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Mahmoud Satte
Najran University
M.D. & Ph.D, Assistant Professor, Faculty of Medicine,
Department of anatomy, Najran, Saudi Arabia,
55461, +966553125185
hageeg.yoo@gmail.com

EFFECT OF THYROPLASTY IN THE TREATMENT OF DYSPHONIA: A REVIEW ARTICLE

Abstract: *CONTEXT AND OBJECTIVE: Thyroplasty is a surgery carries out to change the location of the vocal cord to improve the voice in dysphonic patients. Some studies have proposed a large scale of the practicable process through which thyroplasty may take part in voice disorders treatment. Although, the underlining thyroplasty procedures and their effects on voice disorders are not fully understood. We conducted this study to review the possibilities procedures suggested for the effects of thyroplasty in the treatment of patients with dysphonia.*

DESIGN AND SETTING: Narrative review conducted at the Medical College, Najran University, Najran City; Kingdom of Saudi Arabia.

METHODS: A search in the online databases PubMed, LILACS, and SciELO was selected in August 2020.

RESULTS: 78 articles were included and shown to contain information concerning of thyroplasty surgeries and their purposes. 4 types of thyroplasty procedures can improve the voice permanently in the patients with dysphonia mainly caused by vocal cord paralysis, spasmodic dysphonia, puberophonia (high vocal pitch), and androphonia (low vocal pitch). In some cases, small significant complications may present after a procedure such as edema, wound sepsis, and hematoma and it is treated quickly and easily.

CONCLUSION: The outcome may put some guidelines on the maximum amount of the thyroplasty procedure to treat the dysphonic patients. Nevertheless, further human studies are secured to reduce the small significant complications of thyroplasty surgery.

Key words: *Thyroplasty, dysphonia, treatment.*

Language: *English*

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Introduction

Thyroplasty is a surgical intervention on the larynx that makes a change on laryngeal cartilages to manage the vocal cord to enhance the voice quality for dysphonic patients. The term thyroplasty introduced by Japanese scientists (Isshiki et al) in 1974 [1]. The vocal fold (vocal cord) is the movable fold on each side of the laryngeal inlet and responsible for phonation. Its structures consist of a mucous membrane covering the vocal ligament. The gap between vocal cords is called glottis and measured about 2.5 cm from anterior to posterior in the adult male and less in the female. Five muscles move the vocal cords: the cricothyroid (tensing the vocal cords), thyroarytenoid (relaxing the vocal cords), lateral cricoarytenoid (adducting the vocal cords), posterior cricoarytenoid (abducting the vocal cords), and the transverse arytenoid (approximate the arytenoid cartilage). All of the five muscles are originate from thyroid and cricoid cartilages except the transverse arytenoid take origin from arytenoid cartilage, and all are inserted in the arytenoid cartilage except the cricothyroid which inserted in thyroid cartilage. The recurrent laryngeal nerve supplies all the vocal cords muscles except cricothyroid which supply by the external laryngeal nerve [3]. Recurrent laryngeal

nerve injury can lead to vocal cord paralysis and in turn, causes hoarseness (dysphonia) [4]. Therefore, over adduction of the vocal folds characterized by intermittent voice stoppages, or breaks invoicing in a condition called adductor spasmodic dysphonia [5]. Mutational voice disorders also known as puberphonia which are described by the voice's pitch may be too high and a reverse voice change may occur [6]. The aim of the current study is to focus on the evaluation of the thyroplasty procedures role in treating dysphonia, in the form of a narrative review.

Methods

A narrative review of the literature was managed, using PubMed, SciELO, and LILACS databases to obtained relevant articles describing thyroplasty procedure and their role in treating voice disorders. The search date was in August 2020. The English terms used in the search were “thyroplasty and dysphonia”, “thyroplasty” and “treatment”. The keywords used in the search included “thyroplasty as a treatment”, “thyroplasty” AND “voice disorders”. The scientific articles concerning the evaluation of the different types of thyroplasty procedures in treating dysphonic patients were selected for review and were inspected by the author. Studies were selected if they examined the patients who underwent thyroplasty procedure for treating dysphonia. On the other hand, studies presented non-English literature; studies including patients with other voice disorders treatments such as the injection of laryngoplasty materials, botulinum toxin injection, medical voice-hygiene advice, and all the pathological vocal cord surgical intervention, studies that included non-thyroplasty procedures were all excluded.

