Comparative analysis of upper labial frenulum surgical techniques: from scalpel to laser

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Abstract

The upper labial frenulum (ULF) is a connective tissue band that can significantly impact oral function and aesthetics when hypertrophic or abnormally positioned. This review examines surgical techniques for managing ULF, comparing traditional scalpel-based procedures with laser-assisted methods. Conventional treatments like frenectomy and frenulotomy remain common but have drawbacks such as increased bleeding during surgery, longer healing times, and postoperative discomfort. Z-plasty, while effective at improving both function and appearance, demands advanced surgical skill. Laser-assisted surgery provides a minimally invasive alternative, offering benefits like greater precision, less intraoperative bleeding, faster recovery, and increased patient comfort. Various lasers, including diode, CO_2, and Er: YAG types, enable precise tissue removal and effective blood control, often eliminating sutures. However, their widespread adoption is limited by high equipment costs and specialized training requirements. Although laser surgery offers clear advantages, more randomized clinical trials are needed to establish standardized protocols and enhance long-term outcomes. Future research should explore combining regenerative techniques, such as platelet-rich fibrin (PRF), with advances in AI-assisted laser surgery. This review underscores the expanding role of laser technology in ULF treatment and emphasizes the necessity of ongoing innovation to improve clinical results, patient satisfaction, and accessibility in dental practice.

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Introduction

The upper labial frenulum (ULF) is a thin band of connective tissue connecting the upper lip's center to the maxillary gingiva (1-7). Its anatomical structure and insertion site vary greatly among individuals, affecting oral function and dental development (8-13) (14-17). When hypertrophic or abnormally attached, the ULF can lead to various clinical problems, including midline diastema, gingival recession, altered tooth eruption, and aesthetic and functional issues of the upper lip (Figure 1) (18-23). These issues can negatively impact speech, chewing, and overall patient quality of life (24-29). An excessively short or thick frenulum can sometimes restrict normal lip movement, making it difficult to pronounce certain sounds and affecting smile aesthetics (30-37).

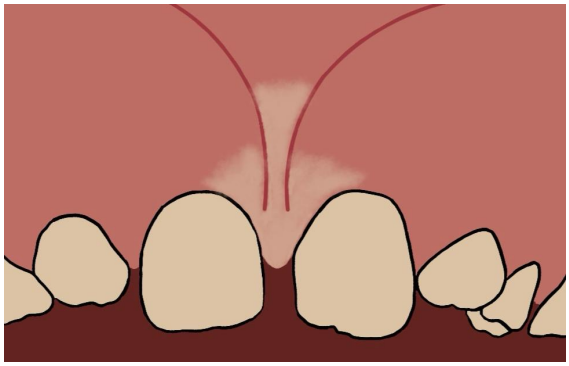

Figure 1. Hypertrophic upper labial frenulum (ULF).

Beyond functional impairments, an abnormal ULF can also disrupt orthodontic treatment, especially in growing patients (38-46). A thickened or fibrotic frenulum might prevent the spontaneous closure of a midline diastema, requiring surgical intervention before or during orthodontic treatment (47-56). An additional important factor is the psychological impact, particularly in children and adolescents, where aesthetic concerns may lead to emotional distress and decreased self-confidence (57-64).

Recent research highlights the benefits of frenulum surgery in enhancing aesthetics, oral function, and overall patient well-being. Early intervention can prevent long-term complications and improve orthodontic outcomes. However, selecting the best surgical approach depends on various factors, including patient age, the severity of the condition, and clinician preferences. With advancements in surgical technology, laser-based procedures have become a strong alternative to traditional methods, offering less intraoperative bleeding, improved postoperative pain management, and faster wound healing. The growing use of this technology has led to more comparative studies evaluating laser surgery versus traditional scalpel techniques to determine which yields the best clinical and aesthetic results.

Objectives of the Review

The main goal of this narrative review is to assess the currently available surgical techniques for ULF treatment, highlighting their advantages and limitations. Specifically, this review compares traditional scalpel-based methods with laser-assisted techniques, examining their impacts on wound healing, postoperative pain, and complication rates. Additionally, this review aims to identify gaps in the current research and emphasizes the need for further clinical studies to develop standardized treatment protocols.

Beyond assessing the effectiveness of various surgical methods, this review also examines the factors influencing the choice of surgical technique, such as patient age, severity of the condition, presence of associated dentoskeletal anomalies, and access to advanced surgical technologies.

