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Observational Study

*Corresponding author
Berk Gurpinar, MD
Department of Otolaryngology
Okmeydani Training and Research Hospital, Istanbul, Turkey
Tel. +90-532-542-82129
E-mail: b_gurpinar@yahoo.com

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Comparison of Tonsillectomy Techniques and their Histopathological Healing Patterns

Berk Gurpinar, MD[1*]; Ziya Salturk, MD[1]; Meltem E. Akpinar, MD[2]; Ozgur Yigit, MD[3]; Artunc Kaan Turanoglu, MD[3]

[1]Department of Otolaryngology, Okmeydani Training and Research Hospital, Istanbul, Turkey
[2]Department of Otolaryngology, Sisli Hamidiye Etfal Training and Research Hospital, Istanbul, Turkey
[3]Department of Otolaryngology, Istanbul Training and Research Hospital, Istanbul, Turkey

ABSTRACT

Objective: This study aims to identify the tonsillectomy method offering the lowest post-operative morbidity, complications and the best healing pattern.
Study Design: Prospective, randomized, double-blinded study.
Setting: Tertiary care hospital.
Subjects and Methods: One hundred and eighty adult male patients complaining of recurrent tonsillitis were enrolled in the study. All the participants were randomly assigned to one of the techniques, including cold knife tonsillectomy (CLST, n=30), electrocautery (ELCTR, n=30), Sutter radiofrequency tonsillectomy (SRF, n=30), plasmacision (PLCS, n=30), coblation (CBL, n=30) and thermal welding (THRWL, n=30). The age of the patient, operative time, bleeding control time, need for additional cautery, amount of blood loss, the degree of difficulty of the technique, post-operative pain in the 1st, 3rd and the 5th days and post-operative complications were recorded.
Results: The SRF group had the least operative time between 3 to 20 minutes (average 10.4±4.28 min. The longest operative time with THRWL ranged between 17-28 minutes (average 22.66 ±4.36 min.) (p<0.00001). CLST showed the least, while PLCS was characterised with the most pain in the 3rd post-operative day (p=0.0026). On the 5th day, the pain scores were similar to that of the 3rd day (p=0.0037). Histopathologically, necrosis was least in CBL and most in PLCS (p<0.00001). Vascular proliferation was least in SRF and most in CBL (p<0.00001). Lymphocyte and histocyte migration was least in the CBL and most in the PLCS (p<0.00001).
Conclusion: Although, inexpensive, CLST is accompanied by a significant amount of intra-operative blood loss and operative time. SRF, CBL and THRWL techniques seemed to have reasonable post-operative pain, lower amounts of blood loss and lower tissue reactions.

KEY WORDS: Tonsillectomy; Sutter; PlasmaKnife; Coblator; Thermal welding.

ABBREVIATIONS: CLST: Cold Knife Tonsillectomy; ELCTR: Electrocautery; CBL: Coblation; PLCS: PlasmaKnife; SRF: Sutter radiofrequency; THRWL: Thermal Welding; OSA: Obstructive Sleep Apnea.

INTRODUCTION

Tonsillectomy continues to be one of the most common surgical procedures in otolaryngology for years.[1] Although, not a routine procedure in adults, it is a frequently performed surgical procedure in the pediatric population. The most common symptoms associated with both adult and pediatric tonsillectomies include recurrent tonsillitis and obstructive sleep apnea (OSA). Recurrent tonsillitis more commonly affects the patient population associated with schools, daycares or military services. Therefore, schoolgoing children or adults living in large communities are generally the most affected group of patients.[2]

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Adult tonsillectomy may cause substantial post-operative pain and morbidity and is often associated with greater blood loss than pediatric tonsillectomy. Developing a condition of increased fibrosis from previous infections, combined with large blood vessels, is thought to be a possible cause of greater blood loss in adult tonsillectomy.[3] To control bleeding intra-operatively, more cauterization is generally required and this substantially increases the post-operative pain on account of thermal injury to the tissue.