Results

The search in SciELO using English key words did not provide any findings on the information of thyroplasty as treatment of dysphonia, while the search in PubMed, LILACS (English language), and other sources capitulated 192, 127, and 9 articles respectively, of which 78 articles were shown to contain information concerning the thyroplasty surgeries and their purposes. Table 1 shows the databases and the number of articles extracted from each database**.**

Table 1. Databases and the number of articles extracted.

Database	Number of articles
PubMed	192
LILACS	127
SciELO	0
Other sources*	9

There are four surgical procedures (thyroplasty types I, II, III, and IV) described by Isshiki et al in 1974. These procedures shortened or elongated the vocal cords and slightly decreased or increased the length or diameter of the interior larynx. Thyroplasty types I, II, III, and IV was proposed to medialization, lateralization, shortening, and lengthening the vocal cord respectively in patients who suffer from voice disorders [1]. Thyroplasty surgery is performed with the patient under local anesthesia so that fine-tuning of the voice is possible by measuring the voice during the surgical intervention [2].

Of the 78 studies, 52 studies on type I thyroplasty procedure: studies on the main surgery steps of type I thyroplasty, type I thyroplasty with Gore-Tex implant, type I thyroplasty with Montgomery (Silastic), type I thyroplasty with TVFMI®implants (Titanium), type I thyroplasty with hydroxyapatite implant (VoCoM system), type I thyroplasty combination, and type I thyroplasty complications. The type I thyroplasty and their subdivision are used in a treatment the patients with dysphonia caused by unilateral vocal cord paralysis, non-paralytic vocal cord insufficient, unilateral vocal cord weakness, and patients with abductor spasmodic dysphonia. 10 studies on type II thyroplasty procedure: studies on the main steps of the type II thyroplasty surgery, the benefits of applying type II thyroplasty, and complications of type II thyroplasty procedure. Type II thyroplasty is used in the treatment of patients with adductor spasmodic dysphonia, or patients with bilateral vocal cord paralysis. 9 studies on type III thyroplasty surgery: studies on type III thyroplasty procedure, and benefits from type III thyroplasty. Type III thyroplasty is used in the treatment of patients with a high pitch voice. 7 studies on type IV thyroplasty: studies on the main steps of type IV thyroplasty surgery, type IV thyroplasty benefits, and complications of the type IV thyroplasty. The type IV thyroplasty is used in the treatment of patients with low voice pitch. Table 2 reveals the most closely connected studies included in this narrative review and briefs their main points.

Table 2. The types of thyroplasty procedures and their purposes.

Procedure	Purpose. Reference
Type I thyroplasty	Medialization of the anterior vocal cord in dysphonic patients with small glottal gape and medialization of the anterior and posterior vocal cord in patients with large glottal gape caused by unilateral vocal cord paralysis or bilateral vocal cord weakness which caused by bilateral vocal cord atrophy or sulcus, and in patients with abductor spasmodic dysphonia.[7-31, 33-54,]
Type II thyroplasty	Lateralization of the vocal cord in patients with adductor spasmodic dysphonia and dysphonic patients with bilateral vocal cord paralysis.[55-64]
Type III thyroplasty	Shortening the vocal cords in patients with high voice pitch.[65-72]
Type IV thyroplasty	Elongating the vocal cords in patients with low voice pitch. Stretching and medialization of the vocal cord in patients with dysphonia caused by unilateral superior laryngeal nerve weakness and unilateral vocal cord paralysis [73-79]

1. Type I thyroplasty procedure

Type I thyroplasty (medialization of the vocal cord) is a surgical procedure used to improve voice for patients suffering from dysphonia caused by unilateral vocal cord paralysis, spasmodic abductor dyphonia, and bilateral vocal cord atrophy. In this procedure, a rectangular window is created in thyroid cartilage and this window is blocked by Silastic implant to bush the vocal cord medially to decrease the glottal gap, and thus can improve the voice. The main steps of operative procedure are that the patient is placed under local anesthesia, a horizontal incision (4-5cm) is made in the skin crease on the side of the neck on the affected side and then exposed the thyroid cartilage, a rectangular window is made lateral to the midpoint of the thyroid cartilage, a suitable size implant is selected and inserted through the window to bush the vocal cord toward the midline under monitoring the suitable voice, and the wounded layers were closed. Mainly the average anterior vocal cord medialization needed was 2.25 mm while the average posterior vocal cord medialization needed was 6.75 mm [7-11].

