# Histopathologic Changes of the Soft Palate After Laser-Assisted Uvulopalatoplasty

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**Objective:** To assess late histopathologic changes of the soft palate after laser-assisted uvulopalatoplasty in patients with snoring and mild obstructive sleep apnea.

**Design:** A nonrandomized, histopathologic controlled study.

**Subjects and Interventions:** Palatal surgical specimens were removed from 10 patients with snoring and obstructive sleep apnea in whom laser-assisted uvulopalatoplasty was not successful and who subsequently underwent uvulopalatopharyngoplasty. The mean interval between the last laser treatment and uvulopalatopharyngoplasty was 24 months. The patients' specimens were compared with those of a control group consisting of 12 palates and uvulae excised during uvulopalatopharyngoplasty.

**Results:** After laser-assisted uvulopalatoplasty, all soft palates displayed marked and progressive pathologic changes that increased with every additional treatment and extended far beyond the point of laser beam application. The loose connective tissue present in the lamina propria was replaced by diffuse fibrosis, which also extended to the central layer, on the expanse of seromucous glands and muscle fibers. Other changes included ulceration of the oral epithelium and a patchy inflammatory reaction.

**Conclusions:** Extensive thermal-induced changes, involving the 3 layers of the organ, were found. They are compatible with clinical observations reported elsewhere and are probably responsible for the worsening of the obstructive sleep apnea status and the sensation of the pharyngeal dryness that developed months after the laser-assisted uvulopalatoplasty. Although it has immediate benefits, the procedure is still relatively new and all its implications are as yet unknown.

*Arch Otolaryngol Head Neck Surg. 1999;125:786-790*

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SINCE ITS INTRODUCTION in 1990 by Kamami,[1] laser-assisted uvulopalatoplasty (LAUP) has become widely used for the treatment of snoring and mild obstructive sleep apnea (OSA). This relatively inexpensive office procedure is regularly performed using a local anesthetic and has been considered by several authors[2-6] to have a low complication rate and a comparable success rate to that of uvulopalatopharyngoplasty (UPPP). Contrary to these encouraging results, other studies have suggested that LAUP has relative deleterious effects on airway stability, and may induce upper airway obstruction in a considerable number of patients. With respect to the latter, Walker et al[7] performed LAUP for snoring and OSA and reported that in 21% of the patients with OSA, postoperative polysomnograms demonstrated deterioration of OSA status compared with preoperative ones. Likewise, Laurentano et al[8] disclosed a decline in the postoperative respiratory disturbance index (RDI) among patients with mild and moderate OSA. The aggravation of OSA in these patients is attributed to circumferential scarring, with diminished velopharyngeal airspace and decreased distensibility.[9] Carenfelt[10] evaluated the efficacy of LAUP vs UPPP and noted a 2-fold increase in the prevalence of velopharyngeal scar formation among patients who underwent LAUP.

It should be emphasized that the aforementioned studies, which indicated the development of palatal scarring after laser treatment, are based on clinical observations alone, and lack pathologic support. To the best of our knowledge, no other work has been published, to date, on the pathologic changes in the soft palates of snorers and patients with OSA after LAUP. Therefore, we undertook the present study to examine the histopathologic changes within the organ in patients who failed LAUP and subsequently

## PATIENTS, MATERIALS, AND METHODS

Twenty-two tissue samples, from 2 groups of patients, were analyzed. Ten soft palate surgical specimens were removed from patients in whom LAUP had not been successful and who later underwent UPPP. The other 12 specimens, which served as controls, were obtained from the soft palates and uvulae of patients with OSA who underwent UPPP. In the first group, there were 9 men and 1 woman, ranging in age from 25 to 71 years (mean age, 49 years). The mean body mass index, which is calculated as the weight in kilograms divided by the square of the height in meters, was 28.6. Five patients had 1 laser session; 3 patients had 2 successive sessions; and 2 patients had 3 successive sessions. The mean number of LAUP procedures was 1.7. The time lapse from the last laser treatment to UPPP was 9 to 37 months, with a mean interval of 24 months. Patients underwent nocturnal polysomnography, and the severity of OSA in each case was expressed in terms of RDI, calculated as the mean number of apneas plus hypopneas per hour of sleep. Prior to LAUP, the mean RDI was 12.9 and the lowest oxygen saturation was 82.7%. A second polysomnogram, obtained after completion of laser therapy, revealed a mean RDI of 23.6 and a lowest oxygen saturation of 83.4%. In the second group, there were 11 men and 1 woman, ranging in age from 28 to 66 years (mean age, 50 years), with a mean body mass index of 28.2. They had also a preoperative nocturnal polysomnographic assessment, and the mean RDI was 24.8.

