of syndrome differentiation to establish more precise and individualized treatment strategies. For instance, in patients with prominent acute inflammatory responses, acupoint combinations with demonstrated anti-inflammatory effects may be emphasized, whereas for those with chronic structural degeneration, warm needling or electroacupuncture could be incorporated to promote tissue repair.

Modern multi-omics technologies offer new opportunities for advancing precision acupuncture. Integrating genomics, proteomics, metabolomics, and other omics approaches may assist in clinical decision-making for personalized treatment planning. Furthermore, integrating advanced imaging modalities such as MRI with artificial intelligence-driven image analysis can yield objective and

quantifiable evaluations of acupuncture's impact on joint morphology and inflammatory activity. Such integration will facilitate the evolution of acupuncture from an experience-based practice to a more precisely targeted intervention, ultimately enabling truly individualized patient care.

5.2. Strengthening Evidence-Based Medical Support for Acupuncture

Although a body of clinical evidence already supports the use of acupuncture in knee osteoarthritis, there remains a need for further validation of its efficacy and safety through more methodologically rigorous and larger-scale RCTs. International multicenter clinical studies should be actively promoted to enhance the credibility and generalizability of research findings.

At the same time, ongoing synthesis and updating of evidence via systematic reviews and meta-analyses will help clarify the differential effects of acupuncture across various patient subgroups. Another critical future task is the establishment of a scientifically sound, unified, and clinically meaningful outcome assessment system. It should encompass not only pain reduction and functional recovery but also multidimensional indicators such as quality of life, psychological well-being, and long-term prognosis, thereby enabling a comprehensive evaluation of acupuncture's clinical value.

6. Conclusion

KOA is a global health problem that seriously impairs patients' quality of life and results in a significant economic burden to society. Conventional treatment with medication and/or surgery has a certain therapeutic effect but is disadvantageous in that it has significant side effects, is expensive, and yields inconsistent therapeutic efficacy. Acupuncture treatment has a wonderful effect to relieve the KOA-related pain and functional impairment due to the multi-target mechanism of action of its anti-inflammatory, neuromodulatory and chondroprotective effects and has a favorable safety profile due to the mild, transitory adverse reactions accompanying its application. Clinical studies have consistently demonstrated that acupuncture significantly reduces scores on standard assessment tools such as WOMAC and VAS. When combined with conventional therapies including hyaluronic acid injections and exercise programs, acupuncture produces a synergistic effect, enhancing both pain relief and functional recovery. This approach is particularly beneficial for older adults and for patients who are intolerant to pharmacological treatments, providing an effective, safe, and cost-efficient complementary or alternative option for the clinical management of knee osteoarthritis.

Nevertheless, even with the positive healing results of acupuncture for KOA, a lot of research has limitations that need to be addressed. These restrictions arise from substantial heterogeneity of designs of clinical trials, sample sizes that are insufficient, lack of data on follow-ups over time, and lack of standardization of acupuncture protocols, as some large random clinical trials have not taken place. All of these factors lead to a degree of uncertainty in and circumscribe the application of the results of these experiments. Overall, concerted action in the direction of larger clinical controlled trials is needed, and multidisciplinary approaches should result in the setting up of individual and precision. With regard to the clinical application of acupuncture for KOA, it is essential to establish a comprehensive evaluation system that encompasses symptom severity, functional capacity, quality of life, and long-term safety. Such a framework would provide a more robust foundation for the scientific assessment of acupuncture and strengthen the evidence supporting its therapeutic value.

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