Type I thyroplasty subdivision and their benefits

This narrative review showed that the type I thyroplasty can subdivide according to implants used in vocal cord medialization as follows:

A. Type I thyroplasty with Gore-Tex implant:

In 2015, Elnashar et al studied type 1 thyroplasty with Gore-Tex implant. The operation was applied to 11 patients suffering from the glottic gap that caused dysphonia. In all postoperative observations, there was a significant improvement in the grade of dysphonia and a highly significant reduction in the size of the glottic gap and prolongation of maximum phonation time [15]. Nouwen et al assessed thyroplasty type I using Gore-Tex implants on 24 patients with unilateral laryngeal nerve paralysis (caused unilateral vocal cord paralysis). Postoperatively, all patients showed improvements in speech and voice [16]. On the other hand, type I thyroplasty with Gore-Tex can be used in improving voice in patients with dysphonia caused by the non-paralytic glottic incompetence which their etiologies included vocal fold hypomobility, paresis, atrophy, and scarring. No significant difference between sexes was noted in perceptual voice measures. All patients with non-paralytic glottic incompetence demonstrated improved their voices except vocal fold scar patients performed worse than all other subgroups across all voice outcome measures [12-14].

B. Type I thyroplasty with Montgomery (Silastic)

Recently, in 2020, Storck et al tested 15 patients with unilateral vocal fold paralysis were underwent type I thyroplasty with a Montgomery implant. The results showed that on the affected side, the implant pushed the paralyzed vocal cord toward the midline and the vocal folds on both sides were the same length in the phonatory position. A significant improvement in voice quality was shown in all patients [17]. Laccourreye et al assessed the type I thyroplasty with Montgomery in 96 patients with a unilateral laryngeal nerve paralysis (causes unilateral vocal cord paralysis). The result showed that this procedure achieved a very well stable phonatory [18]. Michel et al studied the treatment of 63 patients with unilateral vocal fold paralysis by type I thyroplasty with Montgomery implant. The outcome noted an improvement in all patient voice, and the Montgomery implant appears to be an easy, effective, and safe procedure [19]. Nouwen et al evaluated 33 patients with unilateral laryngeal nerve paralysis (caused unilateral vocal cord paralysis) and was managed with thyroplasty type I using Montgomery implants. All patients were reported an improvements in their voice postoperatively [16]. Type I thyroplasty with Silastic implants was applied for external compression of the paralyzed vocal fold in dysphonic patients. A significantly higher vocal fundamental frequency and significantly longer maximum phonation time were

achieved. No perioperative complications were noted. This technique was indicated to correct the large glottal incompetence [20-22].

C. Type I thyroplasty with TVFMI®implants (Titanium)

Maggon et al conducted a study to check the effect of type I thyroplasty with titanium implant and type I thyroplasty with Silastic implant in 26 patients with unilateral vocal fold palsy. 14 patients underwent a Silastic implantation and 12 patients underwent a TVFMI (titanium) implantation. The voice analysis was done preoperatively and postoperatively at 3 months. The mean time taken for Silastic implantation was 83.07 min and titanium implantation was 52.16 min. the result showed that both types of implants achieve good and comparable results. Silastic implant surgery takes a long time but is relatively inexpensive [23]. An observation reported by Malik et al in 40 patients with unilateral vocal cord paralysis, 20 patients underwent type I thyroplasty with Silastic implant and the remaining 20 were treated with titanium. The results have demonstrated that, in cases of unilateral vocal cord palsy, there is a subjective improvement following type I thyroplasty using both Silastic and titanium implants. Video laryngoscopy and stroboscopy demonstrated a reduction in the glottic gap in all cases. A titanium implant presented slightly better results in objective voice analysis. Type I thyroplasty with titanium is faster but more expensive [24]. Twenty-four patients underwent medialization thyroplasty, and performed under local anesthesia with intravenous sedation: 10 patients were included in the silicone cohort and 14 in the titanium cohort. Both silicone and titanium medialization implants showed improvement of the vocal outcome, and the results of the titanium implant being superior [25].