The operations were performed at the Department of Otolaryngology–Head and Neck Surgery, Meir General Hospital, Kfar Saba, Israel, from 1992 to 1996. Two surgical techniques of LAUP were employed. The first one, which was performed on 7 patients, used a continuous beam of 15 to 20 W to incise the uvular base through its full palatal depth and extended bilaterally to the anterior and posterior tonsillar pillars[11] (**Figure 1**, left). The second technique, as described by Krespi et al,[12] was performed on the remaining 3 patients and used vertical trenches in the free edge of the soft palate at both sides of the uvula. Using a flash scanner (SwiftLase; Sharplan Lasers Inc, Allendale, NJ) attached to a carbon dioxide laser, the uvula was reduced in a "fishmouth" manner by removing its core from the bottom up, while preserving the overlying mucosa. The tonsils were also reduced in case they were enlarged (Figure 1, right).

All patients underwent UPPP. Following standard tonsillectomy, their tonsillar pillars were trimmed of excessive mucous membrane. The soft palate was resected just below the preoperatively marked palatal dimple to avoid injury to the levator veli palatini muscle sling. The incisions were then arched laterally through the full thickness of the tonsillar pillars, and careful suturing of the free edges of the anterior and posterior pillars, as well as of the resected soft palate, completed the procedure.

The specimens were fixed in 10% buffered formalin, processed in the usual manner, and embedded in paraffin blocks that were serially cut in either the coronal or the sagittal plane. Deparaffinized 4-μm-thick sections were mounted on glass slides, and every fifth section was alternately stained with either hematoxylin-eosin or periodic acid–Schiff. The hematoxylin-eosin–stained sections differentiated between mucous and serous acini, whereas the periodic acid–Schiff–stained sections demonstrated mucus secretion by submucosal glands. Also, the Masson trichrome stain was used to demonstrate collagen. Light microscopy was employed to study the histopathologic features of the specimens.

underwent UPPP. The data we gathered will provide a unique opportunity to assess laser beam effects on various palatal structures and to establish the possible implication of the pathologic changes on their function.

## RESULTS

The posterior portion of the soft palate, which is removed during UPPP, consists of 3 layers: an external epithelium, an underlying thick lamina propria, and a central musculoglandular layer. The epithelial cover of the oral surface is made of a stratified squamous nonkeratinized type, while that of the nasopharynx comprises 2 different types: a pseudostratified ciliated columnar respiratory type, which covers the anterior portion of the soft palate toward the choanae, and a squamous epithelium type, which is located posteriorly and resembles the oral side, except for its lower height and fewer layers. The lamina propria is composed of loose connective tissue that contains blood vessels and nerves, and is traversed by excretory ducts of the seromucous glands. Also, occasional aggregates of lymphoid tissue are found adjacent to the nasopharyngeal mucosa, which represent mucosal-associated lymphatic tissue. As a rule, the oral side of the lamina propria is thicker than that of the nasopharynx. The central core, which forms the third layer of the soft palate, is composed of muscles

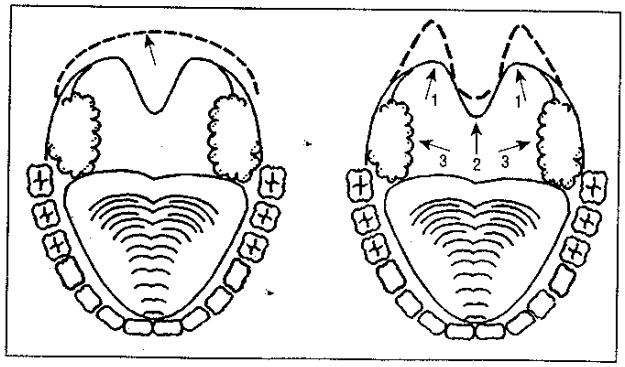


**Figure 1.** *Two types of laser-assisted uvulopalatoplasty. Left, Side-to-side incision that extends along the uvular base, across the distal portion of the soft palate (dotted line). Right, Vertical trenches at both sides of the uvula (1), evaporation of the distal portion of the uvula (2), and laser tonsillotomy (3) in a patient with hypertrophic tonsils.*

intermingled with seromucous glands. The muscularis uvulae is cradled by the underlying levator veli palatini muscle, and islands of fatty tissue are scattered among the muscle fibers. The secretory portion of the palatal glandular tissue is of a mixed type, containing both mucous and serous acini. On hematoxylin-eosin staining, mucous cells appear clear, whereas serous ones are dark. In addition to pure mucous and serous acini, there are also "mixed acini,"

