Provox® Voice Prostheses

MC1070-ThEN 202204

Contents

Summary

This literature review aims to provide an overview of the published work on the different generations of Provox voice prostheses developed by Atos Medical. Included in this work are the following devices: Provox® voice prosthesis, Provox® 2 voice prosthesis, Provox® Vega™ voice prosthesis with Provox® SmarInserter™, Provox® Activalve® voice prosthesis, Provox® NID voice prosthesis, and Provox® Vega™ XtraSeal™ voice prosthesis.

Literature search was conducted in the Pubmed search engine using "voice prosthesis" and "Provox" as key words covering a period of 1990 – 2022. Search results were screened for relevant publications. Additionally, our own company database with publications on these devices was screened for relevant publications.

The present issue has been updated with new publications between January 2020 – March 2022. The document can be read as a whole or in independent product- or topic specific sections, hence, some articles might be mentioned several times.

1. Introduction

During a total laryngectomy, the entire voice box is removed. The trachea is bent forward and sutured to the anterior neck, ending in a tracheostoma. The remainder of the pharynx is closed to restore the digestive tract, see Figure 1.

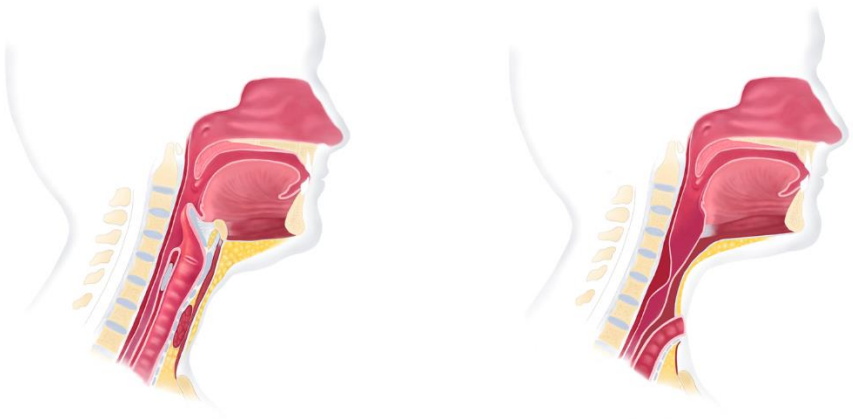
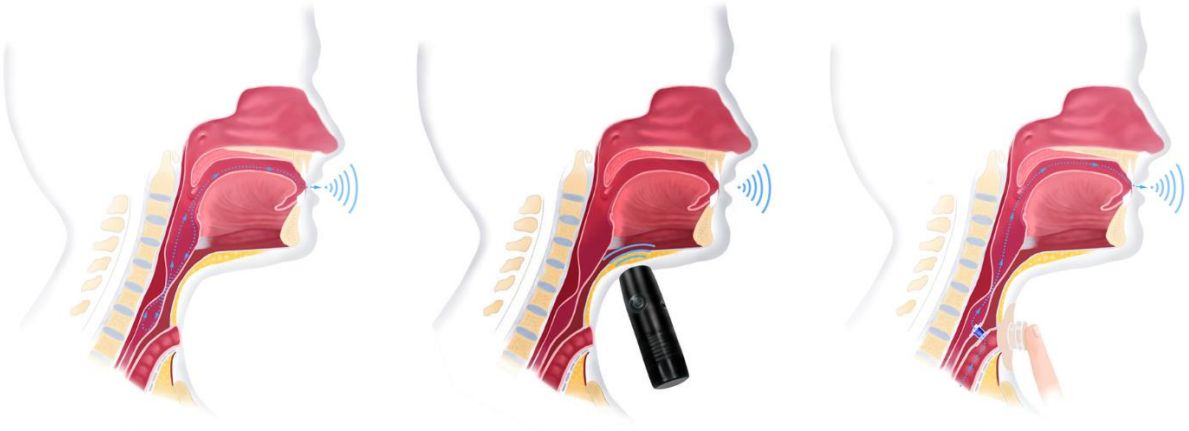


Figure 1 Schematic drawing of normal anatomical situation (left) and anatomical situation after total laryngectomy (right).

Depending on the extent and location of the tumor, a more extensive resection (pharyngolaryngectomy or pharyngolaryngoesophagectomy) and reconstruction may be necessary. The three main methods of voice rehabilitation available to the laryngectomized patient are the use of an electrolarynx (EL), esophageal speech (ES), and tracheoesophageal (TE) speech using a voice prosthesis, see Figure 2.

The three techniques present their advantages and disadvantages. ES is a difficult to learn technique but low cost and does not require additional surgical intervention. EL speech is easy to learn and requires no additional surgical procedures but presents major

disadvantages due to the mechanical sound of the produced voice and cost of equipment. TE speech is the gold standard for voice rehabilitation after Total Laryngectomy and is nowadays the most commonly used method in the developed countries [1]. TE speech is technically easier to learn with a superior vocal quality, but cost of the prosthesis limits its availability for low-income patients and in developing countries [2].



Speaking mode: Hands-free:

Figure 2 Schematic drawings of the three main methods of voice rehabilitation following total laryngectomy: esophageal speech (left), speech using an electrolarynx (middle), and tracheoesophageal speech using a voice prosthesis and heat and moisture exchanger with finger occlusion (right).

In 1973, the very first voice prosthesis for voice rehabilitation after total laryngectomy was described in an article in Polish by Mozolewski [3]. Since then, many efforts have taken place in this area of rehabilitation. In 1980, the first commercially available prosthesis was introduced by Singer and Blom [4]. The first indwelling voice prosthesis (Groningen) was described in 1984 [5].

In 1990, the first Provox® voice prosthesis, manufactured by Atos Medical, was introduced to the market [6, 7], followed by the Provox®2 in 1997[7], the troubleshooting Provox® ActiValve® in 2003 [8], the non-indwelling Provox® NID™ in 2005 [9], the Provox® Vega™ in 2009 [10] with optimized airflow characteristics, and the Provox® Vega™ XtraSeal™ with an extra collar to reduce leakage around the puncture in 2014, see Figure 3 below.

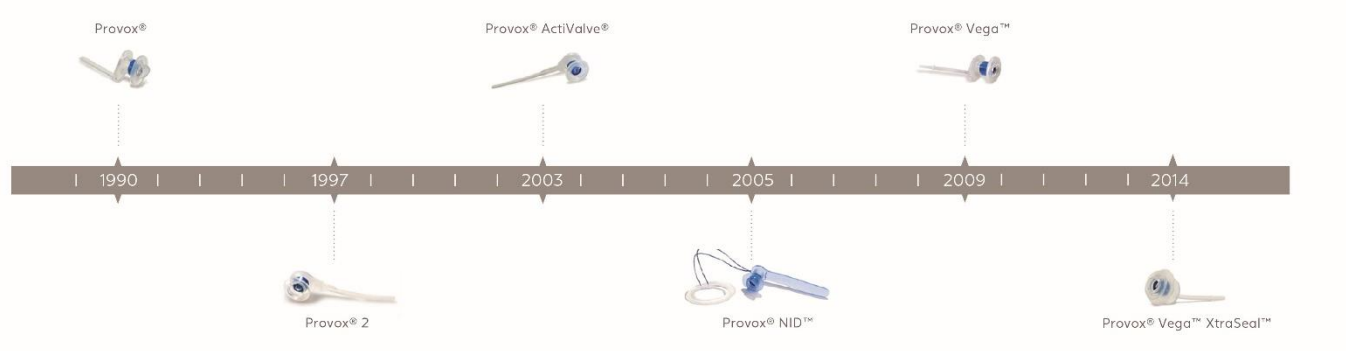


Figure 3 Timeline of the development of the different Provox® voice prostheses

Today, the original Provox® voice prosthesis and the original surgical instruments Trocar and Pharynx Protector are no longer on the market and the most sold Provox® voice prosthesis is the Provox® Vega. The Provox® line of voice prostheses is being used worldwide, see Table 1, which is expressed in many publications in many languages.

This literature review summarizes the published materials about Provox® voice prostheses and focuses on publications that describe their performance and safety characteristics in terms of success rates (ability to communicate effectively), complications, device lifetime, and voice and speech quality.

Although the original Provox® voice prosthesis has been discontinued and the Provox®2 voice prosthesis is currently only used in a small number of patients, the majority of the results from clinical studies with the Provox® and Provox®2 voice prostheses are still considered relevant since the Provox® Vega voice prosthesis is based on the Provox® and Provox®2 voice prostheses. Some studies describe a mixture of Provox® prostheses or different brands of voice prostheses; this is mentioned in the text.

Table 1. Device history of the Provox® Voice prostheses product series (as of 2022)

Device	Year of release to market
Provox®/'Provox®1'*	1990
Provox®2 (incl inserter Provox® Inserter and Loading Tube)	1997 2002 (15mm)
Provox® ActiValve (incl Provox Inserter and loading tube)	2003/2004
Provox® NiD (incl Inserter)	2004
Provox® Vega with SmartInserter	2009/(2011/2013) (SI & SI2)
Provox® Vega with Insertion System	2017/2018
Provox Vega XtraSeal with SmartInserter	2014
Provox® Vega XtraSeal with Insertion System	2017/2018
Provox® Vega Puncture Set	2011
Provox® ActiValve Lubricant	2003
Provox® Dilators	2002 2005 (17&20)
Provox® Flush	2009
Provox® Brush	1991 2002 (XL) 2021 (Provox Brush Short & Long)
Provox® Measures	1997

Provox® Measure Flanges	
Provox® Plug Provox® Vega Plug	1993 2009
Provox® GuideWire	1992
Provox® Trocar and Cannula & Provox® Pharynx Protector*	1993
Provox® XtraFlange	2009
Provox® Capsule	2014
Provox® TwistLock	2018

* Products no longer on the market

1.1 Provox® voice prostheses and clinical evidence

Atos Medical's innovation and voice prosthesis development is backed by strong medical evidence as demonstrated by the amount of clinical and scientific studies conducted on the Provox® voice prostheses over the last 30 years. Between 1990 and 2022, a total of 466 *in vivo/in human* studies on voice prostheses were identified. Of these, 235 publications (50%) mention voice prostheses manufactured by Atos Medical [1, 2]. For list of articles and selection methodology, see Appendix 2.

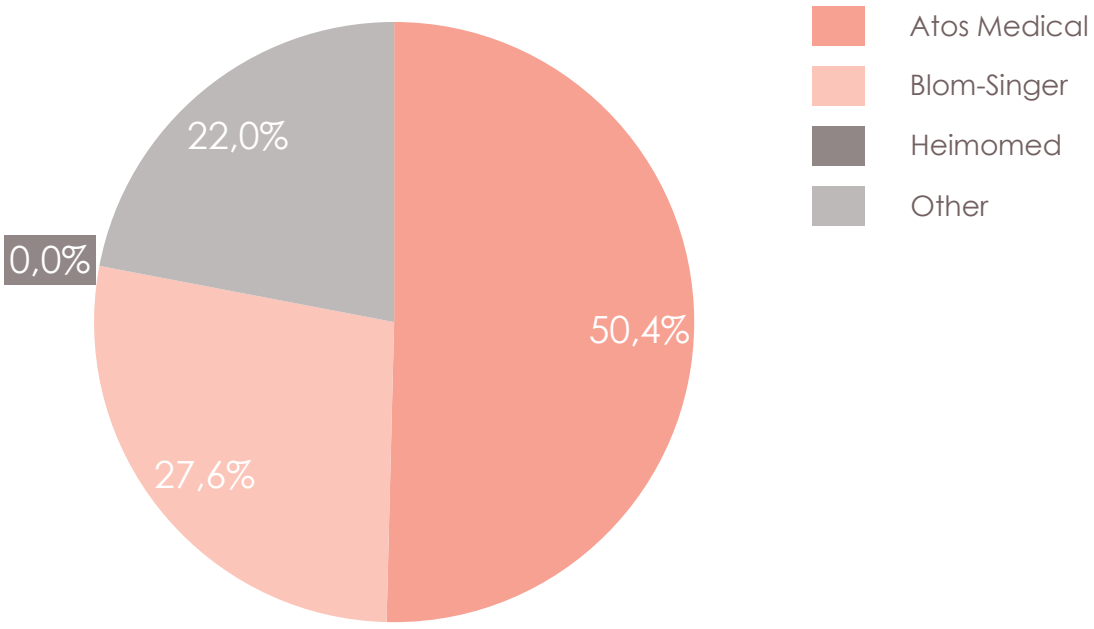


Figure 4. Clinical Evidence on Voice Prosthesis use in laryngectomized patients per manufacturer, based on 466 *in vivo* studies published between 1990 and 2022. Out of 466 publications, 233 (51%) mention voice prostheses manufactured by Atos Medical, 127 (27%) Blom Singer, 0 (0%) Heimomed, and 104 (22%) have no specific mention of voice prosthesis manufacturer.

2. Standard Voice Prostheses

The standard Provox voice prostheses portfolio consists of indwelling (Provox® Vega™ and Provox® 2) and non-indwelling (Provox NiD) devices. It also includes a surgical set for the creation of a tracheoesophageal (TE) puncture with integrated insertion of a Provox® Vega™ voice prosthesis (Provox Vega Puncture Set).

Since the original Provox® voice prosthesis is no longer on the market, device-specific clinical data such as device life and complication rates are provided in Appendix 1.

2.1 The Provox® Vega™ Puncture Set

The Provox® Vega™ Puncture Set (PVPS), based on the Seldinger technique, is a disposable, sterile set of instruments for primary and secondary tracheoesophageal puncture (TEP) and immediate voice prosthesis insertion. The set consists of a curved Puncture Needle to create the TEP, and a GuideWire and a Dilator with a pre-mounted Provox® Vega™ voice prosthesis for the dilation of the TEP and the actual introduction of the Provox® Vega™ voice prosthesis. The set also contains a Pharynx Protector, only to be used for primary TEP during TLE. For secondary punctures traditional methods of pharynx protections, such as a rigid esophagoscope should be used.

After establishing adequate pharynx protection, the Puncture Needle is used to create the TE puncture, then the GuideWire is fed through the puncture needle, the Puncture Needle and Pharynx Protector are removed, leaving the GuideWire *in situ*. Then the Dilator is attached the GuideWire and use for dilatation of the TE puncture followed by placement of the Provox® Vega™ voice prosthesis. The PVPS is available with 17Fr, 20 Fr, and 22.5 Fr Provox® Vega™ voice prostheses.

Figure 5 The Provox® Vega™ Puncture Set (PVPS).

Hilgers et al. [10] describe the results of a multicenter prospective clinical feasibility study investigating the PVPS that was performed in 4 countries and 5 institutions. The publication describes the various investigations conducted during the development of the PVPS, including the results obtained with the final design of the device in 27 patients (20 primary punctures and 7 secondary punctures). All procedures were successful, in 89% (24/27) of the procedures no additional instruments were needed to place the voice prosthesis, in the remaining 3 procedures hemostats were needed to pull the tracheal flange of the voice prosthesis in place. Participating surgeons rated appreciation, ease of use, time consumption and estimated surgical risks using the PVPS as better compared to the use of the legacy Provox surgical tools used.

The PVPS was also evaluated by Lorenz et al. in 21 patients [11]. The average surgical time was 83.5 sec for primary voice prosthesis insertion and 212.57 sec in secondary procedures. The prosthesis could be inserted without complication in 19 patients, while a longer prosthesis needed to be selected intra-operatively in two patients due to a thick membranous wall. No serious complications were observed. Authors conclude that the PVPS proved itself to be a safe aid in the insertion of voice prostheses, that it is significantly easier to use than other systems and tissue trauma is minimal.

In a retrospective chart review by Fukushima et al. 2017 [12] secondary indwelling voice prosthesis insertion (Provox2 and Provox Vega) after total pharyngolaryngectomy (TPL) with free jejunal reconstruction were analyzed. Satisfying communication outcome with Provox insertion was reported for 78.4% of patients (102/130). Communication outcomes were similar regardless of the insertion site (46 patients with jejunal insertion, 84 with esophageal insertion). Complications rate for Provox devices were significantly lower than seen in previous studies. When the Provox Vega Puncture Set was used, the complication rate was as low as zero.

Robinson et al. 2017 [13] conducted a prospective study, comparing intraoperative voice prosthesis placement with delayed voice prosthesis insertion. The device life of the initial intraoperative placed voice prosthesis was 159.7 days, compared to 24.5 days for delayed insertion. Intraoperative placement with Provox Vega was further associated with earlier voicing (13.2 vs 17.6 days), less changes due to resizing (8% vs 80%), reduced hospital stays (17.2 vs 24.5 days) and cost savings. The authors conclude superior clinical and patient benefits to be associated with intraoperative voice prosthesis placement with Provox Vega Puncture Set.

Ricci et al. 2018 [14] used the Provox Vega Puncture Set for retrograde placement of voice prosthesis during secondary TEP in 15 patients. All prostheses were successfully and immediately placed. Good voice restoration and understandable voice was maintained for all patients after 2 months. The authors concluded that secondary TEP is safe and effective with Provox Vega Puncture Set.

2.2 The Provox® Vega™ voice prosthesis

The Provox® Vega™ voice prosthesis is the third generation Provox® voice prosthesis and was introduced in 2009. The Provox® Vega™ voice prosthesis has similar characteristics and features as the Provox®2 voice prosthesis. The housing and valve flap are molded in silicone rubber and the valve seat is made of fluoroplastic. Unlike the Provox®2 they are not molded in one piece. The valve flap is molded separately and placed inside the fluoroplastic, candida-resistant valve seat. The valve seat is angled and lowered into the shaft. The inner lumen of the Provox® Vega™ voice prostheses is larger, while the outer diameter has remained the same. The Provox® Vega™ voice prostheses are designed to have good airflow characteristics. The flanges are slightly thinner and larger. The tracheal flange is oval, designed to better fit the tracheal anatomy. The safety strap is attached as in Provox® to eliminate interaction with the tracheal mucosa. Unlike Provox®2 the clinician does not need to fold the esophageal flange. The flange is folded automatically when the prosthesis is preloaded. The Provox® Vega™ is available in 3 different outer diameters, matching those of the Provox®2 (22.5 Fr) and Provox® NID™ (17 Fr and 20 Fr). Initial placement during surgery is the same as for Provox®, using the Provox Vega Puncture Set, for more information on the puncture set, see Figure 6.

The Provox® Vega™ voice prosthesis comes pre-loaded inside the Provox® Insertion System, see Figure 5. It also comes with a Provox® Brush for cleaning.

Figure 6 Pictures of the Provox® Vega™ voice prosthesis with the Provox® Insertion System.

Device Life, Success Rates, and Complications

The first results of this prosthesis were published by Hilgers et al. [15] in a prospective, short term (2/3 weeks), Phase I feasibility study. No complications were noted during observation time and the prosthesis was noted to have good feasibility. Speech was noted to be better and speaking effort lower with larger diameter prostheses. Subsequently, Hilgers et al. [16] completed a phase II study in two cohorts (one for Provox® Vega™ 20 Fr and one for Provox® Vega™ 22.5 Fr). Each included data for 25 prosthesis changes. The mean was not available for the Provox® Vega™ 22.5 Fr since some devices were still *in situ*. Results indicated that the device life of Provox® Vega™ is

comparable to Provox®2. The median device life for Provox® Vega™ 22.5 Fr was 74 days and the median device life was 93 days for Provox® Vega™ 20 Fr (mean 111 days).

Hancock et al. [17] and Ward et al. [18] conducted a prospective randomized cross-over trial in 31 patients comparing two indwelling voice prostheses; the Provox® Vega™ and the Blom-Singer Classic Indwelling. Hancock et al. [17] reported on patient preference and clinical aspects. Results showed that the majority of patients preferred Provox® Vega™ over the comparator device (Blom-Singer Classic Indwelling). Patients reported better overall voice and speech with the Provox® Vega™ (72 % Provox® Vega™, 14 % Blom-Singer) particularly for better clarity of speech, fluency, volume, and less speaking effort. In addition, patients reported a preference for Provox® Vega™ for cleaning and maintenance. Ward et al. [18] reported on the perception of voice quality from both clinicians and patient. Results showed that both patients and clinicians perceived voice to be better with Provox® Vega™ over the comparator device (Blom-Singer Classic Indwelling). Perceptual judgments by clinicians rated the Provox® Vega™ speech to be less strained, easier to understand, less effortful and the better speech overall.

Lorenz & Maier [19] conducted a prospective study in which 19 Provox® voice prosthesis users were fitted with a Provox® Vega™. Patients completed structured questionnaires on subjective evaluation of voice quality, phonation times and dynamic ranges. Patients were asked their opinion about the replacement procedure. Clinicians were asked to evaluate the ease of use of the new insertion device. Patients reported Provox® Vega™ to be superior compared to their previous Provox®2 in terms of voice quality, loudness and pitch modulation. Mean maximum phonation time improved from 11.3 (SD±9.3) to 15.3 (SD±9.7) and dynamic loudness range increased by 4.7dB. Device life of the new Provox® Vega™ prosthesis was 87.8 days (SD±45.8; median 88), which was lower than the device lifetimes of the two previous Provox®2 voice prostheses (141.1 days (SD±91.2; median 140, and 135.9 days (SD±70.1; median 110) respectively. However, the authors indicate that these figures might be biased by the patient selection (i.e. patients that came in for a replacement during the study period might overrepresented patients with short device lives) and duration of the study (i.e. the 9 month study period was too short for observation of longer device life times).