Traditional tonsillectomy techniques include cold knife tonsillectomy (CLST) and electrocautery (ELCTR). Advances in technology introduced cryosurgery, harmonic scalpel, coblation (CBL), PlasmaKnife (PLCS), microdebrider, sutter (SRF) and thermal welding (THRWL) to the surgical practices in otolaryngology. Most of the above techniques demand the use of radio frequency, causing tissue ablation and coagulation at relatively low temperatures (60 °C-70 °C) thus avoiding thermal injury when compared to electrocautery (150 °C-400 °C). CBL ablates the target tissue by generating a field of ionized sodium molecules. The device uses bipolar radiofrequency energy to ablate and coagulate the soft tissue without causing thermal injury. During coblation, conductive saline solution is converted in the gap between the device tip and the tissue into an ionized plasma layer. Plasmacision ablates the tissues by generating a highly ionized plasma around the active electrode. The tissue heat creates a temperature between 60 °C-90 °C, which is low relative to electrocautery. Sutter is a radiofrequency device that delivers bipolar energy (60 °C-90 °C tissue heat) through an easily held bipolar biting forceps. THRWL facilitates coagulation and dissection in tandem by using a dual control footswitch of the forceps.

This study aims to identify the tonsillectomy method which offers the lowest post-operative morbidity, complications and the best healing pattern. Therefore, we compared the tonsillectomy techniques including CLST, ELCTR, radiofrequency (SRF, CBL and PLCS) and THRWL in the adult population addressing the various pre-operative and post-operative predetermined measures. Additionally, three radio-frequency tonsillectomy techniques were compared. Histopathological evaluation of the post-operative palatopharyngeal arch tissue samples was performed to identify the differences in tissue injury and the healing process for each of the applied techniques. To the best of our knowledge, no research evidences are available in which the technique of thermal welding has been compared with other clinical practices and histopathological evaluation.

MATERIALS AND METHODS

Study Subjects and Design

One hundred and eighty adult male patients complaining of recurrent tonsillitis were enrolled in the study between April 2011 and January 2016. The study protocol was approved by the Institutional Review Board of Istanbul Training and Research Hospital. Informed consent was taken from all subjects participating in the study according to the Declaration of Helsinki. All the participants were randomly assigned to one of the techniques, including CLST (n=30), ELCTR (n=30), SRF (n=30), PLCS (n=30), CBL (n=30) and THRWL (n=30), and all the patients underwent surgery performed by the senior author. The exclusion criteria included the history of peritonsillar abscess, severe unilateral tonsil enlargement and obstructive sleep apnea. Patients unwilling to participate in the post-operative palatopharyngeal arch tissue sampling protocol were operated on, but not included in the study. Each patient signed an informed consent form that mentioned the description of the technique of tonsillectomy and had the information in detail about the tissue sampling on the post-operative 6th day from the left palatopharyngeal arch. All the patients were monitored until the post-operative 14th day.

Surgical Technique

All the clinical subjects were operated under the condition of general anesthesia. Before the study, the surgeon performed at least five tonsillectomies with each method in order to achieve a standard learning curve. Each patient received a dose of midazolam 1.5 mg intravenously for premedication. Nitrous oxide, oxygen and remifentanyl were used for induction of general anesthesia. For maintenance, isoflurane and vecuronium bromide was administered.

As a standard protocol, each patient was placed in the Rose position and a Davis-Boyle mouth gag supported by Draffin bipods were inserted into their mouth.

ELCTR (Valleylab Inc., CA, USA) is the standard method for performing tonsillectomy at our institution and was performed using the electrosurgical handpiece on a setting of 15 W in the coagulation mode. PLCS (Gyrus ENT, Bartlett, TN, USA) setting was 80/20 as coagulation to cutting ratio using the Gyrus ENT workstation as the power source. SRF (Freiburg, Germany) with ToBite clamp was set to 6 in the precise mode using the Bm-780 II workstation as the power source. CBL (ArthroCare Corp., Sunnydale, CA, USA) with the bipolar radio-frequency-based plasma device Evac 70 Wand and Coblator as the power source was set to 6/4 as coagulation to cutting ratio. Welding system and disposable forceps were used for the THRWL (Starion, Sunnyvale, CA, USA) and the device was set to 8/3 as coagulation to cut ratio. CLST was performed with the No.12 scalpel.

The surgical procedure was similar to the applied techniques; the tonsil was grasped with the tonsil-seizing forceps and medially retracted gently. After the incision of the anterior plica, a clear plane of extracapsullar dissection was performed beginning from the superior pole, subsequent dissection was followed-up to the inferior pole. The lower pole was coagulated with the same instrument (in case of cold knife dissection with the bipolar electrocautery) and great care was taken to achieve a state of hemostasis.