D. Type I thyroplasty with hydroxyapatite (VoCoM system) implant.

Storck et al and Park et al [26, 27] were used the type I thyroplasty with hydroxyapatite implant in patients with unilateral vocal fold paralysis. All patients showed a significant improvement in perceptual voice analysis, maximum phonation time, and the dynamic range of voice, and observed that the using of hydroxyapatite implant is a secure and efficient phonosurgical procedure. Dewan et al [28] was studied type I thyroplasty with hydroxyapatite implant in treating patients suffering from Abductor spasmodic dysphonia. The results have shown that this procedure is a safe and effective treatment for abductor spasmodic dysphonia; however, it's provided phonation improvement in the short and long term. In 1995, Bielamowicz et al examined 49 patients were underwent type I thyroplasty with hydroxyapatite implant. All patients were showed a significant improvement in their voice parameters [29].

E. Type I thyroplasty with tensor fascia lata

Two patients with unilateral vocal fold paralysis were undergone a novel approach for type I thyroplasty with a ribbon of autologous tensor fascia lata harvested at the time of surgery. The result showed that this new approach improved the patient voices outcomes and no complications such as extrusion or wound infection is noted [30].

F. Type I thyroplasty with a silicone implant

Adachi et al evaluated a 66-year-old man who underwent type I thyroplasty with silicone block implantation 2 years after the primary esophageal surgery led to his unilateral vocal paralysis. A significant voice improvement was achieved postoperatively and the migration of the silicone implant was not observed [31]. In 2002, Abraham et al examined type I thyroplasty with silicone implant on 11 patients suffered from unilateral cord paralysis which caused their hoarseness following thoracic surgery. The results showed that voice improvement was noted after the procedure and the authors concluded that type I thyroplasty is well [32]. Type I thyroplasty with silicone implantation was done on 20 patients with vocal fold paralysis. All the voice parameters such as maximum phonation time, voice capacity, and intensity were improved postoperatively as reported by Grøntved et al in 2009 [33]. In 2019, Sebova et al examined type I thyroplasty with silicone implant on 10 adult patients suffered from dysphonia caused by unilateral vocal cord paralysis. The postoperative voice quality was significantly enhanced in comparison with the preoperative state [34]. On the other hand, 6 patients had unilateral vocal fold paresis caused them hoarseness and they underwent type 1 thyroplasty. All patients showed a significant improvement of glottal closure and the voice quality improved both in the perceptual evaluation and acoustic analysis [10].

G. Type I thyroplasty with APrevent Vocal Implant System (VOIS)

8 patients with voice disorder caused by their unilateral vocal cord paralysis undergone type I thyroplasty with APrevent Vocal Implant System (VOIS). The novel APrevent® VOIS showed a significant voice improvement for all patients as described by Ho et al in 2020 [35].

H. Type I thyroplasty using autologous nasal septal cartilage.

Type I thyroplasty with autologous nasal septal cartilage implantation was performed on 15 patients with unilateral vocal fold paralysis. All the patients recorded an improvement of voice quality post-operatively and the laryngostroboscopy investigation showed almost complete glottal closure after the procedure in most patients [36].

I. Type I thyroplasty with ceramic shim

Sakai et al was used type I thyroplasty with a ceramic shim in 10 patients with unilateral recurrent laryngeal nerve paralysis caused them dysphonia. All patients experienced subjective improvement of voice

postoperatively. Laryngoscopies in most cases showed that glottic insufficiency improved and the maximum phonation time improved postoperatively [37].

J. Type I thyroplasty with glass ionomer cement implant

An external vocal fold medialization was performed in 53 patients (22 male, 31 female). The underlying cause for the glottic insufficiency was in most cases unilateral laryngeal palsy in turn caused them hoarseness. Ten patients presented with atrophy and/or scar of the vocal folds. In 7 cases new developed implants made out of glass ionomer cement were used. The results showed that an improvement in their voice was observed, no intraoperative or postoperative complications could be observed, the surgical procedure was very well tolerated by all patients, and the degree of glottic insufficiency was significantly reduced [38].

Bilateral medialization

The use of type I thyroplasty on the right and left affected vocal cords (bilateral medialization) was reported. This procedure was mainly used to treat the dysphonic patients caused by presbylaryngis which led to the vocal cords atrophy or sulcus. Significant improvement was observed in all patients' voice parameters and no complications were noted after bilateral medialization [39-43].