Methodology

A thorough literature search was performed using scientific databases like PubMed, Scopus, Cochrane Library, and Embase. The keywords "frenulum," "surgery," and "laser treatment" were used to identify studies involving human subjects, published in open-access journals, and providing comparative data on different surgical methods. Studies involving animal models, systematic reviews, and letters to the editor were excluded.

After an initial screening of abstracts, full-text articles were further examined to assess their eligibility based on specific inclusion and exclusion criteria. Selected studies included randomized clinical trials, prospective and retrospective studies, and observational studies comparing surgical techniques for ULF management.

Inclusion Criteria:

- Studies conducted exclusively on human subjects
- Articles published in English
- Studies comparing laser surgery to traditional surgical methods
- Studies assessing postoperative outcomes like pain, wound healing, and complications.

Exclusion Criteria:

- Studies involving animal models
- Narrative or systematic reviews without primary data
- Letters to the editor and expert opinions without experimental evidence.
- Studies focusing on syndromic craniofacial conditions unrelated to ULF anomalies.

Data extraction involved analyzing sample size, surgical technique, follow-up period, and key clinical outcomes. Particular focus was placed on parameters like postoperative pain reduction, healing quality, and recurrence rates across different surgical methods.

Surgical Techniques

Various surgical approaches have been proposed to treat an abnormally inserted or hypertrophic upper

labial frenulum (ULF). The choice of method depends on factors such as the severity of the anatomical abnormality, the patient's age, any related dental or orthodontic issues, and the clinician's experience. The main options include traditional scalpel-based and laser-assisted surgeries, which have been extensively studied to assess their effectiveness, safety, and patient outcomes.

Traditional Surgery

Traditional ULF surgery is usually done with a scalpel and involves two primary methods: frenectomy and frenulotomy. Frenectomy means completely removing the frenulum, with the wound closed using stitches to help proper healing (Figure 2). This method is typically used when the frenulum is too thick or inserted too deeply, affecting oral function and appearance. However, the procedure has some drawbacks, such as heavy bleeding during surgery, the need for stitches, more postoperative discomfort, and a longer healing time.

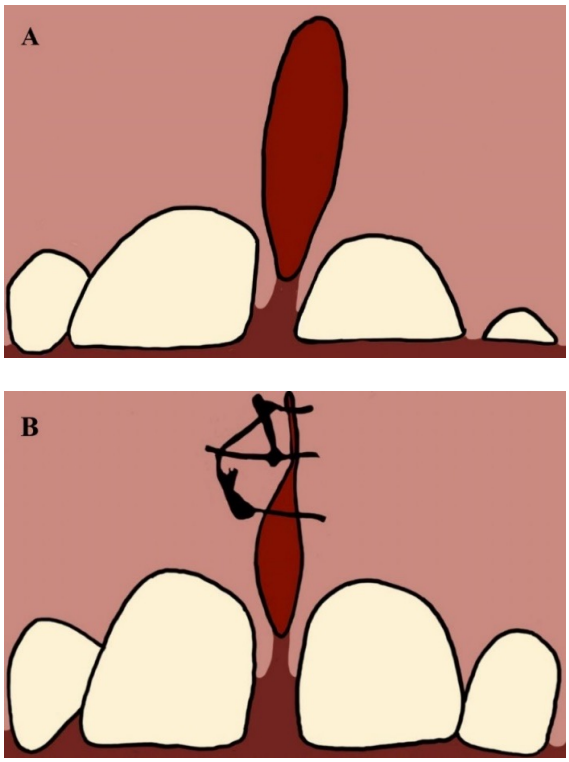

Figure 2. Frenectomy: (**A**) Lozenge-shaped wound following upper labial frenulum removal; (**B**) suture.

Alternatively, frenulotomy involves partially incising the frenulum rather than obliterating it . This method is typically used when a less invasive approach is sufficient to resolve the functional issues caused by the abnormal attachment of the frenulum. Compared to frenectomy, frenulotomy has a shorter healing time and less postoperative discomfort, but it also carries a higher risk of recurrence due to residual frenulum fibers.

Another common traditional technique is Z-plasty, which involves making Z-shaped incisions to relieve tissue tension, promote better wound healing, and prevent the formation of retractive scars (Figure 3). This method is beneficial when excessive scar formation might impair lip mobility or affect the aesthetic outcome . Although Z-plasty can significantly improve functional and aesthetic results, it requires more surgical skill and may be considered more invasive than other methods .