In a poster presentation, Schäfer et al. [20] compared the device life of Provox® Vega™ to Provox®2 in 40 patients and found no statistical differences between device life time of these two types voice prostheses in these patients. Authors concluded that the Provox® Vega™ is a safe and reliable voice prosthesis and for these parameters equivalent to the Provox®2.

In a follow-up study, Hancock et al. monitored 23 patients for device life and reasons for replacement of the Provox® Vega™. Initial device life data revealed 67 % had functioning devices at 3 months, 52 % at 6 months and 29 % at 12 months. Average device life was 207 days (median of 222) [21].

In a prospective, non-randomized study, Kress et al. 2014 [22] compared device life of more recent indwelling voice prostheses Provox® Vega™ and Blom-Singer Dual Valve to device life of well-known standard devices (Provox® 2, Blom-Singer Classic). Average overall lifetime was 108 days, median 74 days. The prosthesis with the longest dwell time was the Provox® ActiValve® (median 291 days). Provox® Vega™ had longer device life compared with Provox®2 (median 92 days vs 66 days; p = 0.006) and compared with Blom-Singer Classic (median 92 days vs 69 days; p = 0.004). There was no significant

difference between the device life of Blom-Singer Classic versus Provox®2 (p = 0.604), Blom Singer Dual Valve versus Provox®2 (p = 0.233) and versus Provox® Vega™. The authors concluded that device lifetimes of Provox® Vega™ and Provox® ActiValve® were better than those of Provox®2 and the Blom-Singer Classic. New voice prostheses, with a defined valve opening pressure (Provox® Vega™, Provox® ActiValve®, Blom-Singer Dual Valve) had longer lifetimes than prostheses without a defined opening pressure (Blom-Singer Classic and Provox®2).

Thylur et al. 2016 [23] conducted a retrospective study of 21 patients with 181 device replacements, comparing the device life of Provox®2 and Provox® Vega™. The mean device life for Provox®2 was 115.6 days (median 110 days), and 65.1 days (median 80 days) for Provox® Vega™.

In a multicenter prospective crossover study by Serra et al. (2017) [24], Provox 2 and Provox® Vega™ were evaluated in terms of device life and voice outcome. Enrolled patients were categorized and divided into four groups based on age, postoperative radiation therapy and gastroesophageal reflux disease. In three out of four patient groups ("normal", "radio-treated" and "elderly"), average recorded prosthetic lifetime was significant improved for Provox® Vega™ over Provox 2. Overall, average lifetime was 146 days for Provox2 and 182 days for Provox® Vega™(P=0.046). The perceptual voice data showed a better rating across all parameters for the Provox® Vega™ samples. The authors concluded Provox® Vega™ having a longer device life and better perceptual voice parameters compared to Provox 2.

In a retrospective observational study by Lewin et al. 2017 [25], the device life of voice prostheses was reexamined. In total 3648 voice prosthesis (VP) were placed in 390 patients between July 2003 and December 2013. In 69.4% the voice prosthesis was replaced because of leakage through. Median (range) device life was 61 (1-816) days for all prosthesis. Indwelling VPs had significantly longer device life than non-indwelling (70 days vs 38 days). The VP with the longest life was the Provox® ActiValve® with a median of 161 days whereas the Provox® Vega had a median device life of 45 (3-138) days. Neither radiation therapy nor extent of surgery had a meaningful impact on device life.

Mayo-Yáñez et al. [26] found non-significant differences in terms of device life between Provox® Vega and Provox®2 in their case-crossover study published in 2018. The study involved data from 34 laryngectomized patients that was retrospectively analyzed. The patient selection criteria was to have a minimum of three replacements with each type of prosthesis. Both prostheses had a median device lifetime of 74 days. The authors concluded that randomized prospective studies with adequate sample sizes are needed to offer more robust and reliable results.

In a retrospective cohort study by Petersen et al. 2019 [27], long-term results of device life of Provox® VPs were published. Data from medical records over a period of 13 years (Jan 2000 – Dec 2012) was collected for a total of 232 patients. The overall median device lifetime of the standard VPs used in the study period (i.e. the regular Provox®2 (n=1664), and Vega (n=1136) prostheses) were not significantly different: Provox®2(median 63 days, 95% CI 61-68), and Vega (median 66 days, 95% CI 63-71).

In a prospective case-crossover study, Mayo-Yañez et al. 2020 [28] compared Provox® Vega™ and Provox® Vega™ XtraSeal device lives. The study included 20 laryngectomized patients (85% male and 15% female) with periprosthetic leakage who had a Provox® Vega™ XtraSeal placed. A total of 230 prostheses were evaluated, 206

(88.4%) Provox® Vega™ and 24 (10.3%) Provox® Vega™ XtraSeal, with a total of 218 replacements. Each patient had a mean of 15.15 ± 9.06 prosthesis changes. For both models, the most frequent reason for replacement was endoprosthetic leakage (n=146, 63%). No difference in reason for VP replacement was found between either the type of prosthesis (p = 0.181) or adjuvant treatment with radiotherapy (p = 0.144). The mean lifetime of Provox® Vega™ was 104 ± 7 days, with a median of 67 days, and 177 ± 26 days, with a median of 175 days for the Provox® XtraSeal (p = 0.012). Complementary treatment with radiotherapy demonstrated a lower device survival in the non-treated group (p=0.007), with a median device lifetime of 63 days versus 84 days for treated patients.

In a study on factors affecting device life, data from 328 Provox® Vega™ users were retrospectively collected and analyzed. The median device life of prostheses in patients above 65 years old was 182 days, versus 146 days for patients younger than 65 years. Neck irradiation was associated with a longer device life of 161 days compared to 126 days for patients with no prior neck irradiation. The use of HMEs was also associated with a significantly increased device life.

2.3 The Provox®2 voice prosthesis

The Provox®2 voice prosthesis is the successor of the Provox® prosthesis, with the main difference being the method of prosthesis placement. While the original Provox® was placed in a retrograde manner through the oral cavity, the Provox®2 prosthesis is replaced in anterograde manner through the tracheostoma. To enable anterograde placement, the flanges of the Provox®2 are more flexible than those of the original Provox® prosthesis. After the introduction of the Provox® Vega™ voice prosthesis, the Provox®2 voice prosthesis has successively been discontinued in most countries and is seldomly used. The outer diameter is 22.5 French, and the prosthesis is available in the lengths 4.5, 6, 8, 10, 12.5, and 15 mm, see Figure 7.

Figure 7 Picture of the Provox®2 voice prosthesis.

Device Life, Success Rates, and Complications

In 1997 the Provox®2 voice prosthesis was introduced to the market and the first clinical results in 44 patients were described by Hilgers et al. [7]. The anterograde replacement was seen as a large benefit by the patients, 91% did not find the replacement uncomfortable at all, and 9% found it slightly uncomfortable. This was a large improvement, since 30% of the patients found retrograde replacement "quite

uncomfortable, while 30% found it "slightly uncomfortable, and only 40% found it "not uncomfortable". 18% of the patients admitted that they delayed replacement of a leaking prosthesis because they found the replacement uncomfortable, on average about 3 weeks. The pull-out force was on average 7.9 N.

Koscielny and Bräuer [29] compared the replacement systems of Provox® and Provox®2 in 45 laryngectomized patients. A total of 177 changing procedures were carried out, 69 with the retrograde Provox® system and 108 with the anterograde Provox®2 system. The Provox® could be changed without problems in 68% of the cases and the Provox®2 in 94% of the cases. On average the device lifetime of the prostheses was 6 months and there was no difference in durability between Provox® and Provox®2. Patient interviews revealed that most patients preferred the Provox®2 changing procedure.

Graville et al. who described results of both the Provox®2 prosthesis and the Blom-Singer Indwelling found that leakage through the device secondary to yeast colonization occurred with equal frequency in the Blom-Singer and Provox®2 prosthesis [30].

In a prospective multi-institutional assessment of the Provox®2 voice prosthesis in four institutions, 239 consecutive laryngectomized patients received a Provox®2 voice prosthesis [31]. Results of this study showed that anterograde insertion was always successful, 97.1% of physicians preferred the anterograde method and 93.7% of patients did. The device lifetime of the Provox®2 voice prosthesis was shorter than Provox® (median of 104 days versus 125.5 days, respectively), but this difference was not statistically significant. The authors explain that this difference is most likely due to a patient-delay: the average reported patient-delay to have a leaking Provox® prosthesis replaced was 18.9 days on average.

In a large retrospective study (Nov 1988-May 1999, 318 patients, 2700 prosthesis replacements) of both the Provox® and Provox®2 voice prosthesis, 95% of patients were successful long-term users of whom 88% had a fair to excellent voice quality [32]. This study showed also that the device life of the Provox®2 prosthesis was shorter than that of the Provox® (median 120 versus 92 days). The first prosthesis, placed at the time of surgery lasted significantly longer than subsequent prostheses. Significant clinical factors for increased device lifetime were no radiotherapy and age over 70 years. Most prostheses were replaced for leakage through the device (73%). Complications were leakage around the prosthesis (13% of replacements; in 10% solved by downsizing and in 3% requiring further treatments such as temporary shrinkage of fistula), and hypertrophy/infection of the puncture (7% of replacements).

Balle et al. [33] report on 10 years of experience with voice prostheses in a total of 88 patients. During the first two years non-indwelling Blom-Singer Duckbill prostheses were used and in the later years Provox® and Provox®2 (the authors report they preferred the Provox® prosthesis due to its low opening pressure, and its hygienic handling, and because it is well tolerated by the patient and the device life is fairly long). The average device life for Provox® was 3.1 months and the average device life for Provox®2 2.3 months. The authors suspect that the shorter device life of Provox®2 in their study may be related to uncareful insertion. Their complications were granulation tissue (in 14 patients) and infection (in 5 patients).

Lequeux et al. [34] also found the device life of Provox® (N=24) to be longer than that of Provox®2 (N=128) (median 303 days versus median 144 days).

Ahmad et al. [35] report results of a retrospective study of 100 patients over a 10-year period (1989-1999). They started with non-indwelling Blom-Singer valves and converted them to Provox® when it became available. Most patients were converted at their own request due to improved voice quality and easier maintenance. When Provox®2 became available, patients were converted to Provox®2 because of a marked patient preference for the ease and convenience during valve change. Eighty-two percent of the patients achieved average to good speech.

A German retrospective study in 58 laryngectomized patients treated over a 6-year period (1993 -1999) analyzed the device life of a total of 378 prostheses (136 Provox®, 78 Provox®2, 172 Blom-Singer) [36]. The average device life was 244 days for Provox®, 96 days for Provox®2, and 107 days for Blom-Singer. The device life of the Provox® was significantly longer than that of the other ones, but the authors state that as they are more difficult to handle, they are not considered for routine use. The device lives for Provox®2 and Blom-Singer were not significantly different.

Hotz et al. [37] describe the results of a retrospective study over a 6-year period (1992-1998) in 82 patients. Both Provox® (initially) and Provox®2 were used. They separate the postoperative follow up in 3 phases; I) 0-9 months, II) 10-30 months, and III) 31- 72 months and determine success based on the HRS scale (quality, use, and care; 12-15 points is considered a success). In phase I device life was longer in the successful users (4.2 months versus 3.9 months) and in Phase II it was the opposite: the unsuccessful users experienced longer device lives. Complications were scarce; aspiration (N=1), ingestion (N=2), aspiration pneumonia due to periprosthetic leakage (N=3), peristomal infection (N=4), granulation (N=2). Periprosthetic leakage was seen more often in the old Provox® prosthesis. In 14 patients the fistula closed spontaneously, 6 of those patients did not use their prosthesis.

Fajdiga et al. [38] report on two different speaker groups; esophageal speakers (n=35) and tracheoesophageal speakers (32) who attended speech therapy between 1998 and 2002. The tracheoesophageal speakers used Provox® and Provox®2 voice prostheses and had initially also used another type of prosthesis (not reported which one). Results for all prostheses are pooled (including the initially used unknown type of prosthesis). Average device lifetime was 5.5 months. Complications were inflammation (12 events in 5 patients), leakage around requiring replacement of prosthesis (19 events in 7 patients), leakage through prosthesis (valve failure) requiring replacement of prosthesis (32 events in 14 patients), leakage through prosthesis (yeast colonization, increased resistance) (160 events in 32 patients), and prosthesis aspiration (4 events in 4 patients).

Trussart et al. [39] retrospectively studied long-term follow-up results (3 to 16 yrs) in 35 patients using 178 prostheses. The average lifespan was 165.5 for the Provox® (N=93), 143.5 for Blom-Singer (N=73), 135 for Groningen (N=5), and 195 days for VoiceMaster (N=7). Complications were pooled for all prostheses and consisted of 12 cases of periprosthetic leakage (6.74%) treated with collagen injection (11) and silastic at tracheal end of prosthesis (1), 31 granulomas (17.4%) treated with CO2laser evaporation (25) or silver nitrate cauterization (8), 3 partial stenoses of the puncture tract (1.6%) treated with CO2 laser under general anesthesia, and one temporarily removed prosthesis (0.5%).

Makitie et al. [40] report on a retrospective review of the records of 95 laryngectomies performed over a 10-year period. They performed voice rehabilitation using a Provox® or a Provox®2 voice prosthesis. The average device life was 10 months. The complication

rate was low; the authors stress the importance of a multidisciplinary approach. Complications were (% of the total number of replacements): leakage through the prosthesis 51.8%, obstruction of the prosthesis 14.2%, inadequate size of prosthesis 12.4%, granulation tissue in fistula 9.2%, leakage around prosthesis 7.3%, puncture too high or low 4.1%, extrusion of prosthesis 0.5%, stricture of tracheostoma 0.5%. 78% of the patients had average to good voice quality.

Device lifetime often differs from country to country. This is thought to be caused by dietary differences, while also economical/healthcare reimbursement difference may play a role. A study in Turkey, including 50 patients using 62 voice prostheses, found an average device lifetime of 24 months [41]. Morshed et al. [42] (article in Polish) present the results of 2 years of using the Provox®2 voice prosthesis in 21 patients. In 7 patients the device was replaced, and device related lifetime was 216 days on average. In non-radiated patients the average was 215 days and in radiated patients it was 150 days.

Lam et al. [43] report on 60 patients operated upon between 1998 and 2004. A total of 203 prostheses were used (192 Provox®, 7 Blom-Singer Indwelling, 3 Blom-Singer Duckbill, 1 VoiceMaster). The median device lifetime for the indwelling prostheses was 8.2 months. Device life was longer in patients under the age of 60 (9.2 months) than in those over 60 (6.5 months). The prostheses were placed at the time of surgery. The device life of the first voice prosthesis was longer than that of the subsequent ones (9.6 months). Complications were pooled for all types of prostheses used and were: persistent tracheoesophageal fistula leakage in 3 patients, frequent valve changes in one patient, extrusion of prosthesis leading to spontaneous fistula closure in 2 patients, and parastomal tumor recurrence leading to prosthesis removal in 2 patients.

Calder et al. [44] retrospectively studied complication rate, hospital admissions and need for further surgery in patients fitted with voice prostheses (Provox®, Provox®2, Blom-Singer) in 99 patients undergoing a total laryngectomy over a 10-year period (1993-2002). The overall complication rate was 45%, granulation tissue formation around the prosthesis was the most common complication (20%). This was treated with silver nitrate cautery or temporary removal of the prosthesis and insertion of a small diameter catheter. However, the authors state that the data for their study were incomplete, date of valve change, type of valve use and reasons for change were often not recorded.

Elving et al. [45] investigated the influence of radiotherapy on device life of Provox®2 and Groningen Low Resistance voice prostheses. All patients primarily received a Groningen LR voice prosthesis and subsequent prostheses were either Provox®2 or Groningen (and a small number of Provox® that was left out of further analyses). The average device lifetime of the first Groningen prosthesis used immediately after surgery was 180 days and of subsequent ones the average was 137 days. The average device lifetime of Provox®2 was 90 days. The difference in device lifetime between Provox®2 and Groningen was not significantly different. The study identified an association between radiation on the primary tumor site with a dose equal to or more than 60Gy and limited lifetime of voice prostheses.

Ozkul et al. [46] report on intelligibility and device lifetime of voice prosthesis (204 Provox®2, 17 Blom-Singer, 5 Groningen, 5 Turvox) over a 10 year period. Intelligibility was investigated using mono- and double-syllable words. Intelligibility with the Provox®2 prosthesis was 72% for mono-syllabic words and 92% for double-syllabic words, percentages for Blom-Singer were 53% and 77%, for Groningen 52% and 75%, and for Turvox 67% and 87%. Average device life was 18 months for Provox and 5 months for the

others. All patients were on a daily intake regime of Turkish yoghurt and kephir which the authors believe to contribute to their low incidence of fungal colonization. Complications are reported to be limited to granulations, aspiration/extrusion, and overgrowth of esophageal mucosa, but no exact figures are given.

Bilewicz et al. [47] report on 39 tracheoesophageal speakers using a Provox®2 voice prosthesis found that 90% of the patients were able to learn tracheoesophageal speech. The mean device lifetime was 295 days. The most common cause for replacement was leakage associated with mycosis infection (Candida) in 26 cases. Complications were infection of the fistula during radiotherapy (n=7) and widening of the fistula (n=4).

Boscolo-Rizzo et al. [48] retrospectively reported on the results of voice restoration in 75 patients with primary TEP and 18 with secondary TEP. Patients were rehabilitated with indwelling Blom-Singer prostheses until September 2001 and then with Provox®2 prostheses. Overall success rate according to the HRS scale was 81.7%. There was no significant difference in success rate between primary and secondary puncture and there was no difference in surgical complications between primary and secondary puncture.

Ramalingam et al. [49] prospectively compared the Provox®2 voice prosthesis with the Blom-Singer low pressure voice prosthesis for voice, complications and device life. Twenty patients received the Blom-Singer prosthesis and 21 received the Provox®2. Speech quality assessment revealed a better quality of voice production in the Provox®2 voice prosthesis. Patient compliance in valve maintenance was better with Provox®2. Prosthesis related problems like granuloma formation, leakage, candida growth over the valves and prosthetic decay were significantly less in the patients fitted with a Provox® valve. Dislodgement of the prosthesis with closure of the tract, persistent fistula formation, and creation of false passage while reinserting the prosthesis were problems that were encountered with the Blom-Singer prosthesis only. The average device life of the Blom-Singer low pressure prosthesis was 3 months and that of the Provox®2 was 15 months.

Boscolo-Rizzo et al. [50] found that device lifetime of the prosthesis is significantly influenced by radiotherapy and gastroesophageal reflux disease (GERD). The mean *in situ* device life was 163.3 days in irradiated and 202.9 days in radiated patients. The mean *in situ* device life was 126.5 days in patients with and 215.7 days in patients without endoscopic evidence of erosive ulcerative GERD.

Tammam and Ahmed [51] noted in a retrospective study of 5 patients that device life ranged from 5 to 60 months with an average of 24.5 months.

In a retrospective study by Bozec et al. [52] of 87 patients, successful voice rehabilitation was obtained in 82% of the cases. The mean device lifetimes were 7.6 and 3.7 months for Provox® and Provox®2 speech valves, respectively.

Mastronikolis reported an 80% success rate in 12 Provox®2 users in Greece [53].

Wierzchowska & Burduk [54] published in 2011 on the early and late complications after insertion of the Provox®2 in 76 patients. Late complications were more frequent, with leakage through and leakage around the prosthesis being the most common complications. Authors conclude that this can often be solved by changing the prosthesis, which should be taken into account by medical insurance companies.

Issing et al. [55], retrospectively comparing the Provox® with the Eska-Herrmann prosthesis with respect to leakage around (103 patients treated between 1989 and 1998) state that most of their patients experienced salivary leakage at some point in time that was solved by removal of the prosthesis to let the puncture shrink (Eska-Herrmann) or by exchanging the prosthesis Provox®2. The author's further state that their data may be incomplete and (despite the fact that they find no significant difference) they presume that the incidence of leakage around is higher in Provox®2 prostheses. They report the device life of Provox to be 4 to 6 months. No device life data for the Eska-Herrmann prosthesis are provided.

In an Albanian study, Boci et al. [56] analyzed in 2012 the device lifetime of the Provox®2 and found a median lifetime of 279 days (range: 184-995).

Zimmer-Nowicka & Morawiec-Sztandera analyzed 184 replacements of the Provox®2 in 42 Polish patients. Mean time between replacements was 260 ± 150 days. Most frequent indications for replacement were leakage of fluids through the prosthesis, phonation problems caused by mucosal overgrowth around the prosthesis, inaccurate sizing, deformation, and spontaneous extrusion. The device life of voice prostheses correlated positively with patients' age [57].