Type I thyroplasty combination

A. Type I thyroplasty with arytenoid adduction or cricothyroid subluxation

Arytenoid adduction or cricothyroid subluxation with stabilization of the arytenoid cartilage may be carried out as subordinate type interference when bad voice modality continues after initial thyroplasty type 1. In 2008, Chrobok et al examined type I thyroplasty combined with arytenoid adduction in 3 cases and cricothyroid subluxation in 3 cases, moreover, these patients are suffered from incomplete closure of the posterior third of the glottis which caused their dysphonia. The result showed that all patients were improved their voice postoperatively [80]. Sasai et al were performed thyroplasty type I followed by arytenoid adduction for 30 patients suffered from unilateral paralytic dysphonia, and the maximum phonation of all patients was improved significantly after surgery [44]. The type I thyroplasty in combination with arytenoid adduction was applied for patients dysphonia which caused by their large posterior glottic gap with unilateral vocal cord paralysis, and their voice quality were raised significantly [45].

B. Type I thyroplasty with Arytenopexy and cricothyrotomy

This procedure was used in patients that presented unilateral vocal fold paralysis (UVFP) with marked posterior glottic gap leading to symptoms of dysphonia. Arytenopexy (adduction arytenoid cartilage) with type I thyroplasty and cricothyrotomy are procedures with a low degree of complication that can be performed under local anesthesia with excellent functional voice results, even in patients with marked posterior glottic gap [46].

C. Type I thyroplasty with a lateral cricoarytenoid muscle pull

A direct pull of the lateral cricoarytenoid muscle (LCA-Pull) and Isshiki's thyroplasty type I are reported. LCA-Pull is very simple and allows the natural adduction of arytenoid by pulling LCA. Sometimes severe unilateral vocal cord paralysis requires both arytenoid adduction and medialization thyroplasty to obtain a good voice. Combinations of LCA-Pull and thyroplasty type1 are very effective for a severe case and could be done in the same operating field by creating an additional window in the thyroid ala. All patients showed significant voice improvement [47].

Type I thyroplasty complications

In several cases, a simple significant complication was recorded after the type I thyroplasty procedure. Kraus et al examined 28 patients underwent type I thyroplasty and complications occurred in 18% and consisted of local wound sepsis (number = 1), hematoma (number = 1), seroma (number = 1), and transient airway edema (number = 2) [48]. Migration of the thyroid cartilage window appears to be a late complication of type 1 thyroplasty when the thyroid cartilage window is left intact and not removed [49]. In 63 patients, a minor complication occurred in 6.5% of the patients and included 4 cases of laryngeal edema successfully treated with oral steroids [19]. A review by Watanabe et al has shown that 2.9% had infection and extrusion into the airway, and inflammation with the granulation formation was seen in 0.5% [50]. A 46-year-old woman suffered from a right-sided unilateral vocal fold palsy that failed to recover. She underwent type 1 thyroplasty with a Gore-Tex implant. After 10 years she presented dysphonia, the investigation revealed granulation tissues and the edge of the implant extruded into the airway. The patients underwent surgery and the implant was removed, and then recovered her voice [51]. Used type I thyroplasty with hydroxyapatite implant in patients with unilateral vocal fold paralysis was examined by Storck et al and Park et al. One case experienced a postoperative wound hemorrhage as a minor complication. No further complications or implant extrusions were observed [26, 27]. A laryngeal complication in 51 patients undergoing type I thyroplasty procedure was studied by Cotter et al. Implant migration presented in 5 patients. 2 patients retained excellent glottal closure despite extrusion. Vocal fold hematoma was identified in 14 patients and resolved within 1 week. Implant movement occurred in three patients 1 week to 6 months after surgery and resulted in poor glottal closure. Female patients may be more prone to complications because of their small laryngeal size [52]. Type I thyroplasty was operated

in 123 dysphonic patients. None of the 123 patients presented early major postoperative complications which included implant dislocation, dyspnoea with the need for tracheostomy, wound infection, and postoperative bleeding. In three patients the implant had to be removed 2-6 months after surgery due to granulation tissue formation. In one patient a subepithelial localization of the implant could be seen without the necessity of removal. Perceptual and acoustic parameters were significantly improved after surgery with long-lasting effect even years after surgery [53]. Fifty-seven patients who undergone type I thyroplasty. All patients were discharged the morning following afternoon surgery (within 24 hours). Complications occurred in four patients. One patient, who was taking warfarin, developed a postoperative hematoma that resolved with conservative treatment. Two patients developed a wound infection three days postoperatively, which resolved with antibiotics. One patient returned with hoarseness five months postoperatively, and the Silastic implant was eroding through the mucosa. This was subsequently removed under general anesthesia. No patients developed complications leading to airway compromise [41].