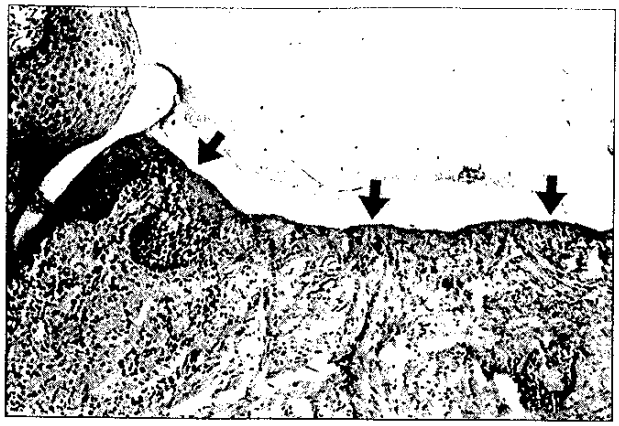

**Figure 2.** *The oral side of the soft palate displays ulceration with interruption of the squamous epithelium (arrows) and accumulation of inflammatory cells at its base (hematoxylin-eosin, original magnification × 100).*

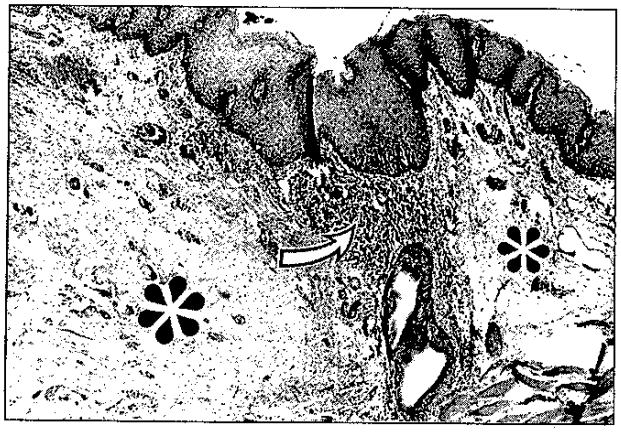

**Figure 3.** *Extensive fibrosis of the lamina propria (large asterisk), separated by a zone of inflammation (arrow) from normal loose connective tissue (small asterisk) (hematoxylin-eosin, original magnification × 100).*

in which mucous cells predominate and serous cells are displaced merely to the blind ends of the terminal portion or into saccular outpockets. The latter appear as dark-stained crescents (demilunes of Giannuzzi) surrounding the ends of the mucous cell tubules. There is a topographic distribution of glands in the soft palate, where mucous acini prevail along the oral side, while mixed glands, containing both mucous acini and serous elements, are found under the nasopharyngeal mucosa. In many sections, bulks of glandular tissue are surrounded by striated muscle fibers. This arrangement probably has functional significance, as contraction of palatal muscle squeezes saliva from glands to provide continuous lubrication of the oropharynx and to prevent dryness and surface irritation during deglutition and speech.

The soft palates of patients with snoring and OSA retained normal tissue architecture, and pathologic changes were inconsistent and found only occasionally. Among the latter, a moderate diffuse fibrosis of the submucosal connective tissue was encountered on the oral as well as on the nasopharyngeal side in 1 specimen. In 2 others, a mild patchy inflammatory response, with polymorphonuclear leukocytes and mononuclear cell infiltration, was found in the lamina propria of the oral side. It is noteworthy that the epithelial linings and the musculoglandular layer were intact in all specimens.