In a Turkish study, Kılıç et al. 2014 [58] evaluated replacements of the Provox®2 in 210 patients (180 males, 30 females). The mean device lifetime was 7.5 months (range 1 to 48 months). Fungal colonization was detected in 141 patients (66%), granulation tissue developed in 30 patients (14%), 3 patients (1%) swallowed their voice prosthesis, enlarged tracheoesophageal fistula was noted in 2 patients and mediastinitis occurred in one patient (1%). Messing et al. 2015 [59] in a US study, found median lifetime of the Provox®2 across 15 patients was 92 days.

In a retrospective study in 41 Provox®2 patients who were rehabilitated between 1997 and 2015, Friedlander et al. 2016 [60] compared the practical management of leakage around the voice prosthesis. Three techniques were presented: peri-prosthetic silicon collar placement, injection of hyaluronic acid into the tracheoesophageal wall and the combination of the two techniques. In addition, a method to reduce the diameter of the tracheoesophageal fistula by removing the voice prosthesis and placing a nasogastric tube through the fistula was also shown. Peri-prosthetic leakage occurred in 6 of the 41 included patients. They were treated with silicone collar, hyaluronic acid injection or combination of both techniques. An increased device life of 56 days (range 7-118 days), 32 days (range 3-55 days) and 63 days (range 28-136 days), respectively for the different techniques was found.

Fukuhara et al. 2016 [61] studied the quality-of-life effects of Provox®2 prosthesis in a 17-year-old patient that had undergone total laryngectomy. The patient was studied until the age of 21. The study demonstrated that this patient improved the scores for the questionnaires over time and that the advantages of this technique may increase once the patients reach working age.

In a retrospective observational study by Lewin et al. 2017[25], the device life of voice prostheses was reexamined. In total 3648 voice prostheses were placed in 390 patients between July 2003 and December 2013. In 69.4% the voice prosthesis was replaced because of leakage through. Median (range) device life was 61 (1-816) days for all prostheses. Indwelling VPs had significantly longer device life than non-indwelling (70 days vs 38 days). The VP with the longest life was the Provox® ActiValve® with a median of 161 days, Provox®2 had a median device life of 77 (1-764) days. Neither radiation therapy nor extent of surgery had a meaningful impact on device life. The overall VP device life is lower than historically reported. This might be explained by the medically and socially complex population as a consequence of the effect of organ preservation treatment protocols.

2.4 The Provox® NID™ voice prosthesis

In 2005, the non-indwelling Provox® NID™ voice prosthesis was introduced. This prosthesis is intended for safe and easy replacement by the patients themselves and is available in 2 different outer diameters: 17 French and 20 French, and in the lengths 6, 8, 10, 12, 14, and 18 mm. The dimensions of the non-indwelling prostheses are different from those of the Provox® indwelling prosthesis to match the dimensions of non-indwelling prostheses of other manufacturers and to facilitate self-insertion. The prosthesis is colored blue to enhance visibility for self-replacement and maintenance, see Figure 8.

Figure 8 Picture of the Provox® NID™ voice prosthesis (left) and Provox® NID™ with inserter (right).

The first results were published by Hancock et al. [9]. Fifteen non-indwelling Blom-Singer Low Pressure users converted to the Provox® NID™. *In vitro* tests showing the more favorable characteristics of the Provox® NID™ were confirmed by the patients reporting less effortful and clearer speech. The pull-out force of the Provox® NID™ was significantly higher than that of the Blom-Singer valves. Accidental aspiration of the Provox® NID™ did not occur, while 21% of the patients had experience aspiration of their previous prosthesis.

In 2014, Lewin et al. [62] completed a longitudinal eight-year retrospective cohort study on 186 patients who used the NID. Results suggest that the Provox® NiD™ offers high patient satisfaction, better than expected durability in patients with early leakage, and favorable voice quality. The median device life of all Provox® NiD™ VPs was 30 days;

45 days for removal due to prosthetic leak, 15 days for removal due to other indications. The median device life of the Provox® NiD™ (based on removal due to prosthetic leak) was significantly longer than that of other non-indwelling VPs (45 vs 29 days, p=0.0061) and did not differ significantly from that of standard indwelling VPs (45 days vs 50 days, p=0.4263).

Conversion from non-indwelling to indwelling

In some countries, the use of non-indwelling voice prostheses is more common than others. In South Africa, historically, the non-indwelling types of prostheses are used more often. A study by Vlantis et al. [63] showed that replacing the non-indwelling prosthesis (Blom-Singer Low Pressure, Duckbill or Bivona type) with a Provox®2 voice prosthesis was technically simple and led to an improvement in voice quality and patient satisfaction. The majority of patients (92.3%) preferred the Provox®2 voice prosthesis compared to the non-indwelling prosthesis.

3. Specialized Voice Prostheses

3.1 The Provox® ActiValve® voice prosthesis

In 2003, a new problem-solving Provox® voice prosthesis was introduced to the market, see Figure 9. The Provox® ActiValve® voice prosthesis was developed with the aim of solving problems in a select patient group that experiences extremely short device lifetimes (less than 4-8 weeks) due to excessive Candida growth or under-pressure in the esophagus during swallowing or inhalation. The under-pressure causes extremely early or sometimes immediate leakage and can be diagnosed by observing the valve of the prosthesis while the patients swallow and inhales. The prosthesis is designed with a Candida resistant fluoroplastic valve and valve seat, using magnets available in three different strengths to support valve closure. Outer diameter and available lengths are equal to Provox®2.

The Provox® ActiValve® is not intended for insertion in a freshly made puncture. It comes in different opening forces (Light, Strong, and XtraStrong) equipped with a Provox® Brush for cleaning and Provox® ActiValve® Lubricant. The Lubricant is a silicone oil that is applied as a thin film on the inner lumen of the Provox® ActiValve® voice prosthesis to help prevent occasional temporary blockage of the valve.

Figure 9 Picture of the Provox® ActiValve® voice prosthesis.

The first results of this prosthesis, the Provox® ActiValve®, were described by Hilgers et al. [8]. Eighteen patients with an average device life of 30 days were included in the study. Device life increased on average 14 times (range 3-39). At the time of analyses 7 prostheses were removed for leakage after an average of 278 days (increased from average 21 days with previous prosthesis), and 7 prostheses were still *in situ* for an average of 344 days (increased from 36 days with previous prosthesis). These findings have been confirmed in a long-term study [64] in a cohort of 42 laryngectomized patients with a median device life of their Provox®2 voice prosthesis of 21 days. The median lifetime of the Provox® ActiValve® prostheses replaced for leakage through the device or still *in situ* at the point of data collection was 337 days: a 16-fold average increase in device lifetime ($p<.001$). Fistula related reasons (10 patients, after a median of 68 days) for replacement included esophageal pouch (N=4), granulation (N=3), extrusion (N=2), and peri-prosthetic leakage (N=1).

In a prospective study, Graville et al. [65] investigated whether the Provox® ActiValve® results in increased device-life in 11 individuals with below average device-life. This study

also looked at cost-effectiveness and impact on voice-related quality of life. The majority (73%) experienced significant improvement as a result of use of the device. Those who continued to wear the device were followed for an average of 30.45 months (range, 14.70–43.49 months) and wore a total of 31 devices over this time. They demonstrated an average increase in device-life of more than 500%, going from an average of 1.93 months with a traditional indwelling device to 10.30 months with the Provox® ActiValve®. Voice-related quality of life was not significantly different from that of a group of controls. Overall satisfaction with the device was high. Overall, there were estimated to be cost savings to third-party payers through use of the Provox® ActiValve® in this population.

Timmermans AJ et al. 2016 [66] investigated the composition and diversity of biofilm of both the silicone and the fluoroplastic material of the Provox® ActiValve® and whether it is susceptible to destruction by Candida. Thirty-three voice prostheses (Provox® ActiValve®) were analysed with Illumina paired-end sequencing (IPES), interaction with fluorescence *in situ* hybridization (FISH), and confocal laser scanning microscopy (CLSM). Results showed that Candida albicans and Candida tropicalis are dominant populations on fluoroplastic and silicone, yet microbial diversity is significantly lower on fluoroplastic. They concluded that the fluoroplastic material of Provox® ActiValve® seems insusceptible to destruction by Candida species, thus extending lifetime of the voice prosthesis.

Leonhard et al. 2017 [67] compared biofilm resistance of different valve flaps on modern voice prostheses in an *in vitro* biofilm model. Five different voice prostheses were incubated for 22 days with a multispecies bacterial-fungal biofilm composition. In comparison to the other prostheses investigated in the study, Provox® ActiValve® showed significantly less surface biofilm formation. The authors concluded that the use of Teflon as valve flap material gives Provox® ActiValve® a stronger resistance to biofilm formation *in vitro*.

In a retrospective observational study by Lewin et al. 2017 [25], the device life of voice prosthesis was reexamined. In total 3648 voice prosthesis (VP) were placed in 390 patients between July 2003 and December 2013. In 69.4% of cases the voice prosthesis was replaced because of leakage through. Median (range) device life was 61 (1-816) days for all prosthesis. Indwelling VPs had significantly longer device life than non-indwelling (70 days vs 38 days). The VP with the longest life was the Provox® ActiValve® with a median of 161 days. Neither radiation therapy nor extent of surgery had a meaningful impact on device life. The overall VP device life is lower than historically reported. This might be explained by the medically and socially complex population as a consequence of the effect of organ preservation treatment protocols.

In a retrospective cohort study by Petersen et al. 2019 [27], long-term results of device life for several generations of Provox® VPs were published. Data from medical records over a period of 13 years (Jan 2000 – Dec 2012) was collected for a total of 232 patients. Provox® ActiValve® VPs had significantly longer median device lifetimes than that of the regular VPs: Provox® ActiValve® Light 143 days (95% CI 111-211), and Provox® ActiValve® Strong 186 days (95% CI 132-245), compared to Provox®2 63 days (95% CI 61-68) and Vega 66 days (95% CI 63-71).

In 2022, Mayo-Yañez et. al [68] performed a prospective case-crossover study in laryngectomized patients with Provox® Vega™ suffering from endoprosthetic leakage to whom a Provox® ActiValve® was placed. A total of 159 prostheses were evaluated with endoprosthetic leakage (N=129; 83.8%) the most frequent reason for replacement in both models. The mean device life of Provox® Vega™ was 45 ± 3 days (median 36 days),

and 317 ± 117 days (median 286 days) for the Provox® ActiValve®. The authors concluded that the Provox® ActiValve® is a cost-effective solution in patients requiring frequent voice prosthesis replacement due to endoprosthetic leakage, saving €133.9 for every replacement not made due to the use of a Provox® ActiValve®.

3.2 The Provox® Vega™ XtraSeal™ voice prosthesis with Insertion System

The Provox® Vega™ XtraSeal™ voice prosthesis was introduced in 2014. The Provox® Vega™ XtraSeal™ has similar characteristics and features as the Provox® Vega™, with an extra collar attached to the esophageal flange. It is intended to help prevent leakage around the prosthesis from the esophagus into the trachea. The Provox® Vega™ XtraSeal™ is inserted as an outpatient procedure with the Provox® Insertion System. The Provox® Vega™ XtraSeal™ is available in various lengths, and in 3 different outer diameters (22.5, 20 and 17 Fr). The Provox® accessories Capsule and TwistLock are not used with the Provox® Vega™ XtraSeal™.

Figure 10 Pictures of the Provox® Vega™ XtraSeal™ voice prosthesis with Insertion System

Provox Vega XtraSeal was evaluated in terms of efficacy, device life satisfaction and ease of placement in a study by Petersen et al. 2018 [69]. All included patients (n=13) had a history of periprosthetic leakage and early device failure. Median device lifetime of the former VP before placement of the first Provox® Vega™ XtraSeal™ was 38 days (95% CI 1–76). With Provox® Vega™ XtraSeal™, the median device life was 68 days (95% CI 56-80), which is comparable to median device lifetimes of the Provox®2 (63 days) or Provox® Vega™ (66 days) reported in literature [27]. Almost all cases of periprosthetic leakage could be solved with the Provox® Vega™ XtraSeal™. Only in one patient the device had to be replaced due to periprosthetic leakage. The authors concluded that Provox® Vega™ XtraSeal™ is a valuable tool for solving periprosthetic leakage.

Periprosthetic leakage is one of the most demanding and long-term complications in voice prosthesis voice rehabilitation. In 2021, Parilla et al. [70] proposed a systematic algorithm/method for management of periprosthetic leakage. In this retrospective cohort study, 115 patients with voice prosthesis treated under 2014-2019 were included. All prostheses were 22.5Fr Provox® Vega or Provox® Vega™ XtraSeal™. All patients who experienced periprosthetic leakage were treated with the same step-by-step approach until treatment was successful. The choice of sequence of steps was made by going from the most conservative option to the least. The nine steps presented were the following: 1) Deep cleaning and prosthesis reallocation *in situ*, 2) prosthesis replacement, 3)

application of thin silicone ring (Provox® XtraFlange) behind the tracheal flange, 4) Placement of a specialized voice prosthesis with enlarged flange (Provox® XtraSeal™ prosthesis), 5) thickening of tract with injectable silicone, 6) lipofilling of tract with adipose tissue, 7) purse string sutures on fistula around prosthesis, 8) fistula shrinkage by removing prosthesis, and 9) definite puncture closure. By following this treatment algorithm, only 2 out of 238 cases of periprosthetic leakage were not resolved.

Significantly higher rate of clinically relevant leakages were found in patients undergoing salvage TL than in primary TLs. Radiotherapy, time of tracheoesophageal puncture (primary or secondary) and type of total laryngectomy did not influence the incidence of periprosthetic leakage. However, salvage total laryngectomy increased the risk of more clinically relevant leakages.

In 2022, Mayo-Yañez et al. performed a systematic review on the prevention of periprosthetic leakage using the Provox® XtraSeal™. The reviewers identified 4 articles with 315 voice prostheses, (94 Provox® XtraSeal™ and 221 controls (Provox® Vega™ and Provox® ActiValve®), in 55 patients. Mean device life of the Provox® XtraSeal™ was 114 ± 73 days compared to 103 ± 18 days for the control prostheses. Out of 226 replacements, endoprosthetic leakage was the most common cause in both groups (62.4%), and periprosthetic leakage was less common in the Provox® XtraSeal™ group (9.6%) than in the control group (22.4%). The authors conclude that management of voice prosthesis patients is complex and requires a multidisciplinary approach, the Provox® XtraSeal™ could therefore be a useful tool in preventing periprosthetic leakage while increasing device life and time between voice prosthesis replacements.

4. Factors influencing device lifetime

There are many factors influencing VP device life and several studies have reported on these factors. This section summarizes some of the most common factors associated with device life.

4.1 Biofilm

A microbiological study of 37 Provox® voice prostheses that were removed for leakage or increased phonation pressure (average device life 24.5 weeks, range 8.5 – 61.2 weeks) showed that valve destruction was mainly caused by Candida colonization, although also other upper respiratory tract commensals such as Staphylococcus Aureus, were also found [71]. Mycological and scanning electroscopic assessment of three Provox® prostheses removed for failure demonstrated that the Candida mycelium on these prostheses was a surface colony rather than growing into the valve substance, suggesting it might be feasible to control its growth by mechanical cleansing or the use of topical antifungal agents [72].

Buijssen et al. [73] investigated 26 Provox®2 voice prostheses and 8 Groningen Ultra Low Resistance voice prostheses that were removed because of leakage through or increased resistance. Thirty-three of the 34 explanted voice prosthetic biofilms contained lactobacilli in close association with the Candida species present.

Fusconi et al. 2014 [74] tested 9 Provox®2 voice prostheses through photographic and electron microscopic assessment and found that the silicone undergoes a degenerative process, thus causing the surface to become rough, deformed, swollen, and translucent. The authors concluded that the degenerative process of the silicone seems to be related to the oxygen present in the trachea and esophagus and to the production of oxygen-free radicals on the biofilm's part and the immune system.

4.2 Factors associated with shorter voice prosthesis lifespan

Lam et al. [43] report on 60 patients operated upon between 1998 and 2004. A total of 203 prostheses were used (192 Provox®, 7 Blom-Singer Indwelling, 3 Blom-Singer Duckbill, 1 VoiceMaster). The median device lifetime for the indwelling prostheses was 8.2 months. Device life was longer in patients under the age of 60 (9.2 months) than in those over 60 (6.5 months). The prostheses were placed at the time of surgery. The device life of the first voice prosthesis was longer than that of the subsequent ones (9.6 months). Complications were pooled for all types of prostheses used and were: persistent tracheoesophageal fistula leakage in 3 patients, frequent valve changes in one patient, extrusion of prosthesis leading to spontaneous fistula closure in 2 patients, and parastomal tumor recurrence leading to prosthesis removal in two patients.

Terada et al. [75], in the largest study on voice prosthesis in Japanese literature, reports on 32 patients (30 secondary punctures) who received a Provox®2 voice prosthesis between Sept 2000 and Dec 2004. The success rate was 90.6%. The average device life in laryngeal carcinoma patients was 27.2 weeks and in hypopharynx carcinoma patients it was 16.6 weeks, for the total group it was 21 weeks on average. Early complications were severe oedema or necrosis around the puncture in three patients (one resolved with

temporary insertion of small diameter catheter, two resolved with conservative treatment). Late complications were granulation tissue formation (3), aspiration pneumonia (2), salivary leakage around prosthesis (1), dropping of cleaning brush in trachea – retrieved with forceps (1).

Bien and Okla [76] (article in Polish) retrospectively studied device life and complications in a group of 106 laryngectomized patients (132 prostheses replacements; included between 2002 and 2004). In 68.9% (73 patients) the prosthesis was placed primarily and in 31.1% (33 patients) secondarily. The average device lifetime was 9.8 months in radiated patients and 9.7 months in non-radiated patients. The most common complications were infection after secondary puncture with placement of the prosthesis (12.1%) and partial extrusion with closure of the puncture tract (7.5%).

Yenigun et al. 2015 [77] assessed the factors that influence the longevity and replacement frequency of Provox® voice prostheses. A strong correlation was found between lifetime of the prosthesis and postoperative follow-up duration. No correlation was found between prosthesis lifetime and time of placement (primary or secondary puncture), reflux history, antifungal use or presence of leakage. The authors recommend frequent patient control visits, proper patient selection and regular prosthesis care to prolong the lifetime of the voice prosthesis.

Pre- and postoperative radiotherapy

Bien and Okla [76] (article in Polish) retrospectively studied device life and complications in a group of 106 laryngectomized patients (132 prostheses replacements; included between 2002 and 2004). In 68.9% (73 patients) the prosthesis was placed primarily and in 31.1% (33 patients) secondarily. The average device lifetime was 9.8 months in radiated patients and 9.7 months in non-radiated patients. The most common complications were infection after secondary puncture with placement of the prosthesis (12.1%) and partial extrusion with closure of the puncture tract (7.5%).

Van Weissenbruch and Albers [78] prospectively studied 37 laryngectomized patients (who used 72 Provox® prostheses) during the period of February 1991 and February 1993. The mean device life was significantly longer in the patient group with laryngeal cancer (7.4 months) compared to the patients with hypopharyngeal cancer (4.3 months). Radiotherapy also seemed to have an influence on device life, although not statistically significant, device life was longest in non-irradiated patients (9.6 months), and longer in patients who had undergone pre-operative radiation (6.1 months) than those who had had postoperative radiation (5.8 months).

In UK, De Carpentier et al. [79] retrospectively studied the device lifetime in 39 patients using 81 Provox® prostheses. Valve failure was determined as leakage around, leakage through, or inability to produce voice. The lifetime of the first valve was negatively affected by previous radiotherapy, subsequent prosthesis failures were neither affected by previous radiotherapy, nor by the length of previous prosthesis lifetimes.

Gastroesophageal Reflux (GERD)

Boscolo-Rizzo et al. [50] found that device life of the prosthesis is significantly influenced by radiotherapy and GERD. The mean *in situ* device life was 163.3 days in irradiated and 202.9 days in radiated patients. The mean *in situ* device life was 126.5 days in patients with and 215.7 days in patients without endoscopic evidence of erosive ulcerative gastroesophageal reflux disease (GERD). These findings regarding the influence of GERD

was supported by Lorenz et al. [80], who found in a 2-year prospective non-randomized study a relationship between pathological supraesophageal reflux and the occurrence of tracheoesophageal puncture complications, especially severe puncture enlargement, in patients who underwent total laryngectomy and prosthetic voice restoration. A significant correlation was found between the occurrence of tracheoesophageal puncture complications and the severity of supraesophageal reflux. It was concluded that an enlarged puncture is not device related, but related to the presence and severity of reflux [81].