Type I thyroplasty mistake

In a previous study, during type I thyroplasty, the surgeon had mistakenly created the window on the cricoid cartilage rather than the thyroid cartilage. When he inserted the silicone prosthesis into the cricoid window, the patient developed acute respiratory obstruction. One year later, she presented to hospital and a revision type I thyroplasty was performed. Intraoperative, we left the cricoid window untouched, opened a new window on the thyroid cartilage, and completed the type I thyroplasty and finally the patient recovered his voice [54].

2. Type II thyroplasty

Thyroplasty type II is a procedure that makes a change in the voice box to lateralize the vocal cord in order treats the patients with acute spasm vocal cord (adductor spasmodic dysphonia), or the patients with bilateral vocal cord paralysis [55]. The main surgical tips during type II thyroplasty procedure includes: the patient should be under local anesthesia, a horizontal neck skin incision about 3cm in length is made at a level of lower to the midpoint of the thyroid cartilage to expose the thyroid cartilage, and sectioned the thyroid cartilage at the midline and carefully make the separation. Then, two titanium bridges are fixed when the maximum voice is recorded. Finally, the wounded layers are sutured [56].

Type II thyroplasty benefits

In 2017, Sanuki and Yumoto have studied type II thyroplasty in 47 patients with adductor spasmodic dysphonia. Significantly their voices are improved longer than 3 years postoperatively [57]. In recent, 10 patients with adductor spasmodic dysphonia was examined by Sanuki et al and they were underwent type II thyroplasty. The result showed that the patient's voices were excellently improved after surgery [58]. Tateya et al assessed how type II thyroplasty effecting on patients with spasmodic dysphonia. They reported that improvement of the patients voice qualities was achieved [59]. In 2014, Sanuki et al evaluated type II thyroplasty procedure in 15 patients with adductor spasmodic dysphonia. The result showed that significantly their voice improved long-term (2 years) after surgery [60]. Sanuki and Isshiki were investigated the effectiveness of type II thyroplasty in adductor spasmodic dysphonia patients. The result showed 70% of the patients improved their voice as excellent and the remaining patients as improved to good or fair [61].

In 1998, Maragos studied 3 adult females with bilateral vocal cord paralysis were underwent a type II thyroplasty procedure. The surgical aim was to tighten the paralysis vocal cords to be lateralized. Postoperative evident showed improvement in patients voice [55]. A 14-year-old boy with Autism spectrum disorders (ASD) associated with a sudden involuntary production of sound (phonic tics). He underwent type II thyroplasty after failed treatment his voice with the other specialists. Six months postoperatively, there was a 90% reduction in tic frequency and a 50% reduction in intensity. Additionally, he has shown improved ability to converse with his peers, participate in school activities, and even has improved nutritional status [62].

Type II thyroplasty complications

A minor complication was associated with type II thyroplasty as reported by Mizoguchi et al in 15 patients with adductor spasmodic dysphonia. 14 patients were presented vocal fold erythema and vocal fold edema in 10 patients. All of them showed complete resolution within one month [56]. Chan et al examined 13 patients with the diagnosis of adductor spasmodic dysphonia who were treated with type II thyroplasty. There were 4 early failures caused by friable thyroid cartilage [63]. Six patients underwent type II thyroplasty. The vocal features of adductor spasmodic dysphonia, diverse preoperatively, disappeared postoperatively and a normal, or almost normal, the voice was attained in 5 of 6 cases. The failure in one patient was attributed to combined focal dystonia of the neck muscles and difficulty in lateralization [64].

3. Type III thyroplasty:

Type III thyroplasty is a procedure that makes a change in the laryngeal voice box to shortening the vocal cord to lower the vocal pitch voice in patients with high pitch voices. During type III thyroplasty surgery, all procedures were performed under local anesthesia. A horizontal skin incision is made in the side of the neck and a vertical incision performed to retract the strap muscles. Then, the thyroid cartilage was exposed. A parallel incision to midline was made

on both sides of thyroid ala and 1.5 mm strips of cartilage were incised on either side of the midline of the thyroid cartilage. The voice was assessed after pushing the mid part of the thyroid cartilage. When the voice is lowered in pitch, the free borders of the thyroid cartilage were sutured and the wound was closed in layers [65-67].