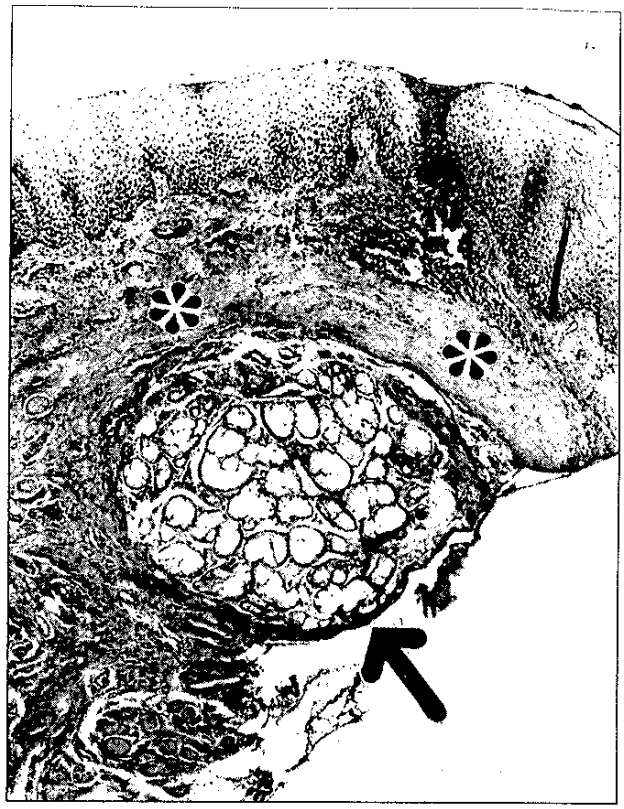

**Figure 4.** *Mucous glands (arrow) encircled by fibrotic tissue (asterisks) (hematoxylin-eosin, original magnification × 100).*

In contrast to the mild and occasional pathologic changes described above, more pronounced ones were observed in the soft palates of all patients after LAUP. These changes involved the 3 layers of the soft palate and affected all dimensions of the oral side, far beyond the immediate range of the laser beam application. Superficial ulcers with interruption of the squamous epithelium and polymorphonuclear leukocytes at their base were found at several locations along the oral side (**Figure 2**). Nonetheless, of all layers, the lamina propria changed most markedly, displaying a dense fibrotic tissue composed of tightly arranged collagen fibers and relatively few fibrocytes, which to a great extent replaced the loose connective tissue throughout the layer (**Figure 3**). Isolated small islands of acute inflammatory reaction were scattered adjacent to the oral mucosa. A marked dilatation of the glandular tissue excretory ducts was found in the lamina propria as well as in the central core of the soft palate. Moreover, the fibrotic changes invaded the central layer of the soft palate and replaced a significant number of glands and striated muscle fibers. In many sections, mucous glands, which are normally encircled by muscle, were surrounded by fibrotic tissue (**Figure 4**). In addition, the structure of muscle bundles was destroyed by massive fibrosis, leaving only few scattered fibers intact, which to a great extent lost their accompanying fatty tissue.

It should be emphasized that epithelial ulcers, submucosal inflammatory reaction, dilatation of the ductal system, fibrosis of the lamina propria connective tissue

along the oral side of the palate, and replacement of muscle and grandular tissue all occurred after a single application of laser treatment. These above-mentioned changes worsened with each additional procedure of LAUP and disclosed extensive and more severe injury to the soft palate structure, including muscle destruction and dwindling of the fatty tissue. The most striking fibrosis was observed after 3 procedures, wherein fibrosis also extended to the lamina propria of the nasopharynx, causing additive destruction of muscle and glands and almost total loss of the normal palatal structure.

The nature and extent of thermal damage were not dependent on the technique carried out, whether by horizontal incision across the palate or by vertical trenches and trimming of the uvula, as similar pathologic changes were observed in all patients who underwent LAUP.

## COMMENT

In contrast to UPPP, LAUP is regularly performed without suturing the resected edges of the palatal and uvular mucosa, and the raw surface is left to heal by second intention, with formation of scar tissue. Furthermore, the healing process of laser-treated tissue takes longer than that of surgery with the use of a scalpel.[13] Ducic et al[14] have recently studied the healing of laboratory animals that underwent trench formation by electrocautery on one side of the palate and carbon dioxide laser on the other side. They examined the histologic appearance of the palate 2, 4, and 5 weeks after surgery and found superficial ulceration with incomplete reepithelialization on the laser side compared with the cauterized side and greater tissue damage with fibrosis and entrapped disorganized muscle cells. Based on these short-term results, they concluded that LAUP offers no advantages over electrocautery treatment.

The present study demonstrates the long-term effects of thermal injury to the palate that can be inflicted by the laser beam. Similar to clinical studies that described palatal fibrosis in a considerable number of patients after LAUP,[9,10] all histologic sections from our patients after LAUP showed extensive formation of fibrous tissue in the soft palate. The fibrotic changes were observed throughout the specimens and were noticed far beyond the treated area. The extent of these delayed pathologic changes increased with each LAUP procedure and was not dependent on the technique of LAUP, as similar changes were noticed in all specimens. The data strongly suggest that despite the immediate beneficial effects of LAUP, as time progresses there is extensive and additive tissue damage to the soft palate.