Socioeconomical factors

In a retrospective cohort study by Petersen et al. 2019 [27], long-term results of device life for several generations of Provox® voice prostheses were published. Compared with a previous cohort study published by Op de Coul et al. 2000 [82] at the same institute. Petersen et al. found that the observed median device lifetime for regular VPs (Provox®2 and Provox® Vega™) was noticeably lower compared to the historical cohort. Potential explanations for the shorter device lifetime according to the authors are the increasing numbers of TLs after prior (chemo)radiation since 1990. In the 2019 cohort 68% of patients had (chemo)radiotherapy as their primary treatment compared to 45% in the historical cohort. Another potential explanation mentioned for the shorter device life is the improved method of replacement of voice prostheses used today. In the 2000 cohort the uncomfortable method of retrograde placement was still used. With the introduction of anterograde placement, the threshold for patients to ask for replacement in case of minor leakage might have decreased. Furthermore, a surprising finding for the authors were the highly significant relation between longer device lifetimes and driving distance to the hospital. A third explanation would therefore be that closer distance to nearest hospital makes a visit for replacement less of a burden. This hypothesis is supported by the longer device lifetimes reported from countries such as Australia, where driving distances are significantly longer than in the Netherlands. Hancock et al 2012 [21] reported the median device life time of Provox® Vega™ to be 222 days in an Australian cohort.

A mean device life of 16 months for Provox® Vega™ was reported in a study by Krishnamurthy et al 2018 [83]. The study included 60 laryngectomized patients rehabilitated with voice prosthesis at a cancer center in South India. The findings were questioned in a "Letter to the Editor" by Mayo-Yáñez 2019 [84] due to the much higher device-life time than the one shown in literature in general. Mayo-Yáñez questioned the fact that the motive of voice prosthesis-replacements, as well as the potential psychosocial and financial burden for the patient, had been left out from the discussion. When comparing device lifetimes between studies, patient characteristics and voice prosthesis reimbursement should be taken into account.

Device lifetime often differs from country to country. This is thought to be caused by dietary differences, while also economical/healthcare reimbursement difference may play a role. A study in Turkey, including 50 patients using 62 voice prostheses, found an average device lifetime of 24 months [41].

Chaturvedi et al., 2014 [85] conducted a pilot study of 58 laryngectomized patients who developed prosthesis dysfunction. Prosthesis lifespan and probable factors affecting it were analyzed. Central leak was found in 43%, peri-prosthetic leakage occurred in 57% and was the most common reason for prosthesis replacement. Mean device lifespan

was 18 months and significant correlations were found between the prosthesis lifespan and the consumption of curd, and between lifespan and history of prior radiation.

4.3 Strategies to prolong device life

Dietary Changes

An *in vitro* study on the influence of dairy products on biofilm formation on voice prostheses showed that the formation of biofilm on prostheses can be lessened by the daily use of certain dairy products, buttermilk having the greatest effect [86]. Application of a buccal adhesive Nystatin tablet was found to be more effective than placebo [87] and more effective than local cleaning of the prosthesis with Nystatin suspension on the Brush [88].

An *in vitro* and *in vivo* study investigated the influence of daily consumption of Buttermilk and Yakult Light fermented milk on device lifetime of Provox®2 voice prostheses in 18 patients (10 Yakult Light group, 8 Buttermilk group) and the influence of the same product *in vitro* [89]. The number of prostheses during the 6 months trial duration were compared with the number needed in the prior 6 months. Patients with a mean device lifetime of less than 75 days during the past 6 months were included. In the Yakult Light group (mean *in situ* lifetime 33 days), device lifetime increased 3.76 times. During the 6-month trial 39 prostheses were used and during the previous 6 months 64 prostheses were used. In the Buttermilk group (mean *in situ* lifetime 34 days), device lifetime increased 1.28 times. During the 6-month trial 51 prostheses were used and during the previous 6 months 59 prostheses had been used. In-vitro test results showed that Yakult Light reduced the amount of bacteria with 22%, but that yeast colonization was stimulated up to 21%. Buttermilk reduced the amount of bacteria to 60% and stimulated yeast colonization up to 483%. The authors concluded that Yakult Light fermented milk drink reduced biofilm formation on Provox®2 voice prostheses and significantly increased device lifetime.

Ozkul et al. [46] report a low incidence of fungal colonization which they believe is due to daily consumption of Turkish yoghurt and Kephir.

Holmes et al. [90] published in 2012 whether a bovine milk product containing anti-Candida albicans immunoglobulin A antibodies ("immune milk") could reduce the adherence of C albicans to voice prosthesis silicone *in vitro*, and whether administration of the milk could reduce C albicans colonization and voice prosthesis damage *in vivo*. Authors found that immune milk inhibited C albicans adherence to silicone *in vitro*. However, in a small clinical pilot study, this effect was not replicated. The conclusion of this study was that there is scope to further investigate the topical use of immune milk for management of voice prosthesis biofilms.

Antifungals

The use of antifungal agents has in some cases shown to prolong voice prosthesis device life. Ol'shansky et al. [91] (article in Russian) investigated biofilm formation on Provox® (N=16) and Blom-Singer (N=11) voice prosthesis after usage of 6 months to 2 years. Prophylactic use of antifungal drugs prolonged device life two-fold. Van Weissenbruch et al. [87] investigated the influence of a buccal bioadhesive slow-release tablet containing miconazole on Provox® device lifetime in 36 laryngectomized patients and

found that the device lifetime was significantly higher in patients treated with the use of the tablet containing antimycotic agents compared to the placebo group (9.3 versus 5.6 months).

Somogyi-Ganss et al. 2016 [92] studied the correlation of oral health and microbial colonization with lifetime of voice prostheses (not specified). Two subgroups were analyzed: (1) patients with microbial analysis of the VP and the mouth were analyzed to identify patterns of common contamination, and (2) patients who were prescribed targeted oral decontamination on the basis of the microbial analysis of the VP were analyzed to evaluate effects on device life. In the TEP-oral microflora subgroup (n = 15), 7 had common microorganisms in the mouth and on the VP. After targeted decontamination, the median device life of prostheses improved from 7.89 to 10.82 weeks ($p = 0.260$). The majority of patients with a suboptimal VP device life in this pilot had polyspecies bacterial and fungal colonization. The authors conclude that an increase in voice prosthesis lifetime can be reached by using targeted decontamination treatment to patients.

Although the use of antifungals has been shown to prolong voice prosthesis device life, long-term medication may develop resistant strains [93], rendering antifungal treatments useless. Thus, long-term use of antifungal treatment is not recommended.

5. Complications and factors influencing complication rates

This section summarizes some publications that describe specific complications, treatment methods of specific complications, or a case of an unusual complication.

Brasnu et al. [94] describe their treatment of enlarged TE fistula's, the prostheses used in their patients were Blom-Singer, Groningen High-Resistance, Traissac, and Provox® (no information is given as to the numbers of each prostheses used and their relationship with enlarged fistula). Leakage around the prosthesis was seen in 45.5% of the patients (31 out of 68 patients). In 11.8% (8 patients) it was inconsistent and non-symptomatic and it resolved without treatment. Twenty-three patients received treatment for an enlarged fistula; since more treatments than patients are reported we have to assume that some patients received several treatments. Twelve events were treated simply by changing the voice prosthesis, 17 events by temporarily inserting a smaller catheter, 9 events with collagen injection, and one with electro coagulation.

Luff et al. [95] reported a case of intractable leakage around that could not be solved with a different valve size, the case was solved by injection of Hyloform®, a colorless viscoelastic gel, circumferentially around the puncture. Other solutions for intractable leakage around the prosthesis published in the literature are treatment with local GM-CSF104 or Bioplastique® [96, 97] and surgery [98].

A very rare complication was described by Hiltmann et al. [99]; the remainder of a Provox® prosthesis that was pushed through into the esophagus (after cutting of the tracheal flange during a normal replacement procedure) got stuck in Bauhin's valve and caused a mechanical ileus.

Scheuermann and Delank [100] describe a case of perforation of the posterior esophageal wall with an abscess of the mediastinum in a patient who first underwent transoral laser surgery, then total laryngectomy with primary puncture and placement of a Provox® prosthesis followed by chemoradiation. A similar complication was reported by Bozzo et al. [101] who described this problem as a consequence of inadequate pharynx protection during secondary TE puncture.

Counter et al. [102] describe a case of esophageal obstruction caused by the impaction of the portion of the Provox®2 prosthesis (that was removed by cutting the tracheal flange of and pushing the remainder of the prosthesis into the esophagus, which is not recommended) on a previously undiscovered benign esophageal stricture.

Smith et al. [103] describe the use of KTP laser for managing hypertrophy and granulation around the voice prosthesis. Gonzalez-Garcia et al. [104] describe the growth of granulomatous tissue in three patients to such an extent that an esophagoscopy was needed to extract the prosthesis.

Hadzibegovic et al. [105] investigated the relationship between pepsin concentration in saliva and the occurrence of tracheoesophageal fistula (TEF) complications and voice prosthesis (VP) complications. The concentrations of pepsin in the saliva of 41 laryngectomized patients were correlated with the incidence of TEF complications (periprosthetic leakage, atrophy, esophageal mucosa hypertrophy, granulations, fistula enlargement, and VP dislocation), VP complications (transprosthetic leakage, Candida infection) and voice quality. In all, 17 (42%) patients had complications. Median value of

pepsin concentration in all patients was 4.8 (range 81.7). Median pepsin concentration was not statistically significant higher in patients free of TEF or VP complications (6.6 vs. 3.2; p=.118). In addition, statistically insignificant negative correlation between pepsin levels and voice quality measured by HRS scale (Spearman's rho, p > 0.05). Authors conclude that, although reflux was proposed as cause of TEF complications and pepsin has been proven as a most sensitive and specific marker of extra-esophageal reflux, they did not find any statistically significant correlation between pepsin levels and occurrence of TEF or VP complications.

Lorenz et al. [106] assessed epithelial-mesenchymal transition in 148 consecutive biopsies from 44 patients with/without fistula enlargement under dual-probe pH monitoring before and after proton-pump inhibitor (PPI) therapy. Results showed that epithelial-mesenchymal transition correlates with severity of reflux and presence of fistula enlargement in patients who underwent prosthetic voice rehabilitation, but epithelial-mesenchymal transition seems to be reversible upon PPI treatment in early stages only.

A more recent study by Lorenz et al. 2016 [107] described two rare cases of fistula-related complications which showed a rapid development of granulation tissue around the voice fistula, leading to complete incarceration of the Provox® voice prosthesis and subtotal/total stenosis of the neopharynx.

Calkovsky et al., 2015 [108] reported a case of a 48-year-old man with secondary Provox® voice prosthesis insertion 16 months post laryngectomy. On the 6th day after the insertion, TEP decayed. After prosthesis removal the tissue defect was sutured. The study suggests that while the overall risk of severe complications seems relatively low, some complications might be challenging and might require specific management.

In a retrospective study by Cocuzza et al. 2014 [109], 61 laryngectomized patients were analyzed for the occurrence of puncture related problems. Patients who received postoperative radiotherapy were compared with those patients that did not. All patients included in the study had known gastroesophageal reflux disease. Results showed a greater incidence of puncture related problems in the group of patients who had undergone post-operative radiotherapy (45%) compared with patients who did not (17%) although all patients were treated with PPI's.

In a retrospective study from 2020, Scherl et al. [110] analyzed voice prosthesis-related complications following TEP, with special focus on prognostic factors and on management strategies. A total of 112 laryngectomies with voice prosthesis placement between the years of 1996 and 2015 were identified and analyzed. In all cases, a Provox® voice prosthesis was placed at the time of initial TEP. Overall, 88.4% of TEPs with placements were done as primary procedures during laryngectomy, and secondary TEP was performed on 11.6% of the cases, either before or after radiotherapy.

Due to biofilm formation, the normal timeframe for VP replacements was between 4-6 months for patients without complications. The 5-year overall complication rate was 65.2%, with most complications occurring during the first 18 months. The most common complications were peristomal leakage (50.0%), TEP enlargement (47.3%) and granulation tissue around the VP (36.6%). Scherl [110] concluded that the most significant prognostic factor for complications was the secondary prosthesis placement after primary surgery, followed by placement after previous irradiation, and laryngectomy with flap reconstruction. Of the preirradiated patients with secondary TEP, 90.1% suffered from TEP complications. Limitations to this study are the sizes of subgroups within the 112

patients. In the study institution, primary VP placement is the main method for VP placement, and hence, the secondary groups are comparatively small.

In a single center retrospective observational study from 2021, Apert et al. [111] studied voice prosthesis survival, complications, efficacy, and impact on quality of life. Forty-nine TL or TPL patients, all with primary VP placement, were included. 48 patients used Provox®2 and 1 Blom-Singer. The main reasons for replacing VP were leakage through (n = 309, 73.2%), leakage around (n = 77, 18.5%), swallowing and expulsion of VP (n =11, 2.6% each), and obstruction of prosthesis (n = 4, 0.9%). Median time between exchanges was 4 months (133 ± 172 days) and mean prosthesis device life were longest for Provox®2 (n = 345, 143 days) and Blom-Singer® large flange (n = 57, 71 days). No relation emerged between the number of prosthesis exchanges per year and quality of life, however, quality of life was negatively affected by voice handicap (P=0.001).

In 2020, Parrilla et al. [112] described their 1-year management of a large cohort of voice prosthesis-rehabilitated laryngectomees and proposed a systematic treatment algorithm that may reduce time and lessen burden on the treating clinicians. Between June 2017 and June 2018, 243 accesses to the clinic were made by 70 voice prosthesis patients. The most common reason for access to clinic was leakage through the prosthesis in 125 occasions (51.86%). Leakage around was noted in 60 cases (24.69% of access, 41.42% of patients) and was in most cases due to an overly long prosthesis effect. Aphonia and dysphonia was reported in 28 cases (11.52%), granuloma at the tracheal wall of the puncture in 16 cases (6.58%), 8 accesses to clinic because >8 months had passed since last replacement, and 2 patients (0.82%) that reported ingestion of voice prosthesis. The review and analysis of the 1-year complication management resulted in a troubleshooting algorithm with a technical flow chart which is presented in the paper.

Dragicevic et al. 2021 [113] reported on complications following secondary voice prosthesis insertion and impact of previous irradiation on patient appearance. The study included 106 TL patients, of which 79 (74.5%) were irradiated, who underwent secondary Provox®2 voice prosthesis insertion. Only 23 patients (22%) presented with complications, 15 of them were previously irradiated. There were no surgery-related complications, and the majority of complications were fistula-related, with voice prosthesis displacement being the most common one. The only prosthesis-related complication presented was a male patient that had increased negative pressure during swallowing, resulting in extremely short prosthesis lifetime (7-21 days). Previous irradiation did not significantly increase the risk of developing complications.

Periprosthetic leakage is one of the most demanding and long-term complication in voice prosthesis voice rehabilitation. In 2021, Parilla et al. [70] proposed a systematic algorithm/method for management of periprosthetic leakage. In this retrospective cohort study, 115 patients with voice prosthesis treated under 2014-2019 were included. All prostheses were 22.5Fr Provox® Vega™ or Provox® Vega™ XtraSeal™ prosthesis. All patients who experienced periprosthetic leakage were treated with the same step-by-step approach until treatment was successful. The sequence of steps progressed from the most conservative option to the least. The nine steps presented were the following: 1) Deep cleaning and prosthesis reallocation *in situ*, 2) prosthesis replacement, 3) application of thin silicone ring (Provox® XtraFlange™) behind the tracheal flange, 4) Placement of a specialized voice prosthesis with enlarged flange (Provox® Vega™ Xtraseal™ prosthesis), 5) thickening of tract with injectable silicone, 6) lipofilling of tract with adipose tissue, 7) purse string sutures on fistula around prosthesis, 8) fistula shrinkage by removing prosthesis, and 9) definite puncture closure. By following this treatment

algorithm, only 2 out of 238 cases of periprosthetic leakage were not resolved. A significantly higher rate of clinically relevant leakages was found in patients undergoing salvage TL than in primary TLs. Radiotherapy, time of tracheoesophageal puncture (primary or secondary) and type of total laryngectomy did not influence the incidence of periprosthetic leakage. However, salvage total laryngectomy increased the risk of more clinically relevant leakages.

Autologous tissue-assisted regenerative procedures have been considered effective in closing different types of fistulas, including leakage around TE punctures. In a retrospective cohort study, Parrilla et al. [114] reviewed clinical records between 2009-2019 of patients with TE fistula enlargement requiring autologous fat grafting (AFG). Out of 164 patients, 146 underwent total laryngectomy, and 20 patients (12.2%) experiencing TE fistula enlargement were treated with AFG. All prostheses were 22.5 Fr voice prostheses (Provox Vega, Provox Vega XtraSeal, or Provox ActiValve). At one-month follow-up, no leakages were observed, and at six-month follow-up, a single injection was sufficient to solve 75% (N=15) of cases. The overall success rate was 80% (N=16) and results remained stable for a follow-up of 5.5 ± 4 years, showing that fat grafting around a voice prosthesis is a valid and lasting option to solve persistent periprosthetic leakages.

6. Factors influencing success rates

Successful voice rehabilitation may be defined as gaining the ability to communicate effectively. In this section, literature that describes success rates and factors influencing successful voice rehabilitation is summarized.

Long-term results with the original Provox® prosthesis in 132 patients, showed that good to fair vocal rehabilitation was achieved in 92% of the patients.

Baumann et al. [115] in an article in German used the HRS (Harrison & Schultz) scale that judges voice quality, use of the prosthesis, and prosthesis care as criteria to report the success of tracheoesophageal speech. According to these criteria, 44% of the patients acquired successful voice rehabilitation (defined as 12-15 points on this scale). They further showed that the successful users needed more frequent replacements of their prostheses (average device life 3.9 months) than the unsuccessful users (average device life 5.6 months).

Yamada et al. [116] reported on the success of the Provox®2 voice prosthesis secondarily inserted in 13 unsuccessful esophageal speakers and 2 successful esophageal speakers who requested a voice prosthesis. Voice rehabilitation was successful in 13 patients; in one patient the prosthesis was removed due to tracheostomal stenosis and in one because of esophageal stenosis.

Gultekin et al. [117] studied the effects of neck dissection and radiotherapy on short-term speech success. Thirty-two male patients treated for laryngeal squamous cell carcinoma were included. Authors conclude that neck dissection and postoperative radiotherapy have no significant influence on short-term speech success in voice restoration for patients using voice prosthesis.

In a retrospective study in 91 patients, with 71 secondary insertions and 20 primary insertions, voice rehabilitation was successful in 75.8% of the patients in a study by Lukinovic et al. [118]. Early complication rate was 4.4%, and 10.9% of patients had late complications, with leakage being the most common problem. No significant differences were found for the complications rate and success rate of rehabilitation between groups of patients, formed according to age, irradiation status and timing of prosthesis insertion.

Kummer et al. [119] carried out a retrospective study of 145 laryngectomized patients who had undergone prosthetic (Provox® and Provox®2) voice restoration between 1990 and 2002. They compared success rates and complications between the patients who had received radiotherapy prior to their total laryngectomy (N=17) and those who did not (N=128). Results showed that previous radiation decreased the rate of success and increased complications.

González Poggioli et al. [120] retrospectively analyzed their experience with voice prostheses in 96 laryngectomized patients treated between Oct 2000 and Dec 2005. The prostheses used were Provox®2 (81), Blom-Singer (7), Herrmann (7), and Groningen (1). Twenty-one prostheses were removed, the majority for lack of use or failure to use. This could be due to a lack of support, the authors' state that the support from a speech therapist is important (in Spain this was not common practice at the time of the study).

Serra et al. [121] reported their 15-year experience with Provox® voice prosthesis. A retrospective clinical analysis was carried out in 95 patients between 1998 and 2013. The overall success rate was 87.5%, 84% in primary TEP and 91% in secondary TEP.

Tracheoesophageal voice failure was recorded in 6% (n=6) of the patients, surgical closure was performed: 2% persistent leakage around the prosthesis, 2% giant trachea-oesophageal granuloma, 1% downward fistula migration, 1 patient with persistent poor vocal quality preferring prosthesis removal.

Yang et al. [122] retrospectively (institutional review) studied the variability of tracheoesophageal prosthesis length in 62 patients who underwent a secondary TEP between January 2008 to November 2019. Primary outcome of the study was to compare the overall change in voice prosthesis length at the time of puncture compared to its stable length, time to reach stable length, number of prosthesis changes, and the time in between changes. Results showed that the overall prosthesis length decreased over time for patients who underwent a secondary TE puncture. The overall change in prosthesis length was – 3.9 mm ± 3.6 with time to first prosthesis change at 2.3 (± 2.7) months. An average of 4.4 (± 3.4) changes were required before reaching a stable prosthesis length. The average time between prosthesis changes was 2.1 (± 2.5) months. Twenty-six patients (42%) had increases in their prosthesis length. History of smoking (P= 0.02), use of Blom-Singer prosthesis type (P= 0.03), and larger diameter (P= 0.01) appeared to be predisposing factors for a fluctuating prosthesis length.

Furthermore, Yang et al. [122] reported that the Provox® Vega™ was the prosthesis of choice for secondary TE punctures at the study institution. SLPs reported patient preference for the Provox® voice prostheses over other brands due to ease of keeping prosthesis clean and clinically noted longer periods between prosthesis changes. The change to prosthesis to a wider diameter (> 20 French) or other brand were seen as last resort when other options had been exhausted but prosthesis problems were still present.