Type III thyroplasty benefits

Garcia-Lopez et al examined type III thyroplasty in an adult male with dysphonia caused by the high vocal pitch voice with the object of lowering his vocal pitch voice. After the surgery, a significant low vocal pitch was attained [68]. A 46-year-old individual has a female-to-male/gender identity disorder with a high pitched voice. He has undergone type III thyroplasty surgery. The result showed that the patients were improved their voice and achieved low voice pitch [69]. Previous studies showed that type III thyroplasty is a successful procedure for treating puberphonia patients who complain from high voice pitch. After the operation, all patients improved their voices which changed to low voice pitch [65-67]. Li et al in 1999, applied type III thyroplasty in eleven male patients with mutational voice disorders (Puberphonia). The preoperative high pitched voices of the all the patients have lowered their voice pitches up to the normal level [70]. The cases consisted of three men with mutational dysphonia, who were aged 37, 35, and 38 years who underwent type III thyroplasty when the voice therapy has proven unsuccessful. The results showed that all patients treated and their high voice pitch become low [71]. 8 Tran's men, unsatisfied with their voice after a minimum of 12 months of gender-affirming hormone treatment, underwent type III thyroplasty to lower the vocal pitch. Their vocal pitch was dropped significantly [72].

4. Type IV thyroplasty

Type IV thyroplasty (cricothyroid approximation) is the procedure that elongates the vocal folds to elevate vocal pitch. It is applied to approximate the cricoid cartilage to the thyroid cartilage with sutures. The thyroid cartilage is moved forward and downward and the cricoid cartilage is displaced backward and upward to decrease the cricothyroid muscle action that elongates the vocal folds which responsible for increasing voice pitch. The procedure is carried out under general anesthesia. A 6 cm horizontal incision is made over the cricothyroid membrane. A vertical incision is carried out, extending from the lower border of the cricoid cartilage to the area just above the laryngeal prominence. The strap muscles are separated in the midline, exposing the lower border of the thyroid cartilage and upper and lower borders of the cricoid cartilage. This will require the part of the cricothyroid muscle to be removed. 2 horizontal mattress sutures with the needle at both ends were used to produce the cricothyroid approximation. Each needle is inserted through the middle of the inferior border of cricoid cartilage but must exit the superior border at its anterior edge. The sutures mustn't enter the lumen of the larynx because of the danger of infection of the no absorbable sutures. The mattress sutures are completed by going under the thyroid cartilage and coming out on the surface, below the level of the vocal folds, approximately 5 to 8 mm apart. The sutures are tied with multiple knots while under monitoring voice pitch [73, 74].

Type IV thyroplasty benefits

Bernal et al studied type IV thyroplasty surgery in a 22-year-old female patient with a masculine low pitch. The patient voice pitch was elevated postoperatively [75]. In 2011, Gibbins et al evaluate type IV thyroplasty procedure was in a 58-year-old female after bilateral superior laryngeal nerve damage to elevate her vocal voice pitch. The result showed that a three-year follow-up for bilateral type IV thyroplasty reveals increased pitch [76]. Kanagalingam et al and Borse et al have examined type IV thyroplasty (Cricothyroid approximation) in 21 male-to-female transsexuals for voice pitch elevation. This procedure changes their voice box mechanism and causes a significant rise in voice pitch [73, 74]. Transgender phono surgery was reviewed by Song and Jiang [77], and the result showed that the cricothyroid approximation technique was improved the voice and is the basic procedure to shorting vocal cord to decrease the vocal high pitch.

Type IV thyroplasty a combined with type I thyroplasty.

The main purpose of this combination is stretching of the vocal cord with the medialization of the affected side. This procedure was used to treat the patients with unilateral superior laryngeal nerve weakness and unilateral vocal cord paralysis. A combination type IV and type I thyroplasty procedure was conducted by Nasseri and Maragos in 9 patients with unilateral superior laryngeal nerve weakness. Voice measurements showed postoperative improvement in patient voice pitch. The authors recommended the combination type IV and type I thyroplasty for surgical treatment of patients with superior laryngeal nerve weakness because it addresses cricothyroid muscle weakness without compromising vocal power [78]. In 2017, Vij et al studied the effect of type IV thyroplasty accompanied by type I thyroplasty in a patient with unilateral vocal fold paralysis. The result showed that all patient voice parameters have been improved [79].