The maintenance of upper airway patency depends on the balance between the negative transmural inspiratory pressure that tends to occlude the upper airway and factors that allow it to open, such as the contraction of the dilator muscles. It is thought that the replacement of the normally present loose connective tissue in the lamina propria, with dense collagen tissue and the decrease of muscle mass in the central layer of the palate, probably contributes to the rigidity, diminished distensibility, and contractility of the soft palate. Obviously, scarring-induced rigidity elevates upper airway resistance, and the latter increases respiratory effort. In addition, the diminished contractility due to muscle loss leads to decreased upper airway caliber and eventually to obstruction. These late pathologic changes may explain the development of OSA in snorers and the aggravation of OSA in patients who underwent LAUP. Indeed, the mean RDI in our series worsened from 12.9 to 23.6 after treatment. Laser-assisted uvulopalatoplasty is considered an effective tool for the treatment of snoring, as it reduces velar flutter and snoring resulting from shortening of the vibratile velum and its concomitant fibrosis. Nevertheless, in the long run, it may have a deleterious effect on the velopharyngeal anatomy and the respiratory dynamics and bring about or worsen OSA in a considerable number of patients.

One cannot ignore the fact that this study was based on patients in whom LAUP was not successful; however, in terms of elimination of snoring and improvement of the obstruction, there is still a large number of patients who benefit from the procedure. The possible reasons for the disparate results of LAUP should therefore be examined. Could they be attributed to different pathologic responses of the soft palate to the laser? The answer to this question is apparently no, since extensive pathologic changes were observed invariably in all palates in the present series, and this is probably a universal phenomenon. The presence of a different anatomy of the velopharyngeal isthmus may offer an alternative and more acceptable explanation for the diversity of the LAUP results. Indeed, after LAUP, Finkelstein et al[9] found a pronounced narrowing of the isthmus in patients with a deep type of velopharynx, compared to those with a flat one.

As previously mentioned, the presence of epithelial ulceration in laboratory animals a few weeks after LAUP is attributed to delayed healing of the oral mucosa.[14] However, in humans, palatal ulceration that developed many months after laser surgery probably has an altogether different origin. Apparently, a rich blood supply is needed to maintain adequate proliferation and repair of palatal mucosa. The palatal epithelium, like other regions of the oral mucosa, is subjected to constant irritation and trauma caused by chewing and deglutition. The extensive subepithelial fibrosis found after LAUP, which is associated with a diminished mucosal blood supply, makes the soft palate more vulnerable to daily trauma and eventually leads to the formation of ulcers.

A sensation of dryness in the throat, and phonatory as well as articulatory problems in speech, occur in 18% to 75% of the patients after UPPP.[15-17] Salas-Provance and Kuehn[17] suggested that changes in the voice quality after UPPP are related to pharyngeal dryness. The human uvula and the posterior portion of the soft palate harbor abundant seromucous glandular tissue that provides continuous lubrication to the oropharynx and probably also to the vocal cords.[18] Thus, surgical extirpation of these organs results in a significant decrease of the glandular tissue and leads to pharyngeal dryness and surface irritation of the vocal cords. Like UPPP, LAUP that causes extensive palatal fibrosis is also associated with a marked decrease in the amount and function of the velopharyngeal glands. With respect to the latter, in a study

of 63 patients who underwent laser-assisted uvulopalatoplasty for snoring and OSA between June 1994 and March 1995, it was demonstrated that 48% of them had annoying pharyngeal dryness and discomfort at the end of the follow-up period (10.6 ± 6.9 [mean ± SD] months) (Y.F., G. Stein, MD, G.B., R. Landsberg, MD, and D.O., unpublished data). It is assumed that more data are needed to arrive at an accurate conclusion on the possible difference between the 2 techniques concerning postoperative pharyngeal dryness and voice problems.

## CONCLUSIONS

Laser-assisted uvulopalatoplasty is considered a safe, bloodless procedure that requires no hospitalization and is known for its insignificant complication rate. Nevertheless, our study demonstrates long-term pathologic changes of the soft palate in patients who underwent LAUP, involving all 3 layers of the organ. The changes, which were observed in patients in whom the procedure failed, are compatible with clinical observations and could account for the worsening of the OSA status, the sensation of pharyngeal dryness, and the phonatory voice problems. It should be noted that despite the universal fibrosis a large proportion of patients still enjoys laser treatment. Since the factors that determine who the best candidates for LAUP are, as well as the full implications of the procedure, have yet to be established, the decision to pursue this treatment should be approached with great caution.

*Accepted for publication July 27, 1998.*

*We express our appreciation to Joelle Bernheim, MD, Department of Pathology, Meir General Hospital, for her invaluable contribution and to Rachel Berger, BA, for her writing and editing assistance.*

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