In 2020, Iype et al. [123] studied acceptance of voice rehabilitation methods, success rates and management of complications in 96 laryngectomy patients at a tertiary care center between August 2014 – June 2018. Voice rehabilitation options such as ES, TEP, and EL speech were presented to the patient's prior intervention. 72 patients opted for voice rehabilitation whereas remaining 24 patients refused voice rehabilitation altogether. Of the 72, 15% (11) received VPs through primary TEP and 22% (16) through secondary TEP, 36% (26) used esophageal speech, and 27% (19) opted for electrolarynx. Patients receiving VPs through primary and secondary TEP, had either advanced laryngeal carcinoma or had, respectively, undergone irradiation or required flap reconstruction. Used prostheses were Provox®, Provox®2, Provox® Vega™ and Blom Singer. Success rates for voice rehabilitation were 72% and 75% for primary and secondary TEP, respectively, and 28% for Esophageal Speech.

Dragicevic et al. 2021 [113] reported on complications following secondary voice prosthesis insertion and impact of previous irradiation on patient appearance. The study included 106 TL patients, of which 79 (74.5%) were irradiated, who underwent secondary Provox®2 voice prosthesis insertion. A 95% (N=101) success rate of voice restoration was reported, the remaining 5% (n=5) suffered from permanent hypertonicity of the neoglottis and underwent surgical closure of the fistula.

6.1 Success after Extensive Reconstruction

Benazzo et al. [124] describe good voice results with the Provox®2 for voice restoration after circumferential pharyngolaryngectomy with free jejunum repair in 6 patients.

Panarese et al. [125] have described the use of the Provox® prosthesis in patients after pharyngolaryngectomy with jejunum transplant reconstruction. Six out of nine patients developed a successful voice with the jejunum transplant and Provox® voice prosthesis. Two patients who originally had received a Blom-Singer prosthesis expressed their preference for the Provox® voice prosthesis as they thought it provided a better voice. Hilgers et al. [126] also showed that in patients with extensive pharyngeal resection and reconstruction, voice rehabilitation with the Provox® was successful in the majority of patients, although voice quality was sometimes of poor quality due to the nature of the reconstruction. Baijens et al. [127] describe a case-study in which a patient after a circumferential pharyngolaryngectomy and neopharyngeal reconstruction with a jejunal free flap is presented. This case demonstrates that after extensive laryngopharyngectomy with jejunal free flap reconstruction, a tailored rehabilitation program can improve voice and swallowing function.

In a prospective study (2 years), Reumuller et al. [128] investigated shunt-related and device-related complications, device life and microbial colonization in patients with jejunal autograft reconstruction (N=9), and a standard total laryngectomy (N=14). No difference in device life was found (reconstruction group mean 116 days, SD±114; TL group mean 129 days, SD±99). Similar complications and reasons for replacement were found. The authors conclude that voice prostheses can be safely used in each group.

In 2017, Fukushima et al. [12] performed a retrospective chart review on secondary Provox® voice prostheses insertions after total pharyngolaryngectomy (TPL) with free jejunal reconstruction (evidence also presented in 12. Standard Voice Prostheses). Satisfying communication outcomes with Provox® insertion was reported for 78.4% of patients (102/130). Neither insertion site (46 patients with jejunal insertion, 84 with esophageal insertion) nor irradiation affected the communication outcome (success rate).

The J-Flap is a surgical technique that uses a tubularized anterolateral thigh free flap that is shaped into a J-shaped phonatory tube. In a prospective study, Tsao et al., 2022 [129] evaluated the vocal outcomes and quality of life after total laryngectomy and voice restoration with J-Flap and with tracheoesophageal voice prosthesis. 38 patients were recruited for the study, 20 received voice prosthesis rehabilitation and 18 the J-flap reconstruction. Although both voice rehabilitation techniques shared similar phonatory outcomes, quality of life was more impaired in the J-Flap group.

7. Aerodynamic Characteristics – Impact on voice quality and speaking effort

In vitro studies of the aerodynamic characteristics of the Provox® voice prosthesis at increasing airflows (0.05 – 0.4 l/s) showed that the opening pressures of the Provox® voice prosthesis are considerably lower than those of the Groningen Standard, Groningen low-resistance and Blom-Singer Duckbill prosthesis [130]. The Blom-Singer low pressure prosthesis shows lower opening pressures than the Provox® voice prosthesis in the low airflow range, but higher opening pressures in the high-airflow and speaking range [131]. Although the voice prosthesis is only responsible for part of the total resistance (the neoglottis is responsible for the other part), favorable airflow characteristics are expected to enable the laryngectomized patient to speak with less effort, which is indeed confirmed by the fact that patients who changed from the Groningen prosthesis to the Provox® prosthesis experienced less effortful speech[4].

Chung et al. [132] compared the aerodynamic performance of the Provox® and Groningen low resistance voice prosthesis both *in vitro* and *in vivo* and their aerodynamic measurements showed that the Provox® voice prosthesis has a lower airflow resistance. The median intra-tracheal phonatory pressure for phonation at 75dB was significantly lower (2.1kPa) in patients using the Provox® voice prosthesis. Although speech rate, maximal phonation time, and maximal vocal intensity showed no significant difference, the intelligibility of speech in noise produced with the Provox® was significantly better than the speech produced with the Groningen LR voice prosthesis. Subjectively, most patients preferred the Provox® prosthesis because speech required less effort. Miani et al. [133] compared the *in vitro* and *in vivo* aerodynamic performance of the Provox® prosthesis with the Staffieri prosthesis and found that the aerodynamics of the Provox® prosthesis were significantly better, both *in vitro* and at high speaking intensities also *in vivo*. Belforte et al. [134] confirmed the favorable *in vitro* airflow characteristics of the Provox® prosthesis in comparison with the Staffieri, Groningen Standard, Groningen Low Resistance and Panje voice prosthesis.

Van den Hoogen et al. [135] prospectively studied speech and voice rehabilitation (phonatory skills, speech quality, voice quality, stoma technique) with the Groningen LR, Nijdam, and Provox® prostheses and found no statistically significant differences between the different types of prostheses.

A study regarding speech quality showed that speech quality with the Provox® voice prosthesis in comparison with the Groningen High Resistance and Groningen Low resistance was good, there was a trend for the Provox® voice prosthesis to produce the best scores [136]. The intelligibility of speech in noise produced with the Provox® was found to be significantly better than the intelligibility of speech produced with the Groningen LR voice prosthesis [132].

A prospective non-randomized cross-sectional study by Dabholkar JP et al., 2015 [137] evaluated voice quality in thirty patients with Provox® voice prostheses. Voice quality measures were taken immediately postoperatively and at 6-month and 1-year intervals using the parameters of functional outcomes GRBAS scale, maximal phonatory duration (MPD), and words per breath (WPB). All patients had good voice results at the end of 1 year after Provox® insertion with voice quality results improving with time.

The in-vivo aerodynamic characteristics total flow, volume range, and intra-tracheal pressure of new and dysfunctional (removed for leakage due to biofilm formation) Provox®2 voice prosthesis were not significantly different; the only parameter that was significantly different was the airflow resistance which was significantly reduced in the dysfunctional prostheses. Unlike in other prostheses where the resistance is known to increase, the resistance in dysfunctional Provox®2 prostheses decreases, which confirms the observation that most Provox®2 prostheses are replaced for leakage problems and not for increased speaking resistance [138].

Kress et al. [139] measured and compared in-vitro airflow characteristics of a variety of voice prostheses used in Europe. Their results showed that the resistance for the patient caused by the prosthesis is mainly determined by the diameter of the device. The airflow resistance of the Provox® and Provox®2 voice prostheses in the speaking range was lower than the airflow resistance of the Blom-Singer Indwelling 16 Fr and 20 Fr, the Blom-Singer Advantage 20 Fr, and the Adeva Highflow prostheses. The airflow characteristics of increased resistance prostheses, intended to provide increased resistance at low airflows created during swallowing and inhalation, showed that the different strengths of Provox® ActiValve® prostheses indeed provided higher opening pressures followed a subsequent steep decrease resulting in low airflow resistance in the speaking range. The other increase resistance prostheses that were tested (Eska Herrman flexion 60, flexion 75, and flexion 90, and Blom-Singer increases resistance 20 Fr) all showed increased resistance in the low airflow range but also in the speaking range, resulting in higher resistance during speaking.

The in-vivo aerodynamic characteristics total flow, volume range, and intra-tracheal pressure of new and dysfunctional (removed for leakage due to biofilm formation) Provox®2 voice prostheses were not significantly different; the only parameter that was significantly different was the airflow resistance which was significantly reduced in the dysfunctional prostheses. Unlike in other prostheses where the resistance is known to increase, the resistance in dysfunctional Provox®2 prostheses decreases, which confirms the observation that most Provox®2 prostheses are replaced for leakage problems and not for increased speaking resistance [138].

Kress et al. [139] measured and compared in-vitro airflow characteristics of a variety of voice prostheses used in Europe. Their results showed that the resistance for the patient caused by the prosthesis is mainly determined by the diameter of the device. The airflow resistance of the Provox® and Provox®2 voice prostheses in the speaking range was lower than the airflow resistance of the Blom-Singer Indwelling 16 Fr and 20 Fr, the Blom-Singer Advantage 20 Fr, and the Adeva Highflow prostheses. The airflow characteristics of increased resistance prostheses, intended to provide increased resistance at low airflows created during swallowing and inhalation, showed that the different strengths of Provox® ActiValve® prostheses indeed provided higher opening pressures followed a subsequent steep decrease resulting in low airflow resistance in the speaking range. The other increase resistance prostheses that were tested (Eska Herrman flexion 60, flexion 75, and flexion 90, and Blom-Singer increases resistance 20 Fr) all showed increased resistance in the low airflow range but also in the speaking range, resulting in higher resistance during speaking.

In 2021, Santos et al. [140] investigated the influence of voice prosthesis position on the pressure distribution inside the pharyngoesophageal segment of TES speakers. Creating

computational models of laryngectomized subjects during phonation, using the Provox®2 as the voice prosthesis model, Santos et al. concluded that the position and angulation of the voice prosthesis have minor influence on the pressure along the TE segment and on the pressure distribution on the pharyngoesophageal segment's wall as well.

8. Biofilm formation

Silicone is a widely used material for implantable medical devices because of its excellent mechanical and moulding properties [141, 142]. However, one of the largest disadvantages of a silicone polymer-based voice prosthesis is the colonization of fungi and bacteria on its surface [143, 144] that lead to biofilm formation. Leakage through the prosthesis and increased airflow resistance are signs of biofilm formation, leading both to a reduction in device life and more frequent replacements [142]. In this section, we cover relevant literature on biofilm formation on voice prostheses and approaches tried to solve this issue.

An early study in 1997 by Van Weissenbruch and Albers [71] prospectively studied 37 laryngectomized patients (who used 72 Provox® prostheses) during the period of February 1991 and February 1993. Cultures of 55 removed prostheses showed that on 89% of the prostheses that were removed for leakage Candida species were detected; other species included proteus mirabilis, streptococci, staphylococci, coliforms, haemophilus, klebsiella, pseudomonas, and enterobacter.

In an observational study Ticac et al. [145] determined the presence of individual microorganisms and the most frequent microbial combinations in the biofilm of the Provox®2 voice prosthesis *in situ* and the influence this has on mean and median device life. 85 patients in 5 years received a Provox®2. 100 voice prostheses were microbiologically processed immediately after replacement. Out of 292 isolates, 67% were bacteria and the remaining 33% were yeast. In 83% both bacteria and fungi were present on the prosthesis. Mean device life was 238 days (median 180 days), but life times differed significantly according to the composition of biofilm.

Nowak and Kurnatowski [146] described a study investigating Candida biofilm formation on silicone voice prosthesis, using C. Albicans and C. Krusei fungal strains with Provox®2 and Provox® ActiValve voice prosthesis. Scanning electron microscopy revealed that Candida biofilms formed on voice prosthesis had highly heterogeneous structure and were composed of blastospores, pseudohyphae, hyphae and germ tubes encased in an extracellular material. Noticeable differences in biofilms structure depended on Candida species and type of voice prosthesis.

Holmes et al. [90] studied whether a bovine milk product containing anti-Candida albicans immunoglobulin A antibodies ("immune milk") could reduce the adherence of C albicans to voice prosthesis silicone *in vitro*, and whether administration of the milk could reduce C albicans colonization and voice prosthesis damage *in vivo*. An *in vitro* assay of C albicans attachment to silicone was developed with radiolabeled C albicans. A pilot crossover *in vivo* trial, over 3 periods of 3 months, was also undertaken for 4 patients with voice prostheses (Provox®2), comparing daily administrations of immune milk and a control milk product. The prosthesis valves were replaced at each changeover and were assessed for wet weight of removable biofilm, yeast numbers in removable biofilm, valve leakage, and valve damage. Authors found that immune milk inhibited C albicans adherence to silicone *in vitro*. However, in a small clinical pilot study, this effect was not replicated. The conclusion of this study was that there is scope to further investigate the topical use of immune milk for management of voice prosthesis biofilms.

In 2020, Pentland et al. [147], analyzed the microbial biofilm composition of 159 early failing voice prostheses from 48 total laryngectomee patients over a 5-year period (2011-2016). The study observed that in most cases, the biofilms were multi-species and mainly

composed of *Candida Albicans* and *Staphylococcus Aureus*. They also demonstrated that the high CO2 environment experienced in the airways promotes *C. Albican* biofilm formation, explaining biofilm prevalence on voice prostheses. Surface topography of a Provox® Vega™ voice prosthesis was studied under Electron Microscopy and Atomic Force Microscopy. Rougher surface was observed on the prosthesis hood compared to the valve, confirming the observation that early voice prosthesis failure often exhibited heavy colonization on the esophageal flange, in particular at the rougher inner edge where the flange interfaces with the valve. Following biofilm characterization, an antifungal approach was proposed to reduce colonization on the voice prostheses. A 20-patient prospective study was performed where patients were put on an Antifungal Treatment Guideline (ATG) over the course of 8 years. The lifetime of 319 prosthesis (143 before and 173 after guidelines) were analyzed. Overall, the implementation of the ATG resulted in a significant ($p < 0.001$) increase in device life within the patient cohort, from 71.9 days prior implementation of ATG to 192.0 days after ATG implementation, representing an average 2.7-fold increase in lifespan. Increase in lifespan was not dependent on manufacturer/model as Blom-Singer Classic and Provox® Vega™ exhibited similar device life.

In a study by Spalek et al. 2020 [143], microbiological and microscopic assessment of biofilms was performed on 187 dysfunctional voice prostheses collected during a 20-month period from 129 patients. They found that in most cases (83%), the biofilm was composed of a mix of bacterial and fungal species whereas the remainder (27%), was only composed of a bacterial species. Contrary to findings in other studies [147], *Candida Albicans* was only the second most common Candida strain after *Candida Krusei* (46.5% and 55.8%, respectively), and the most common bacterial species was *Staphylococcus aureus* (44.2%). In the microscopic evaluation, they found that the esophageal surface of the voice prostheses (esophageal flange, valve flap, and valve seat) were covered by biofilm infestation. Changes in silicone mechanical properties were also observed, such as shape deformation, surface porosity, microcracks, valve obstruction and structural changes and degeneration. No statistically significant correlation between device lifetime and biofilm microorganism composition were found. Hence, they concluded that voice prosthesis degradation is caused by the actual formation of the biofilm and not by its microbial composition.

In another study Spalek et al. 2021 [148] investigated the use of Ceragenins (CSA) as candidacidal agent to prevent biofilm formation on voice prostheses. 60 different yeast strains were isolated from damaged Provox prostheses. The CSAs showed strong candidacidal effect and no significantly developed resistance in Candida over 25 passages. Furthermore, immersing VPs in ethanol solution containing CSAs resulted in impregnation of the silicone material with the CSAs, and *in vitro* testing showed that fungal biofilm formation on the VP surfaces was inhibited by the embedded CSAs.

In a randomized clinical trial in Iran, Sarvestani et al. 2022 [149] performed a molecular characterization of the fungal colonization on Provox® voice prostheses. Failed voice prostheses from 66 laryngectomy patients were collected and analyzed for fungal colonization patterns, as well as susceptibility against antifungal treatments and dietary changes. Fungal species were detected on all collected voice prostheses with *Candida glabrata* (N=25, 32%) the most common fungal species. Furthermore, *in vitro* results showed that the use of white vinegar at very low concentrations decreases fungal colonization on voice prostheses, presenting an affordable and accessible alternative to antifungal treatments.

9. Peer-reviewed overview articles and editorials

In 2011 Balm et al. published an overview article on the use of indwelling voice prostheses [141]. The article states that, since indwelling devices may have a more robust construction, their device-life generally is longer than that of their non-indwelling counterparts. Indwelling devices are described also to have the unique advantage in that patient's dexterity plays a lesser role in the daily maintenance of the device. With a few refinements in the surgery of TLE several postlaryngectomy problems can be avoided or diminished such as hypertonicity of the pharyngoesophageal (PE) segment and a poor contour of the stoma. The combination of Heat and Moisture Exchanger (HME) and indwelling voice prosthesis contributes to a significant improvement of both pulmonary function and voice quality. The solution of the majority of prosthesis and TE-fistula related problems by the well-trained physician, make prosthetic voice restoration a safe procedure [141].

Lorenz KJ. 2015 [150] conducted a literature review on the development and treatment of periprosthetic leakage after prosthetic voice restoration and compared the results with a retrospective analysis on the treatment of 232 patients from 1994 to 2013. 22.5-French voice prostheses (Provox®, Provox®2, Provox® Vega™, Provox® Activalve®) were used. During the study period, the incidence of periprosthetic leakage was 35.7 %. Substantial enlargement of the tracheo-oesophageal fistula which required multiple treatments occurred in 12.5 % of the patients. Granulation tissue that required treatment developed in 43 patients. Lorenz concluded that most problems with voice prostheses are minor and can be easily managed. Tracheo-oesophageal fistula enlargement and periprosthetic leakage is, however, a serious problem. Voice prosthesis diameter and postoperative radiotherapy alone can be largely ruled out as underlying causes. By contrast, reflux disease and radio chemotherapy can considerably elevate the risk of fistula leakage.

10. Provox® Accessories

In addition to the Provox® voice prostheses, several accessories have been developed to perform TE punctures, maintaining punctures and measuring VP lengths, and in general to aid in the maintenance and proper care of the voice prostheses.

10.1 Provox® Brush and Flush

The Provox® Brush is a device helping to clean Provox® voice prostheses or can be used for application of Fluorosilicone oil or Anti-Candida medication into Provox® voice prostheses. The distal end of the brush can help to place Provox® Plugs into the voice prosthesis. In addition to the Provox® Brush, the Provox® voice prostheses can also be cleaned with a Provox® Flush that flushes water or air through the prosthesis.

An *in vitro* study has shown that the use of the Provox® Flush has a cleansing effect on the Provox®2 voice prosthesis [151]. In 2003, Free et al. [151] showed that bacterial prevalence on Provox VPs could be reduced by 45% of control value by using the Provox® Flush (with air) 3 times per day for 9 days, and Hancock et al. 2012 [17] showed in a randomized crossover study that cleaning with the Provox® brush was found easy and efficient.

Figure 11 Image of the Provox® Brush and the Provox® Flush

In the Laryngectomee Guide for Covid-19 Pandemic (2020) [152], Brook recommends flushing the voice prosthesis twice with lukewarm water using the Provox® Flush. By keeping the voice prosthesis clean, using the brush and flush, it may extend device life by preventing the buildup of candida biofilm.

10.2 Provox® XtraFlange™

The Provox® XtraFlange™ is a silicone washer intended to reduce periprosthetic leakage for patients using indwelling Provox® voice prosthesis. It is placed between the tracheal

flange of the prosthesis and the tracheal mucosa and provides an extra seal through the adherence of the silicone sheet to the tracheal mucosa.

Figure 12 Image of the Provox® XtraFlange™

Lorenz KJ. 2015 [150] conducted a literature review on the development and treatment of periprosthetic leakage after prosthetic voice restoration and compared the results with a retrospective analysis on the treatment of 232 patients from 1994 to 2013. Lorenz found that in a total of 21 cases, the use of the Provox® XtraFlange™ prevented leakage with a success rate of 71.5%.

In a retrospective study in 41 Provox®2 patients who were rehabilitated between 1997 and 2015, Friedlander et al. 2016 [60] compared the practical management of leakage around the voice prosthesis. Three techniques were presented: peri-prosthetic silicon collar placement, injection of hyaluronic acid into the tracheoesophageal wall and the combination of the two techniques. In addition, a method to reduce the diameter of the tracheoesophageal fistula by removing the voice prosthesis and placing a nasogastric tube through the fistula was also shown. Peri-prosthetic leakage occurred in 6 of the 41 included patients. They were treated with silicone collar, hyaluronic acid injection or combination of both techniques. An increased device life of 56 days (range 7-118 days), 32 days (range 3-55 days) and 63 days (range 28-136 days), respectively for the different techniques was found.

