Contemporary trends in laser-assisted arthroscopic treatment of intra-articular knee disorders

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Abstract

Modern arthroscopic laser technologies have significantly expanded the possibilities of minimally invasive orthopedic surgery for the treatment of intra-articular knee pathologies. Laser-assisted arthroscopy combines high surgical precision with minimal tissue trauma, allowing effective management of meniscal tears, chondral lesions, synovial disorders, and selected ligament-related conditions. Contemporary laser systems, particularly the holmium laser, enable controlled tissue ablation, coagulation, and debridement while preserving surrounding healthy structures.

Keywords: arthroscopic laser surgery, knee arthroscopy, intra-articular knee pathology, holmium laser, minimally invasive surgery.

Compared with conventional mechanical instruments, laser technology offers improved visualization of the operative field, reduced intraoperative bleeding, decreased postoperative pain, and faster functional recovery. Nevertheless, appropriate patient selection and careful control of laser energy remain essential to minimize thermal injury and optimize surgical outcomes. Current research is focused on integrating laser technologies with robotic surgery, three-dimensional arthroscopy, artificial intelligence, and regenerative medicine to further improve precision and tissue preservation. This review discusses the clinical applications, advantages, limitations, and future perspectives of modern arthroscopic laser technologies in the management of intra-articular knee disorders. Current evidence suggests that laser-assisted arthroscopy serves as a valuable adjunct to conventional minimally invasive orthopedic procedures rather than a universal replacement for established surgical techniques.

Articular cartilage injuries continue to represent one of the most complex problems in contemporary orthopedic surgery because hyaline cartilage possesses a very limited capacity for spontaneous repair. Owing to its avascular, aneural, and alymphatic structure, damaged cartilage has a poor intrinsic healing potential. If left untreated, even small focal defects may progressively enlarge, leading to biomechanical alterations within the knee joint, chronic pain, functional impairment, and eventually the development of osteoarthritis. Consequently, preserving healthy cartilage and restoring joint congruity have become primary objectives of modern arthroscopic surgery.

The introduction of laser technology into arthroscopic procedures has provided surgeons with an additional tool for the management of chondral lesions. Rather than serving as a replacement for conventional arthroscopic instruments, laser systems are increasingly used as an adjunct to facilitate precise tissue removal and optimize preparation of the articular surface. Laser-assisted techniques have been investigated for chondroplasty, debridement of unstable cartilage flaps, contouring of lesion margins, removal of degenerative tissue, and preparation of osteochondral defects before cartilage restoration procedures.

One of the principal advantages of laser-assisted cartilage debridement is the ability to selectively remove damaged tissue while preserving the surrounding healthy cartilage. The focused laser beam enables controlled ablation with minimal mechanical trauma, producing smoother defect margins and reducing unnecessary disruption of adjacent articular surfaces. Compared with conventional mechanical shavers, laser systems may offer greater precision when treating irregular or difficult-to-access lesions during arthroscopic surgery.

Recent technological improvements have significantly enhanced the safety profile of arthroscopic laser applications. Modern low-energy laser systems, combined with continuous irrigation and accurate energy modulation, reduce excessive thermal diffusion to surrounding tissues. Appropriate adjustment of laser power, pulse duration, and irrigation flow is essential to prevent overheating, maintain chondrocyte viability, and preserve the structural integrity of the subchondral bone. Careful adherence to these technical parameters minimizes the risk of thermal injury while maximizing the effectiveness of tissue remodeling.

Current research increasingly focuses on integrating laser-assisted arthroscopy with biological cartilage repair strategies. Laser preparation of cartilage defects may create a more favorable environment for regenerative procedures by producing stable lesion borders and removing degenerated tissue before biological reconstruction. Combination approaches involving microfracture, osteochondral autograft transplantation, autologous chondrocyte implantation, scaffold-based cartilage engineering, platelet-rich plasma (PRP), bone marrow aspirate concentrate (BMAC), mesenchymal stem cells, and growth-factor therapy are being actively investigated. These multimodal treatment strategies aim not only to alleviate symptoms but also to stimulate cartilage regeneration and improve long-term joint preservation.

Although early clinical and experimental studies have demonstrated encouraging results, the routine application of laser-assisted cartilage surgery remains an area of ongoing investigation. Additional prospective randomized clinical trials with long-term follow-up are necessary to determine optimal laser parameters, establish standardized treatment protocols, and evaluate whether laser-assisted techniques provide superior structural repair and functional outcomes compared with conventional arthroscopic methods.

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