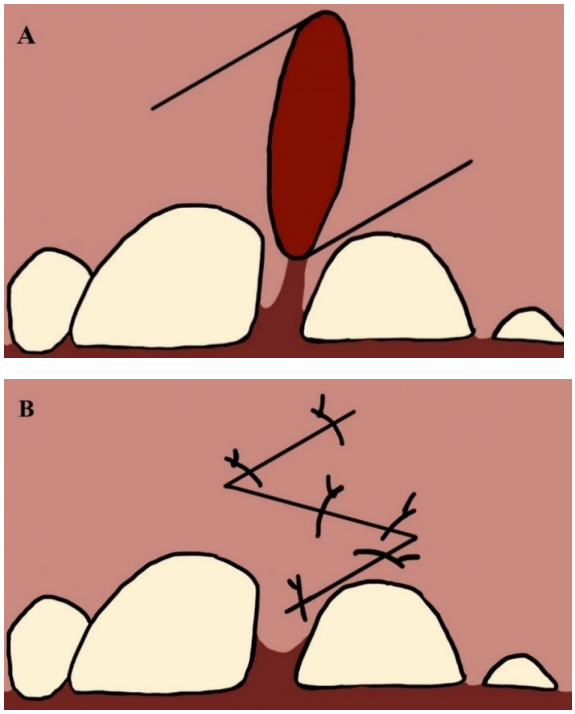

Figure 3. Frenectomy with Z-plasty: (**A**) Wound after frenulum removal and incision design for "Z" plastic; (**B**) suture after Z-plasty.

One of the main limitations of traditional surgical methOne of the main limitations of traditional surgical methods is the relatively high risk of postoperative discomfort caused by suture irritation and longer healing times. Additionally, intraoperative bleeding can obscure the surgical field, making the procedure more technically challenging. Although these methods are still widely used, advancements in laser technology have introduced alternative approaches that may address some of the shortcomings of scalpel-based surgery.

Laser Surgery

The introduction of laser-assisted frenectomy and frenulotomy has revolutionized the surgical treatment of ULF by offering a minimally invasive alternative to traditional scalpel techniques (Figure 4). Different types of lasers, including diode lasers, CO_2 lasers, and Er: YAG lasers, have been utilized in frenulum surgery. These devices allow for precise tissue removal, minimizing collateral damage and improving clinical outcomes.

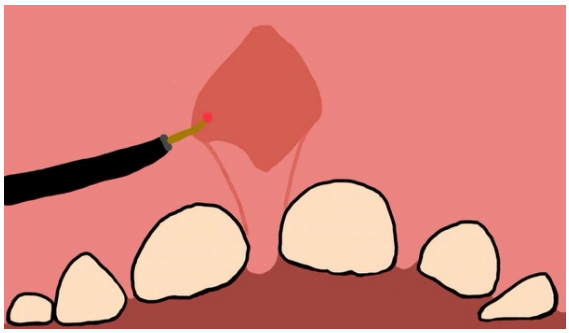

Figure 4. Laser removal of the upper labial frenulum (ULF).

One of the main benefits of laser surgery is its hemostatic effect, which decreases intraoperative bleeding and often eliminates the need for sutures. Lasers enhance visibility in the surgical field by cauterizing blood vessels during tissue removal, increasing the procedure's precision. Laser-assisted surgeries are associated with less postoperative pain, minimal swelling, reduced inflammation, and faster wound healing, making them a more comfortable option for patients.

However, laser surgery also has some limitations. The initial cost of laser equipment is relatively high, and practitioners need specialized training to ensure the safe and effective operation of laser devices. Additionally, incorrect laser settings—such as excessive power—can cause unintended thermal damage, increasing the risk of tissue necrosis or delayed healing. Laser surgery continues to grow in popularity despite these challenges because of its many clinical benefits, especially in pediatric patients and those requiring a more conservative approach.

When choosing between traditional surgery and laser surgery, clinicians must carefully evaluate the patient's individual needs, the anatomical features of the frenulum, and the available surgical expertise. While laser technology offers notable precision and reduces complications, traditional methods remain practical when laser equipment is unavailable or when the surgeon has extensive experience with scalpel-based procedures. Future research should focus on refining laser protocols to enhance safety, increase cost-effectiveness, and support broader clinical adoption.