Discussion

This narrative review included 78 articles that evaluated thyroplasty procedures roles in the treatment of dysphonic patients, moreover, permitted us to recognize and modernize the most information relating to thyroplasty procedures. According to our knowledge, this review is the first study to evaluate thyroplasty procedures in the management of patients

with dysphonia. This review reveals that there are four different thyroplasty surgical techniques which include type I, II, III, and IV to treat patients with unilateral vocal cord paralysis, spasmodic dysphonia, puberphonia (low vocal pitch), and androphnia (high vocal pitch) respectively [8, 61, 65, 73]. A small significant complication after thyroplasty procedures were observed and can be rapidly treated within 1 week to 1 month, and the main factors in charge of postoperative problems are the incorrect indication and an unsuitable surgical procedure to realize the satisfaction from an overmuch narrow glottal closure. Therefore, the thyroplasty technique can give poor outcome in patients had undergone cordectomy and the unchanged voice disorder can be explained by scarring of the vocal cord [80, 81]. According to our research, this narrative review showed that the type I thyroplasty is the most common procedure and presented more complications in compared with the other types, hence, the explanation of presented complication is due to the different implantation materials used during type I thyroplasty procedure through the window created on the thyroid cartilage to push the vocal cord inward, and this may lead to presented of some mild symptoms after the operation, such as edema, inflammation, granular formation, and implant displacement, fortunately, these complications were perceived and treated quickly and easily. Type II thyroplasty has a less postoperative side effect and this explained by the fact that there is a Titanium Bridge which implanted in thyroid cartilage to lateralization the vocal cord in patients with adductor spasmodic dysphonia, and this implanted material can lead to rare complication appearances, such as edema and friable thyroid cartilage [56, 63]. The current review demonstrated that the complications are almost non-existent after type III and type IV thyroplasty procedures, and this is because it does not use implanted materials like what is used in type I and type II thyroplasty.

This narrative review showed that the type I thyroplasty has different available implantation substances which includes Silastic, Gore-Tex, Titanium, and hydroxyapatite, autologous tensor fascia lata, silicone block, Aprevent Vocal Implant System, autologous nasal septal cartilage, ceramic, and cement, however, these materials can be used to push the paralyzed vocal cord medially to improve the patient's voice, thus, can give a wide range of opportunities in the treatment of the dysphonic patients caused by unilateral vocal cord paralysis, bilateral vocal cord weakness, non-paralytic vocal cords problems, and abductor spasmodic dysphonia. According to the type of the implant used in type I thyroplasty, the different was founded in the cost, outcome, and duration of the procedure; in type I thyroplasty with the titanium implant, it is presented slightly better result in objective voice analysis and faster, but more expensive than Silastic implant [24]. Moreover, type I thyroplasty is used to medialization of the anterior part of the paralyzed vocal cord, and this can minimize the anterior glottal gab only, for this reason, it needs to be accompanied with arytenoid adduction if the patient has a large posterior glottal gap. Although patients with unilateral superior laryngeal nerve weakness and unilateral vocal cord paralysis were treated by type I thyroplasty a companied with type IV thyroplasty [78].

This reviewed study showed a significant permanent improvement in dysphonic patients treated with thyroplasty procedures. Also, it is a safe process and has no major side effects after surgery. Using designed new surgical equipment and material during thyroplasty procedures can minimize and prevent surgical complications [82, 83].

Conclusion

In conclusion, thyroplasty surgeries are a successful modality in the treatment of patients suffering from dysphonia caused by unilateral vocal cord paralysis, bilateral vocal cord weakness or atrophy, spasmodic dysphonia, puberophonia (high vocal pitch), and androphonia (low vocal pitch). Moreover, thyroplasty procedure can treat the patients with dysphonia caused by the non-paralytic glottic incompetence which their etiologies included vocal fold hypomobility, paresis, atrophy, and scarring. All patients with non-paralytic glottic incompetence demonstrated improved their voices after type I thyroplasty except vocal fold scar patients performed worse than all other subgroups across all voice outcome measures. In some cases, small significant complications were recorded after type I and type II thyroplasty surgeries and can be treated quickly and easily. The information presented in this narrative review can be assisting the phoniatricians team in the treatment of patients suffering from voice disorders.

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