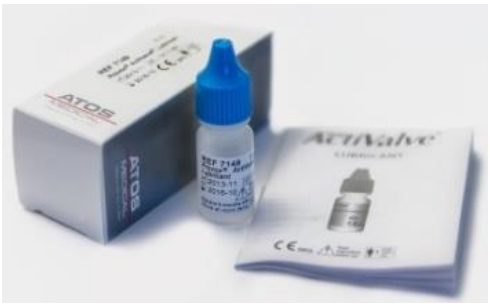
Erdim et., al 2016 [153] presented an application of silicon ring expanding the Provox® and Provox®2 voice prostheses in patients with large and persistent peri-prosthetic fistula that experienced difficult leakage problems. They concluded that this was a successful treatment, and that device lifetime and speech quality was not affected by these modifications.

In a retrospective study by Parrilla et al., 2021 [70], a 9-step systematic algorithm for management of periprosthetic leakage was proposed. The proposed steps progress from the most conservative option to the least. The use of a thin silicone ring, specifically the Provox® XtraFlange™, was proposed as one of the initial conservative steps to prevent periprosthetic leakage.

10.3 Other Provox® accessories

In Table 2 below, Provox® accessories that have not been specifically studied in the scientific literature are presented. However, they form an integral part of the insertion or maintenance of Provox® voice prostheses.

Table 2. List of other Provox® Accessories

Product name	Product image	Product Description
Provox® ActiValve® Lubricant		Medical grade silicone oil used with Provox® ActiValve® voice prosthesis to help prevent occasional temporary blockage of the valve.
Provox® Dilators		The Provox® Dilators are tapered curved silicone rods used for dilating (increase the diameter of) TE punctures.
Provox® Measure		Provox® Measure is intended for sizing the length (corresponding to voice prosthesis length) of TE punctures.

Product name	Product image	Product Description
Provox® Plug and Provox® Vega™ Plug		The Provox® Plug and Provox® Vega™ Plug is a first-aid tool for temporarily stopping leakage through the voice prosthesis. The device is inserted into the opening of the voice prosthesis and hence blocking any leakage through the valve.
Provox® GuideWire		The Provox® GuideWire is a device for introduction and replacement of indwelling Provox® voice prostheses. The GuideWire has a connector for attachment of the safety strap of the new voice prosthesis and a Stopper for transoral removal of the remnant of the old voice prosthesis.
Provox® Capsule		The Provox® Capsule is used for insertion of the Provox® Vega™ voice prosthesis using only the insertion pin. It's used for patients with narrow stomas, narrow esophagus or difficult to reach TE punctures. The voice prosthesis is manually kept in place, while the

Product name	Product image	Product Description
		patient is drinking water until the Capsule is dissolved and the esophageal flange has unfolded on the esophageal side of the TE-puncture.
Provox® TwistLock		The Provox® TwistLock is placed on the top of the Insertion System to keep the folding tool in a closed position to facilitate easy insertion of a voice prosthesis into a Provox® Capsule.

11. Summary

In summary, the large amount of literature shows that all types of Provox® voice prostheses are used successfully worldwide. Device life may differ and is most likely influenced by the formation of biofilm, dietary habits and economic factors. The values reported may also differ due to the definition used to determine device life and success rates. Most studies report prosthesis related device life only, but some also include puncture-related changes such as downsizing. Table 3 summarizes the data for device life found in the various studies. Interpretation of the results is sometimes difficult due to the fact that some studies have used averages, and some have used medians. The medians are usually lower than the averages since they do not account for the extremely long device lives that some patients have. Complication rates are acceptable and may differ due to definitions used in describing complications, but also due to treatment and prevention. If dealt with in a timely or systematic manner, most complications can be resolved easily and before becoming serious.

Table 4 summarizes the data found for complications, while Table 5 represents the success rates with Provox® voice prostheses. In Table 6, an overview of newly added publications is given.

Table 3. Overview of device lifetime of Provox® prostheses.

Authors	Prostheses	Device Life	Comments
Hilgers et al., 1990 [6]	Provox®	Mean 154 days	Prospective 79 patients, 67 converted from Groningen, 12 primary insertion
Balle and Thomsen, 1993 [154]	Provox® Duckbill	Provox®: 6-8 months Duckbill: 1-3 months	Retrospective may 1989 – august 1992 24 patients, converted from Bivona Duckbill
Van Weissenbruch & Albers, 1993 [78]	Provox®	Average 5.4 months	Prospective Feb 1991 – Feb 1993 37 patients 72 changes
Hilgers et al.1993 [155]	Provox®	Mean 235 days Median 141 days Longer in laryngeal cancer (7.4 months) compared to hypopharyngeal cancer (4.3 months); longer in unirradiated (9.6 months), than in pre-op radiation (6.1 months) or post-op radiation (5.8 months)	Prospective 132 patients
Heaton and Parker, 1994[156]	Provox® (16) Groningen HR (83) Groningen LR (71)	Provox® mean 4.1 months, median 2 months GHR mean 6.0 months, median 4 months; GLR mean 4.4 months, median 3 months. Differences not statistically significant	Prospective consecutive structured data collection oct 1986 – august 1993 49 patients 203 prostheses Groningen prostheses were relatively more often changed for increased

Authors	Prostheses	Device Life	Comments
			speaking resistance than Provox® prostheses
Callanan et al, 1995 [157]	Provox®	Mean 148 days Median 120 days	Cohort study 28 patients
Van den Hoogen et al., 1996 [158]	172 Provox® 220 Nijdam 453 Groningen (higher number of Groningen because this was the only one available up to 1990)	Provox® mean 13 weeks Groningen mean 15.8 weeks Nijdam 19 weeks	Prospective, randomized replacement of current vp (Groningen) for one of three types jan 1991-july 1993 158 patients 845 consecutive placements Groningen prosthesis relatively more often replaced for increased speaking resistance. Nijdam more often replaced for different type prosthesis due to prosthesis related problems.
Toma et al., 1996 [159]	Provox®	Average 148 days	Cohort 31 patients
Ollas et al., 1996 [160]	Provox® (95) Blom-Singer indwelling (4) Groningen (2)	Combined for all three types median 327 days	Retrospective June 1991-Nov 1995 101 patients
De Carpentier et al.,1996 [79]	Provox®	Median 4.5 months (failure determined as leak around or through (resizing), and inability to produce voice)	Retrospective 39 patients 81 prostheses A small group of patients (7.7%) required frequent replacement and accounted for 24.7% of the valve failures.
Hilgers et al., 1997 [7]	Provox®2	Good feasibility Main reason for replacement leakage through	First study on Provox®2 + anterograde replacement
Slavicek et al., 1997 [161]	Provox® (all secondary puncture)	Median 98 days (range 43-589)	Retrospective 1992-1996 53 patients 372 prostheses
Lacourreye et al., 1997 [162]	Provox®	Mean 311 days (33% replaced for leakage through, 27% for leakage around, 24% for deterioration of the prosthesis, and 16% for increased airflow due to crusting.	Retrospective (Nov 1990 – June 1994) 37 patients 100 prostheses
Cavalot et al., 1997 [163]	Provox® (16) Blom-Singer indwelling (14)	Mean Provox® 6 months Mean Blom-Singer 5 months	Prospective RCT Provox® vs Blom-Singer 30 patients, 16 Provox®, 14 Blom-Singer
Aust and McCaffrey, 1997 [164]	Provox®	Mean 166 days (leakage through in 12.5%, resizing in remainder)	Retrospective 21 patients 24 replacements in 13 patients

Authors	Prostheses	Device Life	Comments
Nasser et al., 1997 [165]	Provox®	Average 8 months	Prospective Mar 1994 – Sep 1996 52 patients
Delsupehe et al., 1998 [166]	Provox® Blom-Singer indwelling	Median Provox® 14.5 weeks Median Blom-Singer 15 weeks	Prospective RCT 52 patients 113 prostheses
Graville et al., 1999 [30]	Provox®2 (6) Blom-Singer indwelling (24)	Leakage through the device secondary to yeast colonization occurred with equal frequency in both devices	Retrospective 30 patients
Ackerstaff et al., 1999 [31]	Provox®2	Median 104 days	Prospective, multi-center 239 patients
Baumann et al., 2000 [115]	Provox® (1992-mid 1997) Provox®2 (mid 1997-1998)	Average 3.9 months in 'successful' rehabilitated and 5.6 months in 'unsuccessful'	Prospective, 1992-1998 105 patients 478 replacements
Biacabe et al., 2000 [167]	Provox®	Average 241 days	Retrospective 68 patients 197 replacements
Koscielny and Bräuer, 2000 [29]	Provox® Provox®2	Average 6 months	Prospective 45 patients 177 replacements
Op de Coul et al., 2000 [32]	Provox® Provox®2	Median Provox® 120 days Median Provox®2 92 days Main reason for replacement leakage through (73%). Device life time was significantly longer in patients who had not received radiotherapy and in patients older than 70 years First prosthesis placed at surgery lasted substantially longer than subsequent prostheses	Retrospective Nov 1988 – May 1999 318 patients 2700 replacements
Balle et al., 2000 [33]	Provox® Provox®2	Average Provox® 3.1 months Average Provox®2 2.3 months	Retrospective May 1989-May 1999 88 patients Conversion from Blom-Singer (non-indwelling) Duckbill to Provox®
Schafer et al., 2001 [36]	Provox® (136) Provox®2 (78) Blom-Singer indwelling (172)	Average Provox® 244 days Average Provox®2 96 days Average B-S 107 days Provox® Significantly longer than Provox®2 and B-S. No significant difference between Provox®2 and Blom-Singer.	Retrospective 1993-1999 58 patients 378 prostheses
Hotz et al., 2002 [37]	Provox® Provox®2	In 'early' follow-up phase (0-9 months) device life was longer in 'successful' users (4.2 vs 3.9 months)	Retrospective 1992-1998 82 patients

Authors	Prostheses	Device Life	Comments
Fajdiga et al., 2002 [38]	Provox® Provox®2 Other (unnamed)	Overall 5.5 months average	Retrospective 32 patients 1998-2002
Elving et al., 2002 [45]	Provox®2 (296) Groningen LR (377) Provox® (12)	GLR immediately postop average 180 days GLR 137 days Provox®2 90 days Radiation does >60Gy associated with limited device life time	Retrospective jan 1993-Nov 1999 101 patients 685 prostheses
Hilgers et al., 2003 [8]	Provox®ActiValve®	Average 14-fold increase in device lifetime compared to device life of Provox®2 in patients with device life problems	18 patients with average device life of 30 days
Cornu et al., 2003 [168]	Provox®	Average 303 days (range 10 -1191 days)	Prospective 1995-1998 128 patients 63 replacements
Lequeux et al., 2003 [34]	Provox® (24) Provox®2 (128)	Median Provox® 303 days Median Provox®2 144 days	Retrospective March 1993 – Nov 2000 38 patients 152 prostheses
Trussart et al., 2003 [39]	Provox®/ Provox®2 (93) Blom-Singer (73) Groningen (5) VoiceMaster (7)	Averages in days: Provox®165.5 Blom-Singer 143.5 Groningen 135 VoiceMaster 195	Retrospective long-term follow up (3 – 16 years)
Makitie et al., 2003 [40]	Provox® Provox®2	Average 10 months	Retrospective 1992-2002 95 patients
Ozkul et al., 2003 [46]	Provox® (204) Blom-Singer (17) Groningen (5) Turvox (5)	Provox® 18 months Blom-Singer 5 months	231 patients
Demir et al., 2004 [41]	Provox®2	Average 24 months	Retrospective 50 patients 60 prosthesis
Hancock et al., 2005 [9]	Provox®NID™	Overall average 74 days	Feasibility study in 15 patients, conversion from Blom-Singer Low Pressure
Morshed et al., 2005 [42]	Provox®2	Average 216 days	retrospective 21 patients 2 years
Lam et al., 2005 [43]	Provox®2 (192) Blom-Singer indwelling (7) Blom-Singer Duckbill (3) Voicemaster (1)	Overall median 8.2 months First prosthesis 9.6 months	Retrospective 1998-2004 60 patients 203 prosthesis
Bien and Okla, 2006 [76]	Provox®2	Average 9.8 months in radiated in 9.7 months in non-radiated patients	Retrospective 2002-2004 106 patients 132 replacements
Terada et al., 2007 [75]	Provox®2	Averages:	Cohort 2002-2004

Authors	Prostheses	Device Life	Comments
		Laryngeal ca 27.2 weeks Hypopharynx ca 16.6 weeks Overall 21 weeks	32 patients
Gonzalez Poggioli et al., 2007 [120]	Provox®2 (81) Blom-Singer (7) Herrmann (7) Groningen (1)	Overall average 9 months	Retrospective oct 2000-dec 2005 96 patients
Bilewicz et al., 2007 [47]	Provox®2	Mean 295 days	Prospective 39 TE speakers, 10 esophageal speakers
Ramalingam et al., 2007 [49]	Provox®2 (21) Blom-Singer Low Pressure (20)	Average Provox®2 15 months Average Blom-Singer 3 months	Prospective comparative
Boscolo-Rizzo et al., 2008 [50]	Before Sep 2001 Blom-Singer indwelling After Sep 2001 Provox®2	Average radiated 163.3 days, non-radiated 202.9 days Average non GERD 126.5 days and non-GERD 215.7 days	Retrospective 1998-2006 106 patients 515 replacements
Soolsma et al., 2008 [64]	Provox®ActiValve®	Median 337 days (improved from median 21 days with Provox®2)	Retrospective 42 patients with short device life time Long-term follow up
Tammam and Ahmed, 2009 [51]	Provox®2	Device life ranged from 5 to 60 months with an average of 24.5 months	Retrospective study 5 patients
Bozec et al., 2010 [52]	Provox® and Provox®2	Mean device life for Provox® 7.6 months; Provox®2 3.7 months	Retrospective study 87 patients
Hilgers et al., 2010 [16]	Provox® Vega™	Provox® Vega 22.5 median 74 days Provox Vega 20 median 93 days, mean 111 days).	Prospective study, two cohorts 25 prosthesis changes
Schäfer et al, 2011 [20]	Provox® Vega™	Mean 70 days; no difference compared to Provox®2	Prospective 40 patients
Graville et al., 2011 [65]	Provox® ActiValve®	Mean traditional indwelling device life 1.93 months. With Provox® ActiValve mean 10.30 months	Prospective 11 patients
Boci et al., 2012 [56]	Provox® and Provox®2	Mean device life for Provox®; and Provox®2" 279 days	Prospective, 106 patients
Zimmer-Nowicka & Morawiec-Sztandera, 2012 [57]	Provox®2	Average 260 days	Retrospective 42 patients
Hancock et al. 2013 [21]	Provox® Vega™	Average 207 days; median 222 days	Prospective 23 patients
Lewin et al. 2014 [62]	Provox® NiD™, Provox®2, BS Classic, Provox® Vega™, BS non-indwelling Duckbill, BS low pressure,	Provox® NiD™ (median 45 days)	Longitudinal retrospective cohort study 186 patients

Authors	Prostheses	Device Life	Comments
	Bivona Ultra low, Bivona Duckbill		
Kress et al. 2014 [22]	Blom-Singer Classic, Blom-Singer Dual Valve, Provox®2 , Provox® Vega™ and Provox® ActiValve®	Provox® ActiValve® (median 291 days); Provox® Vega™ (median 92 days; Provox®2 (66 days); Blom Singer classic (median 69 days)	Prospective 102 patients 749 voice prostheses
Chaturvedi P, et al 2014 [85]	Provox®	Mean lifespan :18 months, Median 9 months, range 1 to 87 months)	58 patients
Kilic et al. 2014 [58]	Provox®2	Mean device life time 7.5 months (range 1 to 48 months).	210 patients (180 males, 30 females; mean age 58±11.9 years; range 37 to 83 years)
Messing et al. 2015 [59]	Provox®2	Median lifespan : 92 days	15 patients (95% confidence interval
Yenigun et al 2015 [77]	Provox®	mean lifespan: 17.1 months (range 1-36 months)	Retrospective 27 patients
Serra et al. 2015 [121]	Provox® Provox®2 Provox® Vega™	median device life: Provox® 150 days, Provox®2 125 days, Provox® Vega 140 days	Retrospective 95 patients
Thylur et al 2016 [23]	Provox®2 Provox® Vega™	mean (median) device life: Provox®2 115.6 (110) days, Provox® Vega™ 65.1 (80)days	Retrospective 21 patients 181 voice prostheses
Lewin et al. 2017 [25]	Provox®2 (1096) Provox® Vega™ (44) Provox® ActiValve® (40) Provox® NiD™ (340) Blom-Singer Duckbill (4) Blom-Singer Low Pressure (255) Blom-Singer Indwelling (1383) Blom-Singer Indwelling Standard Enlarged Flange (205) Blom-Singer Advantage (251) Bivona Duckbill (10) Bivona Ultra Low (20)	Median device life per model: Provox® NiD™ 47 days, Provox®2 77 days, Provox® Vega™ 45 days, Provox® ActiValve® 161 days, Blom-Singer Duckbill 18 days, Blom-Singer Low Pressure 33 days, Blom-Singer Indwelling 59 days, Blom-Singer Indwelling Standard Enlarged Flange 42 days, Blom-Singer Advantage 67 days, Bivona Duckbill 7 days, Bivona Ultra Low 20 days.	Retrospective 390 patients 3648 voice prostheses
Friedlander et al. 2016 [60]	Provox®2	Average: 56 days (Periprosthetice silicon collar inserted) Average: 32 days (Hyaluronic acid treatment) Average: 64 days (Combination of both)	
Serra et al. 2017 [24]	Provox®2 (82) Provox® Vega™ (82)	Average lifetime: Provox®2: 146 days Provox® Vega™: 182 days	Multicenter prospective crossover study 82 patients

Authors	Prostheses	Device Life	Comments
Robinson et al. 2017 [13]	Provox® Vega™, PVPS	Average lifetime: intraoperative placed VP: 159.7 days delayed insertion: 24.5 days	Prospective study 24 patients (Intraoperative = 14, delayed = 10)
Mayo-Yáñez et al. 2018 [26]	Provox®2 (192) Provox® Vega™ (214)	Median device lifetime per model: Provox 2: 74 days Provox Vega: 74 days	Retrospective case-crossover study 34 patients
Krishnamurthy et al. 2018 [83]	Provox®2 Provox® Vega™	Mean lifetime: 16 months	Retrospective study 60 patients
Petersen et al. 2018 [69]	Provox® Vega™ XtraSeal	Median lifetime; 68 days	Prospective study 13 patients
Petersen et al. 2019 [27]	Provox®2 (1664) Provox® Vega™ (1136) Provox® ActiValve® Light (171) Strong (121)	Median device life per model: Provox 2: 63 days Vega: 66 days ActiValve light: 143 days ActiValve strong: 186 days	Retrospective cohort study 232 patients
Iype et al. 2020 [123]	Provox®1, Provox®2, Provox® Vega™	Average device life: 7.4 months	Retrospective study 96 patients
Pentland et al. 2020 [147]	Provox® Vega™	Average device life previous to Antifungal treatment: 71.9 days (143 voice prostheses) Average device life after Antifungal treatment: 192 days (No sign. Difference between Blom-Singer Classic and Provox® Vega™)	Prospective/*In vitro* Biofilms from 159 voice prostheses from 48 patients 20 patients in prospective study
Scherl et al., 2020 [110]	Provox® Vega™ XtraSeal	Average device life between 4-6 months for patients without complications	Retrospective study 112 patients
Mayo-Yañez et al., 2020 [28]	Provox® Vega™ Provox® Vega™ XtraSeal	Mean device life per model: Provox® Vega™: 104.4 days Provox® Vega™ XtraSeal: 176.8 days	Prospective case-crossover study 20 patients
Apert el al., 2021 [111]	Provox®2 Blom-Singer	Mean device life per model: Provox®2: 143 days (n=345 prostheses) Blom-Singer Large flange: 71 days (n=57 prostheses)	Single center observational study 49 patients
Parrilla et al., 2021 [112]	Provox® ActiValve®, Provox® Vega™ XtraSeal	Median device life: 4.85 months	Retrospective study 243 clinical accesses by 70 patients

Authors	Prostheses	Device Life	Comments
Mayo-Yañez et al. 2022 [68]	Provox® Vega™, Provox® ActiValve®	Provox® Vega™: mean 45 ± 3 days (median 36 days), Provox® ActiValve®: 317 ± 117 days (median 286 days)	Prospective cross-over study 5 patients
Mayo-Yañez et al. 2022 [169]	Provox® Vega™, Provox® ActiValve®, Provox® Vega™ XtraSeal	Mean device life: Provox® XtraSeal: 114 ± 73 days Provox® Vega™, Provox® ActiValve®: 103 ± 18 days	Systematic review 55 patients, 315 voice prostheses
Pribuišis et al. 2022 [170]	Provox® Vega™	Median device life: 154 days (3 – 995 days)	Retrospective cohort study 59 patients, 328 voice prostheses

Table 4. Overview of complications with Provox® prostheses (prosthesis and puncture related).