Results and Discussion

A hypertrophic or abnormally inserted ULF can contribute to midline diastema development, gingival recession, altered tooth eruption, and an increased risk of carious and periodontal disease in the maxillary central incisors. Additionally, this condition may impair upper lip function and affect smile aesthetics, potentially leading to speech difficulties and a reduced overall quality of life.

Various surgical techniques have been explored to address ULF anomalies, including scalpel-based excision, electrosurgery, and laser-assisted procedures. While electrosurgery is a well-established method for ULF treatment, this review mainly compares traditional surgery with laser technology. Comparative studies have yet to reach a consensus on the most effective approach. However, evidence suggests that conventional surgery, unless combined with tissue-plasty techniques such as Z-plasty, may be less favorable in cases of a short frenulum or shallow vestibular depth. In such situations, the risk of excessive scar contracture could worsen the initial condition, making conventional surgery a less suitable choice. Scalpel-based procedures require suturing, whereas electrocautery provides adequate hemostasis but may result in visible scarring and significant postoperative discomfort. Conversely, laser surgery allows for precise, bloodless incisions, improving surgical field visibility, enhancing patient comfort, and encouraging adherence to postoperative care. Several studies have demonstrated the advantages of laser surgery over traditional methods, particularly in hemostasis, shorter surgical times, reduced intraoperative and postoperative pain, decreased edema and inflammation, and faster wound healing. Despite its benefits, laser surgery requires accurate power calibration to avoid potential complications.

Also, proper safety measures must be followed, including eye protection for the clinician and patient. Excessive energy output can damage underlying bone structures, and certain laser types may overheat nearby tissues, raising the risk of temporary tissue necrosis and postoperative pain. One of the main limitations in the current literature is the variability in methods across studies, such as differences in patient selection, surgical protocols, and outcome measures. Future large-scale randomized clinical trials are crucial to establish standardized protocols and determine the most effective surgical approach for ULF management.

Conclusions

Laser technology for ULF treatment has become a highly effective alternative to traditional scalpel-based surgery, offering numerous benefits such as reduced postoperative pain, faster healing, improved hemostasis, and lower complication rates. Laser-assisted procedures provide greater patient comfort and better aesthetic results, making them an increasingly popular choice in clinical practice. However, some challenges remain, especially regarding equipment costs, operator training, and the need for further standardization of surgical protocols. Although traditional surgical methods are still widely used due to their familiarity, cost-effectiveness, and proven clinical outcomes, they also have drawbacks like longer healing times, more intraoperative bleeding, and increased postoperative discomfort. In contrast, laser-assisted techniques offer a minimally invasive approach that decreases surgical time and postoperative morbidity, while enhancing overall patient satisfaction.

Nevertheless, despite the promising results of laser surgery, further large-scale, randomized clinical trials are needed to establish clear guidelines for the most effective treatment protocols. Current research is often limited by variability in study methodologies, including differences in laser settings, patient selection criteria, and follow-up durations. Future studies should address these inconsistencies by standardizing laser

parameters, optimizing patient selection guidelines, and evaluating long-term outcomes. Another important aspect for future research is exploring the potential of combining laser surgery with adjunctive regenerative techniques, such as platelet-rich fibrin (PRF) applications or biomaterial-based wound dressings, to improve tissue healing and reduce recurrence risk. Additionally, advancements in portable, affordable laser technologies may help enhance access to laser-assisted procedures, especially in general dental practices and community health settings. To promote clinical adoption, it is essential to incorporate comprehensive laser training programs into dental and surgical education. As technology advances, developing automated laser settings, AI-assisted tissue diagnostics, and real-time procedural guidance could improve precision, making laser surgery more user-friendly and consistent across different clinical environments. At the same time, laser surgery has already demonstrated significant improvements over traditional methods; ongoing innovation and research are crucial to achieve optimal patient outcomes, broader accessibility, and long-term success. The future of ULF management will likely involve a multidisciplinary approach, incorporating advances in bioengineering, digital imaging, and regenerative medicine to refine surgical techniques further and improve patient care.

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Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

Abbreviations

ULF	Upper Labial Frenulum
CO_2	Carbon Dioxide (CO_2) Laser
Er:YAG	Erbium:Yttrium-Aluminum-Garnet Laser
Nd:YAG	Neodymium:Yttrium-Aluminum-Garnet Laser
Er,Cr:YSGG	Erbium, Chromium:Yttrium-Scandium-Gallium-Garnet Laser
PRF	Platelet-Rich Fibrin

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