The first cold liquid diet was given 4-6 h after the operation. The patients were allowed to return to their normal diet

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on the post-operative 7th day; if unable, the soft diet was continued until they were able to receive the normal diet.

Post-operative medications were considered as the standard for liquid antibiotic regimens (cefuroxime axetil 500 mg b.i.d, 7 days) and liquid oral analgesics (acetazolamide 500 mg t.i.d, 7 days).

Measures Evaluated

The age of the patient, operative time, bleeding control time, need for additional cautery, amount of blood loss, the degree of difficulty of the technique, post-operative pain in the 1st, 3rd and the 5th days and post-operative complications were recorded. The operative period, after the induction of the anesthesia, was recorded as a sum of bilateral tonsillectomies. If the bleeding occurred intra-operatively, the bleeding control time was also measured using a chronometer and instantly noted. For all the implemented techniques, the unexpected bleeding was controlled by bipolar cautery.

For each patient, blood loss was measured using separate suction canisters. Irrigation volume was standardized and subtracted from the canister to ensure that blood within the suction tube was accurately measured.

The degree of difficulty for the procedure was settled by the surgeon on a four-point scale such that a rating of 1 was considered as the easiest and 4 as the most difficult technique. The convenience of the method, the need for the use of additional cautery, easy and clear achievement of the correct dissection plan determined the overall degree of difficulty of the performed procedure.

All subjects were asked to clarify the level of post-operative pain on the 1st, 3rd and the 5th days using a visual analogue scale from 1 to 10 (1=No pain, 10=Suffering). If any post-operative complication occurred, it was recorded for each patient separately.

On the post-operative 6th day, the left palatopharyngeal arch upper portion of each patient was locally anesthetized by pulverization using Lidocaine 10 mg (Xylocaine pump spray, AstraZeneca, Cambridge, UK) and administration of 2 cc of Lidocaine HCl 20 mg/ml + Epinephrine HCl 0.0125 (Jetokain ampoule, ADEKA, Japan). A standard tissue sample of 0.2×0.2 cm was taken from each patient from the upper portion of the left palatopharyngeal arch. No excess or uncontrolled bleeding occurred, since a five minute waiting interval was maintained between the local anesthesia infiltration and tissue biopsies to ensure vasoconstriction. Each specimen was examined by the same pathologist and tissue necrosis, leukocyte, lymphocyte or histocyte migration (Figures 1 and 2), tissue edema and degree of vascular proliferation were analysed (Figure 3). Histological

Figure 1: Histopathologic Evaluation of the Tissue Samples in the Post-operative 6th Day and Lymphocyte Predominance in the Plasmaknife Tonsillectomy (Hematoxylin eosine, 400 X).

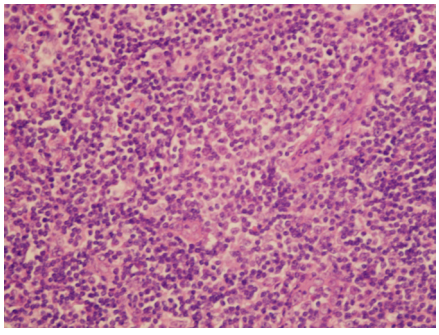


Figure 2: Histopathologic Evaluation of the Tissue Samples in the Post-operative 6th Day and Neutrophyl Predominance in the Coblation Tonsillectomy (Hematoxylin eosine, 400 X).

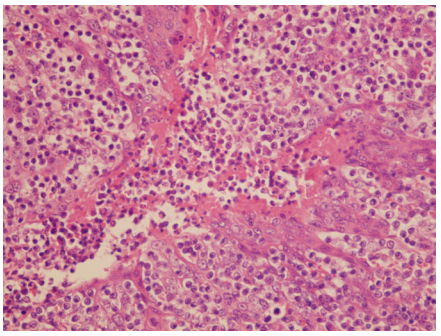
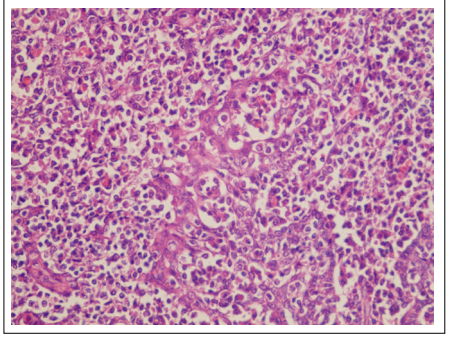


Figure 3: Histopathologic Evaluation of the Tissue Samples in the Post-operative 6th Day and Increased Vascularization in the Coblation Tonsillectomy (Hematoxylin eosine, 400 X).