Authors	Prostheses	Complications	Comments
Hilgers et al., 1990 [6]	Provox®	Short-term fistula enlargement (8); hypertrophic scarring with fistula closure (3); surgical closure for intractable leakage (3).	79 patients, 67 converted from Groningen, 12 primary insertion
Hilgers et al., 1993 [131]	Provox®	Temporary widened fistula 20.5% of patients; intractable leakage around due to enlarged fistula 3% (surgical closure); hypertrophic scarring/prolapse/infection 4.5%.	132 patients
Callanan et al., 1995 [157]	Provox®	No major surgical complications. Overgrowth by esophageal mucosa solved with larger prosthesis (3); ingestion of prosthesis (1); leak around due to too long prosthesis pistoning (2)	28 patients
Van den Hoogen et al., 1996 [158]	172 Provox® 220 Nijdam 453 Groningen (higher number of Groningen because this was the only one available up to 1990)	Hypertrophia and granulation most frequent complication. Provox®: Granulation 6%, Hypertrophia 4%, Infection 2% Groningen: Granulation 6%, Hypertrophia 4%, Infection 0% Nijdam: Granulation 12%, Hypertrophia 10%, Infection 0%	158 patients 845 consecutive placements
Toma et al., 1996 [159]	Provox®	Fistula migration (4), esophageal mucosa overgrowth (3), prosthesis ingestion (1)	Cohort 31 patients
Ollas et al., 1996 [160]	Provox® (95) Blom-Singer (4) Groningen (2)	Ingestion (2), extrusion (1)	101 patients

Authors	Prostheses	Complications	Comments
De Carpentier et al., 1996 [79]	Provox®	Leakage around requiring temp stenting with small catheter (7.7%), granulation formation (no % mentioned).	Retrospective 39 patients 81 prostheses
Slavicek et al., 1997 [161]	Provox® (all secondary puncture)	Local inflammatory reaction in 28.1% resulting in extrusion or removal in 14.2%	53 patients 372 prostheses
Lacourreye et al., 1997 [162]	Provox®	Early cellulites (1), granulation (6), puncture necrosis due to ill fitted prosthesis (1),	Retrospective (Nov 1990 –June 1994) 37 patients 100 prostheses
Cavalot et al., 1997 [163]	Provox® (16) Blom-Singer (14)	Pooled for both types: Fistula dilation 10%, cellulitis 6.6%, extrusion 6.6%.	Prospective RCT Provox® vs Blom-Singer 30 patients, 16 Provox®, 14 Blom-Singer
Aust and McCaffrey, 1997 [164]	Provox®	Partial retraction of prosthesis into esophagus due to too short prosthesis (2), granulation (1), cellulites (1)	Retrospective 21 patients 24 replacements in 13 patients
Nasser et al., 1997 [165]	Provox®	Temporary leakage around (9 events) 'obstruction' (30 events) Porstheses migration (17 events)	Prospective Mar 1994 – Sep 1996 52 patients
De Racourt et al., 1998 [171]	Provox® (majority but no exact numbers) Herrmann (until 1993) Traissac Blom-Singer	Pooled for all types: Enlarged fistula 16 patients, 37 episodes, 28 treated with shrinkage, 2 healed spontaneously, 7 surgical closures with repuncture in 4.	Retrospective, patients treated between Dec 1987 and Feb 1998, all with 5 year follow up. 62 patients
Baumann et al., 2000 [115]	Provox® (1992-mid 1997) Provox®2 (mid 1997-1998)	Complications in 26 out of 478 used prostheses: mucosal overgrowth/embedding (14), aspiration/ingestion of prosthesis (3), aspiration pneumonia (3), local infection (4), granulation (2).	Prospective, 1992-1998 105 patients 478 prosthesis changes
Op de Coul et al., 2000 [32]	Provox® Provox®2	Leakage around prosthesis not solved by downsizing in 3% of replacements, hypertrophic scarring in 7% of replacements, spontaneous loss of the device in 1% of 'replacements'.	Retrospective Nov 1988 – May 1999 318 patients 2700 replacements
Balle et al., 2000 [33]	Provox® Provox®2	Granulation tissue (14 patients), Infection (5)	Retrospective May 1989-May 1999 88 patients Conversion from Blom-Singer (non-indwelling) Duckbill to Provox®
Hotz et al., 2002 [37]	Provox® Provox®2	Aspiration (1), ingestion (2), aspiration pneumonia (2), granulation (2)	Retrospective 1992-1998 82 patients
Fajdiga et al., 2002 [38]	Provox®® Provox®2 Other (unnamed)	Pooled for all prostheses including unknown brand: Inflammation (12 events in 5 patients), prosthesis aspiration (4 events in 4 patients)	retrospective 32 patients 1998-2002

Authors	Prostheses	Complications	Comments
Cornu et al., 2003 [168]	Provox®	22 adverse events in 16 patients: posterior displacement of prosthesis (5), anterior displacement of prosthesis (9), granulation (2), enlarged fistula (3), leakage adjacent to fistula (3).	Prospective 1995-1998 128 patients 63 replacements
Trussart et al., 2003 [39]	Provox®/Provox®2 (93) Blom-Singer (73) Groningen (5) VoiceMaster (7)	Pooled for all types: Periprosthetic leakage (12: 11 treated with collagen and 1 with silastic sheet), granulomas (17.4%)	Retrospective long-term follow up (3 – 16 years)
Makitie et al., 2003 [40]	Provox® Provox®2	In % of replacements: Granulation 9.2%, leakage around 7.2%, extrusion 0.5%	Retrospective 1992 - 2002 95 patients
Hancock et al., 2005 [9]	Provox® NID™	Increased safety with increased flange resistance and safety medallion	Feasibility study in 15 patients, conversion from Blom-Singer Low Pressure
Bien and Okla, 2006 [76]	Provox®2	Infection after 2ndary puncture 12.1%, partial extrusion 7.5%	Retrospective 2002-2004 106 patients 132 replacements
Calder et al., 2006 [44]	Provox® Provox®2 Blom-Singer	Incomplete dataset and information in article 20% granulation	Retrospective 1993-2002 99 patients
Terada et al., 2007 [75]	Provox®2	Oedema/necrosis around puncture (3 patients), granulation (3), aspiration pneumonia (2), leakage around (1).	Cohort 32 patients 2002-2004
Bilewicz et al., 2007 [47]	Provox®2	Infection (N=7) Widening of fistula (N=4)	Prospective 39 TE speakers 10 esophageal speakers
Ramalingam et al., 2007 [49]	Provox®2 (21) Blom-Singer Low Pressure (20)	Less prosthesis related complications in Provox®	Prospective 41 patients, comparative
Soolsma et al., 2008 [64]	Provox®ActiValve®	Esophageal pouch (N=4) Granulation (N=3) Extrusion (N=1)	Retrospective 42 patients with short device life time Long-term follow up
Gultekin et al., 2011 [117]	Provox®	No complications neck dissection and postoperative radiotherapy	Retrospective 23 patients
Wierzchowska et al., 2011 [54]	Provox®2	Granulation (n=11) Spontaneous falling out prosthesis (n=6) Leakage through or around prosthesis: 97.4%	Retrospective 76 patients
Lukinovic et al. 2012 [118]	Provox®2	Early complication rate was 4.4%, and 10.9% of patients had late complications, with leakage being the most common problem.	Retrospective 91 patients
Cocuzza et al. 2014 [109]	Provox®	Fistula related complications	Retrospective study 61 patients

Authors	Prostheses	Complications	Comments
Imre et al. 2013 [172]	Provox®	Granulation (n=2, 4.2%), swallowing prosthesis (n=6 12.7%), Leakage around prosthesis (n=9 , 19.1%); mediastinitis (n=1, 3.1%), paraesophageal abscess (n=1, 3.1%)	Retrospective 47 male patients
Bozzo et al. 2014 [101]	Provox®2	Mediastinal abscess and esophageal stricture	Case study 1 patient
Lorenz et al. 2015 [106]	Provox®2 , ActiValve®	Fistula enlargement	Prospective cohort study 44 patients
Lorenz KJ. 2015 [150]	Provox®, Provox® 2, Provox® Vega™, Provox® ActiValve®	Periprosthetic leakage: 35.7%. Substantial enlargement of the tracheo-oesophageal fistula: 12.5 % Granulation (n=43).	Retrospective, 1994 - 2013 32 patients,
Chaturvedi P, et al 2014 [85]	Provox®	Central leak ; 43%, peri-prosthetic leakage: 57%	58 patients
Calkovsky et al 2015 [108]	Provox®	Secondary voice prosthesis inserted through a T-E shunt. Day 6 post insertion the shunt decayed	Case study 1 patient
Serra et al 2015 [121]	Provox®, Provox®2, Provox® Vega™	Overall complication rate was 13%: 90% pharyngocutaneous fistula, 5% bleeding, 5% other medical complications.	Retrospective 95 patients
Lorenz et al.2016 [107]	The type of Provox® voice prosthesis was not mentioned.	Rapid development of granulation tissue & incarceration of the prosthesis.	Case-study 2 patients
Fukushima et al. 2017 [12]	Provox®2, Provox® Vega™, PVPS	Complication rate: 15.4% (20 patients) Local infection, leakage, stenosis, and spontaneous extrusion	Retrospective study 130 patients
Robinson et al. 2017 [13]	Provox® Vega™, PVPS	Postoperative complications: Intraoperative group 29% PCF (3), pulmonary embolism (1)Delayed group 20% PCF (2)	Prospective study 24 patients (Intraoperative = 14, delayed = 10)
Parrilla et al. 2021 [114]	Provox® ActiValve®, Provox® Vega™, Provox® Vega™ XtraSeal	Persistent periprosthetic leakage solved with autologous fat grafting. 80% success rate (16 patients)	Retrospective study 20 patients
Apert el al. 2021 [111]	Provox®2	Leakage through (n = 309, 73.2%) Leakage around (n = 77, 18.5%) Swallowing and expulsion of VP (n =11, 2.6% each) Obstruction of prosthesis (n = 4, 0.9%)	Single center observational study 49 patients

Authors	Prostheses	Complications	Comments
Dragicevic et al. 2021 [113]	Provox®2	22% (n = 23) suffered complications, 15 of 23 were previously irradiated. Swallowing difficulties (n=1, 1%) Excessive granulation (n=3, 3%) Prosthesis displacement (n=14, 13%)	Retrospective study 106 patients, 2ndary TEP
Parilla et al. 2021 [70]	Provox® models	330 cases of Periprosthetic leakage (24% of all accesses)	Retrospective study 1374 clinical accesses by 115 patients
Parrilla et al. 2021 [112]	Provox® ActiValve®, Provox® Vega™ XtraSeal	Leakage through (125 cases, 51.9%*) Periprosthetic leakage (60 cases, 24.7%*) Aphonia and dysphonia (28 cases, 11.5%*) Granuloma (16 cases, 6.6%*) Prosthesis ingestion (2 cases, 1%*) *% of accesses	Retrospective study 243 clinical accesses by 70 patients
Iype et al. 2020 [123]	Provox®1, Provox®2, Provox® Vega™	62% complication rate (n=27 patients with voice prosthesis), main complication was leakage through or around, and prosthesis dislodgement	Retrospective study 96 patients
Scherl et al. 2020 [110]	Provox® Vega™ XtraSeal	5-year overall complication rate was 65.2% Most common complications: peristomal leakage (50%), TEP enlargement (47.3%), and tissue granulation (36.6%)	Retrospective study 112 patients
Mayo-Yañez et al. 2020 [28]	Provox® Vega™ Provox® Vega™ XtraSeal	Endoprosthetic leakage (n=146; 67%) Periprosthetic leakage (n=39; 17.9%) Extrusion (n=17; 4.1%)	Prospective case-crossover study 20 patients
Mayo-Yañez et al. 2022 [68]	Provox® Vega™, Provox® ActiValve®	Endoprosthetic leakage (n=129; 84%) Periprosthetic leakage (n=9; 6%) Extrusion (n=12; 8%)	Prospective cross-over study 5 patients
Mayo-Yañez et al. 2022 [169]	Provox® Vega™, Provox® ActiValve®, Provox® Vega™ XtraSeal	Endoprosthetic Leakage (N=166; 62.4%) Periprosthetic leakage (n=53; 19.9%) Endo + Periprosthetic leakage (n=7; 2.6%) Extrusion (n=20; 7.5%)	Systematic review 55 patients, 315 voice prostheses

Table 5. Overview of success rates with Provox® voice prostheses.

Authors	Prostheses	Success Rates	Comments
Hilgers et al., 1990 [6]	Provox®	91% good voice quality 88% long-term users	79 patients 67 converted from Groningen 12 primary insertion
Hilgers et al., 1993 [131]	Provox®	Fair-good voice 92%	132 patients
Callanan et al., 1995 [157]	Provox®	Good speech intelligibility	28 patients
Toma et al., 1996 [159]	Provox®	Long-term succes rate 88%	Cohort 31 patients
Ollas et al., 1996 [160]	Provox® (95) Blom-Singer (4) Groningen (2)	95% of patients had fluent voice	63 patients that were alive at time of evaluation and used a voice prosthesis
Slavicek et al., 1997 [161]	Provox® (all secondary puncture)	85% fluent speech	53 patients 372 prostheses
Cavalot et al., 1997 [163]	Provox® (16) Blom-Singer (14)	96% success	Prospective RCT Provox® vs Blom-Singer 30 patients 16 Provox® 14 Blom-Singer
Aust and McCaffrey, 1997 [164]	Provox®	88% success rate	Retrospective 21 patients 24 replacements in 13 patients
Nasser et al., 1997 [165]	Provox®	78% good to excellent speech	Prospective Mar 1994 – Sep 1996 52 patients
Delsupehe et al., 1998 [166]	Provox® Blom-Singer	Voice quality overall good and comparable for both types of prostheses	Prospective RCT 52 patients 113 prostheses
Chung et al., 1998 [132]	Provox®	lower airflow resistance by 2.1kPa	Invitro and invivo study Provox®vs. Groningen
Ahmad et al., 2000 [35]	Provox® Provox®2	82% good to average speech	Retrospective 1989-1999 100 patients converted from Blom-Singer non-indwelling to Provox®
Op de Coul et al., 2000 [32]	Provox® Provox®2	95% long-term users 88% good to fair voice quality	Retrospective Nov 1988 – May 1999 318 patients 2700 replacements
Cornu et al., 2003 [168]	Provox®	Good voice quality in 74%	Prospective 1995-1998 128 patients 63 replacements
Yamada et al., 2003 [116]	Provox®2	86% successful speech	Cohort 15 patients
Makitie et al., 2003 [40]	Provox® Provox®2	Good voice quality in 78%	Retrospective 1992 - 2002 95 patients

Authors	Prostheses	Success Rates	Comments
Ozkul et al., 2003 [46]	Provox® (204) Blom-Singer (17) Groningen (5) Turvox (5)	92% success rate Intelligibility highest for Provox® prosthesis	Retrospective (?) 231 patients
Hancock et al., 2005 [9]	Provox® NID™	Conversion successful in 14 out of 15 patients. Majority of patients prefers Provox® NID™ due to decreased speaking effort, increased speech quality, and increased safety	Feasibility study in 15 patients, conversion from Blom-Singer Low Pressure
Terada et al., 2007 [75]	Provox®2	90.6% success rate	Cohort 2002-2004 32 patients
Gonzalez Poggioli et al., 2007 [120]	Provox®2 (81) Blom-Singer (7) Herrmann (7) Groningen (1)	74% used prosthesis as usual means of communication	Retrospective Oct 2000-Dec 2005 96 patients
Bilewicz et al., 2007 [47]	Provox®2	90% of patients acquired successful TE speech	Prospective 39 TE speakers 10 esophageal speakers
Ramalingam et al., 2007 [49]	Provox®2 (21) Blom-Singer Low Pressure (20)	Better quality of voice production in Provox®2	Prospective 41 patient, comparative
Boscolo-Rizzo et al., 2008 [48]	Until Sep 2001: Blom-Singer indwelling; From Sep 2001 : Provox®2	81.7% success rate on HRS scale. Success rate similar in primary and secondary puncture	Retrospective 93 speakers
Mastronikolis et al., 2008 [53]	Provox®2 (12)	Good and intelligible speech in 80%.	Retrospective 12 patients.
Hancock et al.,2012 [17]	Provox®Vega™	Patients prefer Provox® Vega over comparator device for cleaning and maintenance, voice quality and speaking effort.	Prospective randomized cross-over trial in 31 patients
Gultekin et al., 2010 [117]	Provox®	neck dissection and postoperative radiotherapy no influence on speech	Retrospective 23 patients
Hilgers et al.,2010 [15]	Provox®Vega™	Speech better and speaking effort lower with larger diameter prostheses.	Prospective feasibility study; short term (2/3 weeks)
Ward et al,2011 [18]	Provox®Vega™	Voice perceived to be better with Provox® Vega by clinicians and patients	Prospective randomized cross-over trial in 31 patients
Lukinovic et al. 2012 [118]	Provox®2	75.8% of all patients had successful rehabilitation	Retrospective, 91 patients
Polat B, et al 2014 [173]	Provox®	Voice prosthesis improved quality of life, self-esteem and sexual function. Depression and anxiety decreased.	Uncontrolled single-arm study 30 patients

Authors	Prostheses	Success Rates	Comments
Dabholkar JP et al 2015 [137]	Provox®	70% developed a good voice, 30% an average voice.	Prospective nonrandomized cross-sectional observational study 30 patients
Serra et al 2015 [121]	Provox®, Provox® 2, Provox® Vega™	success rate 87.5 %, 84% primary TEP, 91% secondary TEP	Retrospective 95 patients
Yenigun et al 2015 [77]	Provox	Fluent and understandable speech in 85%	Retrospective 27 patients
Timmermans et al. 2016 [66]	Provox® ActiValve®	The fluoroplastic material of Provox® ActiValve® seems insusceptible to destruction by Candida	Microbiological study 33 voice prostheses
Serra et al. 2017 [24]	Provox®2 (82) Provox® Vega™ (82)	The perceptual voice data showed a better rating across all parameters for the Provox Vega in relation to Provox 2.	Multicenter prospective crossover study 82 patients
Fukushima et al. 2017 [12]	Provox®2, Provox® Vega™, PVPS	Satisfying communication outcome with Provox insertion: 78.4% (102)	Retrospective study 130 patients
Robinson et al. 2017 [13]	Provox® Vega™, PVPS	Intraoperative placement with Provox Vega: earlier voicing (13.2 vs 17.6 days), less changes due to resizing (8% vs 80%), reduced hospital stay (17.2 vs 24.5 days) and cost savings.	Prospective study 24 patients (Intraoperative = 14, delayed = 10)
Leonhard et al. 2017 [67]	Provox® ActiValve® (Provox®2 , Provox® Vega™, Blom Singer Advantage, Phonax)	Provox® ActiValve® (and Blom Singer Advantage) showed significantly less surface biofilm formation.	*In vitro* study 12 valve flaps/vp
Yang et al. 2021 [122]	Provox® models	Prosthesis length decreases over time for 2ndary TEP patients	Retrospective study 62 patients
Iype et al. 2020 [123]	Provox®1, Provox®2, Provox® Vega™	Success rates of 72% and 75%, respectively, for 1ary and 2ndary TEP patients 28% success rate for ES patients	Retrospective study 96 patients
Dragicevic et al. 2021 [113]	Provox®2	Success rate: 95% (n=101) Surgical closure of fistula: 5% (n=5)	Retrospective study 106 patients

Table 6 Overview of newly added publications

Authors	Titles	Prostheses	Comments
Pribuišis et al. 2022 [170]	Factors Affecting the Lifetime of Third-Generation Voice Prosthesis After Total Laryngectomy	Provox® Vega™	Retrospective cohort study 59 patients, 328 voice prostheses
Sarvestani et al. 2022 [149]	Molecular Characterization of Fungal Colonization on the Provox™ Tracheoesophageal Voice Prosthesis in Post Laryngectomy Patients	Provox® models	Randomized clinical trial 66 patients
Mayo-Yañez et al. 2022 [68]	Long-term outcomes and cost-effectiveness of a magnet-based valve voice prosthesis for endoprosthesis leakage treatment	Provox® Vega™, Provox® ActiValve®	Prospective cross-over study 5 patients
Mayo-Yañez et al. 2022 [169]	Prevention of periprosthetic leakage with double flange voice prosthesis: a systematic review and management protocol proposal	Provox® Vega™, Provox® ActiValve®, Provox® Vega™ XtraSeal	Systematic review 55 patients, 315 voice prostheses
Tsao et al. 2022 [129]	Comprehensive Evaluation of Vocal Outcomes and Quality of Life after Total Laryngectomy and Voice Restoration with J-Flap and Tracheoesophageal Puncture	Provox® Vega™	Prospective study 38 patients
Spalek et al. 2021 [148]	Assessment of Ceragenins in Prevention of Damage to Voice Prostheses Caused by Candida Biofilm Formation	Provox® models	*In vitro* study 60 voice prostheses
Parrilla et al. 2021 [114]	Regenerative Strategy for Persistent Periprosthetic Leakage around Tracheoesophageal Puncture: Is It an Effective Long-Term Solution?	Provox® ActiValve®, Provox® Vega™, Provox® Vega™ XtraSeal	Retrospective study 20 patients
Santos et al. 2021 [140]	Influence of position and angulation of a voice prosthesis on the aerodynamics of the pseudo-glottis	Provox®2	Numerical, In silico study Provox®2 as computational model
Apert el al. 2021 [111]	Speech restoration with tracheoesophageal prosthesis after total laryngectomy: An observational study of vocal results, complications and quality of life	Provox®2	Single center observational study 49 patients
Yang et al. 2021 [122]	The Dynamic Tracheoesophageal Prosthesis Length	Provox® models	Retrospective study 62 patients