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evaluation was determined according to the scale defined by Sultana et al[4] and Gal et al[5].

Statistics

All the groups were compared with respect to the operation time, bleeding control time, amount of blood loss, additional electrocautery requirement, degree of difficulty of the technique, post-operative complications, pain on the post-operative 1st, 3rd and the 5th days and post-operative histopathological healing characteristics (Table 1). A second comparison of the observations were performed using the three radio-frequency tonsillectomy techniques (Table 2).

Statistical analysis was performed using SPSS v15.0 (SPSS, Inc, Chicago, IL, USA). Continuous data was displayed as mean±standard deviation. Statistical significance was accepted when $p<0.05$. Normality analysis showed non-parametric distribution. Therefore, Kruskall-Wallis and the non-parametric Analysis of variance (ANOVA) tests were applied to determine statistically significant variances. Differences in the operative time and blood loss were recorded using the Student's *t*-test and additional cautery use was analysed using the chi-square test.

RESULTS

The age group for the patients being studied was between 22 and 32 years with an average age of 27.81±2.09 (Table 3). All the participants were associated with the study till completion. The SRF group had the least operative time between 3 to 20 minutes (average 10.4±4.28 min.) The longest operative time with THRWL ranged between 17-28 minutes (average 22.66±4.36 min.) ($p<0.00001$). We did not use extra cautery for SRF and for 6 cases of CBL, but we needed bipolar cautery for all the other techniques ($p<0.00001$). The easiest technique to apply was SRF, while the most difficult surgical technique to perform was PLCS and the other applied techniques were found to be similar ($p<0.00001$). Post-operative pain in the 1st day was not found to be statistically significant among the implemented techniques ($p=0.055$). CLST showed the least, while PLCS was

Table 1: Subject Characteristics.

Variable	SRF	PLCS	CLST	ELCTR	THRWL	CBL	*p* value	Test result
Blood amount (cc)	4.66	107	206.66	26.46	20.20	9.33	0.0000000001	Statistically significant
Easiness of the technique(1: Easy; 4: Hard)	1	4	2	2	2	2	0.0000000000	Statistically significant
Pain (1st day)(1:Lowest; 10:Highest)	6	8	7	7	6	7	0.0558480000	Not significant
Pain (3rd day)(1:Lowest; 10:Highest)	2	7	1	4	5	5	0.0026010000	Statistically significant
Pain (5th day)(1:Lowest; 10:Highest)	1	4	1	4	4	4	0.0037150000	Statistically significant
Vascular proliferation	+	++	++	+++	++	++++	0.0000000884	Statistically significant
Lymphocyte-Hystiocyte migration	++	++++	++	+++	++	+	0.0000000061	Statistically significant
Necrosis	++	++++	++	++	++	+	0.0000037700	Statistically significant
Edema	+++	++++	+++	+++	+++	++	0.0000861720	Statistically significant

SRF: Sutter Radiofrequency Tonsillectomy; PLCS: PlasmaKnife Tonsillectomy; CLST: Cold knife Tonsillectomy; ELCTR: Electrocautery Tonsillectomy; THRWL: Thermal Welding Tonsillectomy; CBL: Coblation Tonsillectomy.

Table 2: Comparison of the three Radiofrequency Tonsillectomy Techniques.

Variable	Arrangement in order	Statistical significance
Operative time	COB>PLCS>SRF	Yes
Blood loss	PLSC>CBL>SRF	Yes
Easiness	SRF>CBL>PLCS	Yes
Additional cautery use	PLSC>CBL>SRF	Yes
Pain (1st day)	PLSC>SRF>CBL	No
Pain (3rd day)	PLSC>CBL>SRF	No
Pain (5th day)	PLSC>CBL>SRF	No
Necrosis	PLSC>CBL>SRF	Yes
Vascular proliferation	SRF>CBL>PLCS	Yes
Edema	SRF>PLSC>CBL	Yes
Leucocyte migration	PLSC>SRF>CBL	Yes

CBL: Coblation Tonsillectomy; PLCS: PlasmaKnife Tonsillectomy; SRF: Sutter Radiofrequency Tonsillectomy.

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Table 3: Subject Demographics.

		CLST	ELCTR	SRF	PLCS	CBL	THRWL
Age		26.74±1.4	25.67±2.3	29.86±2.7	28.59±1.3	27.32±1.9	28.68±2.8
Gender	Male	100%	100%	100%	100%	100%	100%
	Female	-	-	-	-	-	-
Education level	Primary	48%	51%	54%	50%	47%	49%
	Secondary	43%	32%	39%	41%	55%	40%
	Tertiary	9%	17%	7%	9%	8%	11%
Dwelling area	Urban	52%	47%	56%	48%	49%	53%
	Rural	48%	53%	44%	52%	51%	47%

SRF: Sutter Radiofrequency Tonsillectomy; PLCS: PlasmaKnife Tonsillectomy; CLST: Cold knife Tonsillectomy; ELCTR: Electrocautery Tonsillectomy; THRWL: Thermal Welding Tonsillectomy; CBL: Coblation Tonsillectomy.

characterised with the most pain in the 3rd post-operative day (p=0.0026). On the 5th day, the pain scores were similar to that of the 3rd day (p=0.0037).

Twelve subjects (10 subjects of the PLCS, 1 subject of CBL and 1 subject of CLST) reported early post-operative bleeding for 1-5 days. Seven of the patients were admitted to the operating theater and hemostasis was achieved under general anesthesia while hemostasis of the remaining surgical techniques was controlled in the office.

Histopathologically, necrosis was least in CBL and most in PLCS (p<0.00001). Vascular proliferation was least in SRF and most in CBL (p<0.00001). Lymphocyte and histocyte migration was least in the CBL and most in the PLCS (p<0.00001).

DISCUSSION

Tonsillectomy remains as one of the most common surgical procedures worldwide.[6] The most common indication is that of recurrent tonsillitis.[7] Although, pediatric tonsillectomy is tolerable, adult patients frequently experience moderate to severe odynophagia, bleeding, nausea, and airway complications, and the recovery period may even exceed 10 days.[8] Many strategies have been implemented to reduce the post-operative pain and morbidity, including pre-operative steroids, intra-operative local anesthetic injection, corticosteroids or nonsteroidal antiinflammatory medications. Additionally, modified techniques such as intracapsular tonsillectomy for selected indications have aimed at improving morbidity.[9]

Advances in technology have introduced new devices in the field of operations, such as CBL, PLCS, SRF or THRWL. Still, we lack adequate data to utilize these devices optimally towards decreasing the morbidity rate and complications. This study is an attempt to assist the surgeons to decide on the course of the treatment and procedure; however, the final decision concerning the surgery should be ultimately based on clinical judgment, anecdotal experience, and evidence where available.[10]

Traditional electrocautery involves the transmission of electrical current from a single electrode *via* a path of return through the patient's body. Concentrated electric current results in a burn that coagulates the tissue and stops bleeding, resulting in scar formation. Coagulation at high temperatures of up to 400 °C causes substantial collateral damage to the surrounding tissue and causes post-operative pain and morbidity.[11] On the other hand, it is the safest way to attain a state of hemostasis; for this reason, we used the bipolar electrocautery to control unexpected bleeding in all the applied techniques.

CLST is the most conventional and commonly applied technique. In our study, it showed the lowest morbidity rate due to lack of thermal tissue damage. Despite the favorable operation time, the period of hemostasis was longer relative to the other methods. The post-operative complication rate was thus, parallel to the published data.[12] In most institutions, it is the most preferred method of tonsillectomy startingly for educational purposes. Yet, also in our study, we must accept that the operative field in this technique is not as clear as the other tecniques.

THRWL uses a heating element at the tip of the instrument combined with pressure to denature the protein molecules within the tissue. The tissue is squeezed between insulated jaws as focused heat is applied to the localized region. The protein molecules in the tissue are denaturated and fused to one another, forming a tight seal. It has been shown to be associated with lower post-operative pain than electrocautery.[13] In our study, no post-operative complications occurred in the THRWL group. Additionally, both the THRWL and SRF tecniques were the easiest, most convenient and complication free methods.

SRF, CBL and PLCS are implemented to reduce post-operative pain, cause limited tissue damage and improve recovery.[14] Coblation is associated with the passage of radiofrequency bipolar electric current through a medium of normal saline, resulting in a plasma field of ionized particles, which was able

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to break down intercellular bonds and divide the tissue at a temperature of 70 °C.[3] The PlasmaKnife produces a highly ionized gaseous state or "plasma" around the active electrode through the use of local tissue electrolytes. This highly excited tissue state requires lesser electric current to attain molecular dissociation between low working temperatures (60-90 °C).[11] Controversially, published data showed that the PLCS group was characterised with more pain in the early post-operative period and the bipolar dissection group returned to normal activities in a larger proportion relative to the PLCS group post-operatively.[15] SRF consisted of a radio-frequency generator and an easy-hold non-stick bipolar forceps.[16] In our study, we compared three radio-frequency techniques to each other. SRF had the least operative time, did not need additional cautery for homeostasis and was the easiest technique showing lower post-operative pain level. Also, this technique indicated minimal blood loss and no post-operative complications. The hardest technique to apply was the PLCS showing the highest post-operative pain levels. Again, mostly the subjects on whom this surgical technique was performed, showed an early post-operative complication of bleeding. We are aware that the complication rate of PLCS is higher than the published data,[15] but all operations were standardized by the same surgeon after having achieved a satisfactory learning curve. The results obtained for CBL were allied to the findings in the literature; the method was considered more effective than the conventional techniques and PLCS.

Additional factors that should be considered when using new techniques demand careful attention to the operative time and blood loss. Most surgeons performing tonsillectomy today would agree that cold techniques result in a greater blood loss than monopolar cautery and radiofrequency. In fact, one study demonstrated that the mean intra-operative blood loss was approximately 10 mL with electrocautery *versus* 190 mL with sharp dissection.[17] In our study, the average blood loss recorded was 4.66 ml for SRF, 9.33 ml for CBL, 107 ml for PLCS, 20.20 ml for THRWL, 26.46 ml for ELCTR and 206.66 ml for CLST. The cross comparisons of the groups were significant.

Unlike most operative procedures, tonsillectomy leaves the patient with an open wound that heals by secondary intention. The post-operative course is worsened by inflammation and a spasm of the pharyngeal muscles that can lead to a protracted pain cycle until the exposed tissue mucosalizes.[18] A presumptive benefit of the radio-frequency devices and the THRWL is that they create a more precise incision, which results in a more rapid wound healing. A histological study using a porcine model was performed, in which incisions made by the PlasmaKnife, harmonic scalpel, and Coblation were compared for their healing characteristics.[11] The investigators found that the PlasmaKnife incisions were covered with a vascularized tissue, which could be compared favorably to incisions made using monopolar cautery, Harmonic scalpel, and Coblation that leave poorly organized wound cover and cause a greater damage to the surrounding muscles.

In our study, all histopathological parameters were independently statistically significant for the applied techniques (p<0.00001). Since the tonsil itself is a lymphoid tissue, presence of the lymphocyte is considered as less valuable than the presence of the neutrophil which we accepted as a major marker of tissue reaction and found that the CBL shows the lowest degree while PLCS showed the highest degree of tissue reaction among all the six methods that were applied. Necrosis, similarly, was highest in the PLCS and lowest in the CBL group. Edema was highest in CBL and lowest in ELCTR group. We could not explain why ELCTR had the lowest score for tissue edema, because as a tissue reaction, it is well known that electrocautery delivers 400 °C tissue heat while radio frequency delivers 60 °C-90 °C. In that case, the least edema would be expected in the cold knife tonsillectomy group, which was not the case. To better understand, we used the scale defined by Sultana et al[4] and Gal et al[5]; one completing the other, but still these measurements are all semi-quantitative and subjective to the researcher. To standardize, all specimens were assessed by the same pathologist who was blinded to the techniques applied. To best of our knowledge, this was the most objective study design so far.

Our study has some limitations; first of all, all surgeries were performed by the same surgeon. Secondly, the learning curve for all instruments might not be equal. Thirdly, all the patients being studied were males. All of the above mentioned parameters have a reasonable explanation; to relieve bias and standardize the study design. Another limitation was the single histological evaluation (6th day) that does not fully describe how the post-operative healing process occurs.

CONCLUSION

Although, inexpensive, CLST is accompanied by a significant amount of intra-operative blood loss and operative time. SRF, CBL and THRWL techniques seemed to have been associated with reasonable post-operative pain, lower amounts of blood loss and lower tissue reactions.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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