Authors	Titles	Prostheses	Comments
Dragicevic et al. 2021 [113]	Complications following secondary voice prosthesis insertion and impact of previous irradiation on their appearance	Provox®2	Retrospective study 106 patients
Parilla et al. 2021 [70]	Periprosthetic Leakage in Tracheoesophageal Prosthesis: Proposal of a Standardized Therapeutic Algorithm	Provox® models	Retrospective study 115 patients
Parrilla et al. 2021 [112]	A one-year time frame for voice prosthesis management. What should the physician expect? Is it an overrated job?	Provox® ActiValve®, Provox® Vega™ XtraSeal	Retrospective study 243 clinical accesses by 70 patients
Iype et al. 2020 [123]	Voice Rehabilitation After Laryngectomy: A Regional Cancer Centre Experience and Review of Literature	Provox®1, Provox®2, Provox® Vega™	Retrospective study 96 patients
Spalek et al. 2020 [143]	Biofilm Growth Causes Damage to Silicone Voice Prostheses in Patients after Surgical Treatment of Locally Advanced Laryngeal Cancer	Provox® models	Prospective/*In vitro* 187 voice prostheses from 129 patients
Pentland et al. 2020 [147]	Precision Antifungal Treatment Significantly Extends Voice Prosthesis Lifespan in Patients Following Total Laryngectomy	Provox® Vega™	Prospective/*In vitro* 159 voice prostheses from 48 patients
Scherl et al. 2020 [110]	Secondary Tracheoesophageal Puncture After Laryngectomy Increases Complications With Shunt and Voice Prosthesis	Provox® Vega™ XtraSeal	Retrospective study 112 patients
Mayo-Yañez et al. 2020 [28]	Use of double flange voice prosthesis for periprosthetic leakage in laryngectomised patients: A prospective case-crossover study	Provox® Vega™ Provox® Vega™ XtraSeal	Prospective case-crossover study 20 patients

References

1. Tang, C.G. and C.F. Sinclair, *Voice Restoration After Total Laryngectomy.* Otolaryngol. Clin. North Am, 2015. **48**(4): p. 687-702.
2. Staffieri, A., et al., *Cost of tracheoesophageal prostheses in developing countries. Facing the problem from an internal perspective.* Acta Otolaryngol, 2006. **126**(1): p. 4-9.
3. Mozolewski, E., E. Zietek, and K. Jach, *Surgical rehabilitation of voice and speech after laryngectomy- Polish.* Pol. Med. Sci. Hist Bull, 1973. **15**(4): p. 373-377.
4. Singer, M.I. and E.D. Blom, *An endoscopic technique for restoration of voice after laryngectomy.* Ann. Otol. Rhinol. Laryngol, 1980. **89**(6 Pt 1): p. 529-533.
5. Manni, J.J., et al., *Voice rehabilitation after laryngectomy with the Groningen prosthesis.* J. Otolaryngol, 1984. **13**(5): p. 333-336.
6. Hilgers, F.J. and P.F. Schouwenburg, *A new low-resistance, self-retaining prosthesis (Provox) for voice rehabilitation after total laryngectomy.* Laryngoscope, 1990. **100**(11): p. 1202-1207.
7. Hilgers, F.J.M., et al., *Development and clinical evaluation of a second-generation voice prosthesis (Provox 2), designed for anterograde and retrograde insertion.* Acta Otolaryngol, 1997. **117**(6): p. 889-896.
8. Hilgers, F.J., et al., *A new problem-solving indwelling voice prosthesis, eliminating the need for frequent Candida- and "underpressure"-related replacements: Provox ActiValve.* Acta Otolaryngol, 2003. **123**(8): p. 972-979.
9. Hancock, K., et al., *First clinical experience with a new non-indwelling voice prosthesis (Provox NID) for voice rehabilitation after total laryngectomy.* Acta Otolaryngol, 2005. **125**(9): p. 981-990.
10. Hilgers, F.J., et al., *Development and (pre-) clinical assessment of a novel surgical tool for primary and secondary tracheoesophageal puncture with immediate voice prosthesis insertion, the Provox Vega Puncture Set.* Eur. Arch. Otorhinolaryngol, 2013. **270**(1): p. 255-262.
11. Lorenz, K.J., F.M. Hilgers, and H. Maier, *[A novel puncture instrument: the Provox-Vega(R) puncture set : Its use in voice prosthesis insertion following laryngectomy] in German.* HNO, 2013. **61**(1): p. 30-37.
12. Fukushima, H., et al., *Indwelling voice prosthesis insertion after total pharyngolaryngectomy with free jejunal reconstruction.* Laryngoscope Investigative Otolaryngology, 2017. **2**(1): p. 30-35.
13. Robinson, R.A., et al., *Total laryngectomy with primary tracheoesophageal puncture: Intraoperative versus delayed voice prosthesis placement.* Head Neck, 2017. **39**(6): p. 1138-1144.
14. Ricci, E., et al., *In-clinic secondary tracheoesophageal puncture and voice prosthesis placement in laryngectomees.* Eur Ann Otorhinolaryngol Head Neck Dis, 2018. **135**(5): p. 349-352.
15. Hilgers, F.J., et al., *Clinical phase I/feasibility study of the next generation indwelling Provox voice prosthesis (Provox Vega).* Acta Otolaryngol, 2010. **130**(4): p. 511-519.

16. Hilgers, F.J., et al., *Prospective clinical phase II study of two new indwelling voice prostheses (Provox Vega 22.5 and 20 Fr) and a novel anterograde insertion device (Provox Smart Inserter).* Laryngoscope, 2010. **120**(6): p. 1135-1143.

17. Hancock, K., et al., *A prospective, randomized comparative study of patient perceptions and preferences of two types of indwelling voice prostheses.* Int. J. Lang Commun. Disord, 2012. **47**(3): p. 300-309.

18. Ward, E.C., et al., *Perceptual characteristics of tracheoesophageal speech production using the new indwelling Provox Vega voice prosthesis: a randomized controlled crossover trial.* Head Neck, 2011. **33**(1): p. 13-19.

19. Lorenz, K.J. and H. Maier, *[Voice rehabilitation after laryngectomy : Initial clinical experience with the Provox-Vega(R) voice prosthesis and the SmartInserter(R) system.] in German.* HNO, 2010. **58**(12): p. 1174-1183.

20. Schafer, P., K. P, and F. Schwerdtfeger. *Provox 2 und Provox Vega Stimmprothesen- gibt es Unterschiede inder Verweildauer?* 2011.

21. Hancock, K.L., N.R. Lawson, and E.C. Ward, *Device life of the Provox Vega voice prosthesis.* Eur. Arch. Otorhinolaryngol, 2013. **270**(4): p. 1447-1453.

22. Kress, P., et al., *Are modern voice prostheses better? A lifetime comparison of 749 voice prostheses.* Eur. Arch. Otorhinolaryngol, 2014. **271**(1): p. 133-140.

23. Thylur, D.S., et al., *Device Life of Two Generations of Provox Voice Prostheses.* Ann Otol Rhinol Laryngol, 2016. **125**(6): p. 501-7.

24. Serra, A., et al., *Multicenter prospective crossover study on new prosthetic opportunities in post-laryngectomy voice rehabilitation.* J Biol Regul Homeost Agents, 2017. **31**(3): p. 803-809.

25. Lewin, J.S., et al., *Device Life of the Tracheoesophageal Voice Prosthesis Revisited.* JAMA Otolaryngol Head Neck Surg, 2017. **143**(1): p. 65-71.

26. Mayo-Yanez, M., et al., *Provox 2((R)) and Provox Vega((R)) device life-time: a case-crossover study with multivariate analysis of possible influential factors and duration.* Eur Arch Otorhinolaryngol, 2018. **275**(7): p. 1827-1830.

27. Petersen, J.F., et al., *Postlaryngectomy prosthetic voice rehabilitation outcomes in a consecutive cohort of 232 patients over a 13-year period.* Head Neck, 2019. **41**(3): p. 623-631.

28. Mayo-Yanez, M., et al., *Use of double flange voice prosthesis for periprosthetic leakage in laryngectomized patients: a prospective case-crossover study.* Clin Otolaryngol, 2020.

29. Koscielny, S. and B. Brauer, *[What is the best system for changing of voice prosthesis - Provox1 or Provox2?] in German.* Otorhinolaryngol Nova, 2000. **10**(April): p. 5.

30. Graville, D., et al., *The long-term indwelling tracheoesophageal prosthesis for alaryngeal voice rehabilitation.* Arch. Otolaryngol. Head Neck Surg, 1999. **125**(3): p. 288-292.

31. Ackerstaff, A.H., et al., *Multi-institutional assessment of the Provox 2 voice prosthesis.* Arch. Otolaryngol. Head Neck Surg, 1999. **125**(2): p. 167-173.

32. Op de Coul, B.M., et al., *A decade of postlaryngectomy vocal rehabilitation in 318 patients: a single Institution's experience with consistent application of provox indwelling voice prostheses.* Arch. Otolaryngol. Head Neck Surg, 2000. **126**(11): p. 1320-1328.

33. Balle, V.H., L. Rindso, and J.C. Thomsen, *Primary speech restoration at laryngectomy by insertion of voice prosthesis--10 years experience.* Acta Otolaryngol. Suppl, 2000. **543**: p. 244-245.

34. Lequeux, T., et al., *A comparison of survival lifetime of the Provox and the Provox2 voice prosthesis.* J. Laryngol. Otol, 2003. **117**(11): p. 875-878.

35. Ahmad, I., et al., *Surgical voice restoration following ablative surgery for laryngeal and hypopharyngeal carcinoma.* J. Laryngol. Otol, 2000. **114**(7): p. 522-525.

36. Schafer, P., N. Klutzke, and F.P. Schwerdtfeger, *[Voice restoration with voice prosthesis after total laryngectomy. Assessment of survival time of 378 Provox-1, Provox-2 and Blom-Singer voice prosthesis] in German.* Laryngorhinootologie, 2001. **80**(11): p. 677-681.

37. Hotz, M.A., et al., *Success and predictability of provox prosthesis voice rehabilitation.* Arch. Otolaryngol. Head Neck Surg, 2002. **128**(6): p. 687-691.

38. Fajdiga, I., I.H. Boltezar, and M. Zargi, *Voice prostheses - ten years after*. 2002.

39. Trussart, C., G. Lawson, and M. Remacle, *Voice prostheses: long-term follow-up retrospective study (three- to sixteen-year follow-up of 22 patients).* Rev. Laryngol. Otol. Rhinol. (Bord.), 2003. **124**(5): p. 299-304.

40. Makitie, A.A., et al., *Postlaryngectomy voice restoration using a voice prosthesis: a single institution's ten-year experience.* Ann. Otol. Rhinol. Laryngol, 2003. **112**(12): p. 1007-1010.

41. Demir, D., et al., *[Factors that affect in situ lifetime of Provox voice prosthesis] in Turkish.* Kulak. Burun. Bogaz. Ihtis. Derg, 2004. **13**(5-6): p. 126-131.

42. Morshed, K., et al., *[Speech rehabilitation using Provox voice prosthesis] in Polish.* Otolaryngol. Pol, 2005. **59**(2): p. 225-228.

43. Lam, P.K., et al., *Long-term performance of indwelling tracheoesophageal speaking valves in Chinese patients undergoing laryngectomy.* Arch. Otolaryngol. Head Neck Surg, 2005. **131**(11): p. 954-958.

44. Calder, N., C. MacAndie, and F. MacGregor, *Tracheoesophageal voice prostheses complications in north Glasgow.* J. Laryngol. Otol, 2006. **120**(6): p. 487-491.

45. Elving, G.J., et al., *The influence of radiotherapy on the lifetime of silicone rubber voice prostheses in laryngectomized patients.* Laryngoscope, 2002. **112**(9): p. 1680-1683.

46. Ozkul, M.D., et al., *Ten-year experience with voice prosthesis*. 2003.

47. Bilewicz, R., et al., *[The surgery voice rehabilitation after total laryngectomy with the Provox system] in Polish.* Otolaryngol. Pol, 2007. **61**(3): p. 265-270.

48. Boscolo-Rizzo, P., et al., *Long-term results with tracheoesophageal voice prosthesis: primary versus secondary TEP.* Eur. Arch. Otorhinolaryngol, 2008. **265**(1): p. 73-77.

49. Ramalingam, W., et al., *Tracheo-esophageal Puncture (TEP) for Voice Rehabilitation in Laryngectomised Patients Blom-singer Vs Provox Prosthesis: Our Experience.* MJAFI, 2007. **63**(1): p. 15-18.

50. Boscolo-Rizzo, P., et al., *The impact of radiotherapy and GERD on in situ lifetime of indwelling voice prostheses.* Eur. Arch. Otorhinolaryngol, 2008. **265**(7): p. 791-796.

51. Tammam, N., *Voice Rehabilitation using Provox following Total Laryngectomy in Bahrain. A preliminary Report on 5 Cases*, in *Journal of Bahrain Medical Society*, A. MM, Editor. 2009. p. 275-279.

52. Bozec, A., et al., *Results of vocal rehabilitation using tracheoesophageal voice prosthesis after total laryngectomy and their predictive factors.* Eur. Arch. Otorhinolaryngol, 2010. **267**(5): p. 751-758.

53. Mastronikolis, N.S., et al., *Voice restoration after total laryngectomy using provox 2 (generation II) prosthesis.* Eur. Rev. Med. Pharmacol. Sci, 2008. **12**(5): p. 327-330.

54. Wierzchowska, M. and P.K. Burduk, *[Early and late complications after implantation of the Provox 2 voice prosthesis in patients after total laryngectomy] - Abstract only, article in Polish.* Otolaryngol. Pol, 2011. **65**(3): p. 184-187.

55. Issing, W.J., S. Fuchshuber, and M. Wehner, *Incidence of tracheo-oesophageal fistulas after primary voice rehabilitation with the Provox or the Eska-Herrmann voice prosthesis.* Eur. Arch. Otorhinolaryngol, 2001. **258**(5): p. 240-242.

56. Boci, B., R. Isufi, and K. Thomai, *Postlaryngectomy vocal rehabilitation in Albania.* J. BUON, 2012. **17**(3): p. 478-482.

57. Zimmer-Nowicka, J. and A. Morawiec-Sztandera, *[Causes and indwelling times of multiple voice prosthesis replacements in patients after total laryngectomy - analysis of 184 replacements in 42 patients] in Polish.* Otolaryngol. Pol, 2012. **66**(5): p. 322-327.

58. Kilic, C., U. Tuncel, and E. Comert, *[Provox 2 use for voice restoration after total laryngectomy] in Turkish.* Kulak. Burun. Bogaz. Ihtis. Derg, 2014. **24**(6): p. 339-343.

59. Messing, B.P., et al., *Evaluation of prophylaxis treatment of Candida in alaryngeal patients with tracheoesophageal voice prostheses.* Laryngoscope, 2015. **125**(5): p. 1118-1123.

60. Friedlander, E., et al., *Practical management of periprosthetic leakage in patients rehabilitated with a Provox(R) 2 voice prosthesis after total laryngectomy.* Acta Otorrinolaringol Esp, 2016. **67**(6): p. 301-305.

61. Fukuhara, T., et al., *Post-laryngectomy voice rehabilitation with a voice prosthesis in a young girl with advanced thyroid cancer.* Auris Nasus Larynx, 2016. **43**(5): p. 579-83.

62. Lewin, J.S., et al., *Clinical application of the Provox NiD voice prosthesis: a longitudinal study.* Laryngoscope, 2014. **124**(7): p. 1585-1591.

63. Vlantis, A.C., et al., *Conversion from a non-indwelling to a Provox2 indwelling voice prosthesis for speech rehabilitation: comparison of voice quality and patient preference.* J. Laryngol. Otol, 2003. **117**(10): p. 815-820.

64. Soolsma, J., et al., *Long-term results of Provox ActiValve, solving the problem of frequent candida- and "underpressure"-related voice prosthesis replacements.* Laryngoscope, 2008. **118**(2): p. 252-257.

65. Graville, D.J., et al., *Determining the efficacy and cost-effectiveness of the ActiValve: results of a long-term prospective trial.* Laryngoscope, 2011. **121**(4): p. 769-776.

66. Timmermans, A.J., et al., *Biofilm formation on the Provox ActiValve: Composition and ingrowth analyzed by Illumina paired-end RNA sequencing, fluorescence in situ hybridization, and confocal laser scanning microscopy.* Head Neck, 2016. **38 Suppl 1**: p. E432-40.

67. Leonhard, M., et al., *In vitro biofilm growth on modern voice prostheses.* Head Neck, 2017. **40**(4): p. 763-769.

68. Mayo-Yanez, M., et al., *Long-term outcomes and cost-effectiveness of a magnet-based valve voice prosthesis for endoprosthesis leakage treatment.* Eur Arch Otorhinolaryngol, 2022.

69. Petersen, J.F., et al., *Solving periprosthetic leakage with a novel prosthetic device.* Laryngoscope, 2018.

70. Parrilla, C., et al., *Periprosthetic Leakage in Tracheoesophageal Prosthesis: Proposal of a Standardized Therapeutic Algorithm.* Otolaryngol Head Neck Surg, 2021: p. 194599820983343.

71. van Weissenbruch, R., et al., *Deterioration of the Provox silicone tracheoesophageal voice prosthesis: microbial aspects and structural changes.* Acta Otolaryngol, 1997. **117**(3): p. 452-458.

72. Natarajan, B., et al., *The Provox voice prosthesis and Candida albicans growth: a preliminary report of clinical, mycological and scanning electron microscopic assessment.* J. Laryngol. Otol, 1994. **108**(8): p. 666-668.

73. Buijssen, K.J., et al., *Lactobacilli: important in biofilm formation on voice prostheses.* Otolaryngol. Head Neck Surg, 2007. **137**(3): p. 505-507.

74. Fusconi, M., et al., *Degradation of silicone rubber causes provox 2 voice prosthesis malfunctioning.* J Voice, 2014. **28**(2): p. 250-254.

75. Terada, T., et al., *Voice rehabilitation with Provox2 voice prosthesis following total laryngectomy for laryngeal and hypopharyngeal carcinoma.* Auris Nasus Larynx, 2007. **34**(1): p. 65-71.

76. Bien, S. and S. Okla, *[Analysis of complications after surgical voice and speech rehabilitation in laryngectomized patients. Problems related to implantation and change of voice prosthesis] in Polish.* Otolaryngol. Pol, 2006. **60**(2): p. 129-134.

77. Yenigun, A., et al., *Factors influencing the longevity and replacement frequency of Provox voice prostheses.* Singapore. Med. J, 2015. **56**(11): p. 632-636.

78. van Weissenbruch, R. and F.W. Albers, *Vocal rehabilitation after total laryngectomy using the Provox voice prosthesis.* Clin. Otolaryngol. Allied Sci, 1993. **18**(5): p. 359-364.

79. de Carpentier, J.P., et al., *Survival times of Provox valves.* J. Laryngol. Otol, 1996. **110**(1): p. 37-42.

80. Lorenz, K.J., et al., *Role of reflux in tracheoesophageal fistula problems after laryngectomy.* Ann. Otol. Rhinol. Laryngol, 2010. **119**(11): p. 719-728.

81. Margolin, G., et al., *Leakage around voice prosthesis in laryngectomees: treatment with local GM-CSF.* Head Neck, 2001. **23**(11): p. 1006-1010.

82. Op de Coul, B.M., et al., *A decade of postlaryngectomy vocal rehabilitation in 318 patients: a single Institution's experience with consistent application of provox indwelling voice prostheses.* Arch. Otolaryngol. Head Neck Surg, 2000. **126**(11): p. 1320-1328.

83. Krishnamurthy, A. and S. Khwajamohiuddin, *Analysis of Factors Affecting the Longevity of Voice Prosthesis Following Total Laryngectomy with a Review of Literature.* Indian J Surg Oncol, 2018. **9**(1): p. 39-45.

84. Mayo-Yanez, M., *Analysis of Factors Affecting the Longevity of Voice Prosthesis Following Total Laryngectomy with a Review of Literature.* Indian J Surg Oncol, 2019. **10**(1): p. 219.

85. Chaturvedi, P., et al., *Microbial colonization of Provox voice prosthesis in the Indian scenario.* Indian J Cancer, 2014. **51**(2): p. 184-188.

86. Free, R.H., et al., *Biofilm formation on voice prostheses: influence of dairy products in vitro.* Acta Otolaryngol, 2000. **120**(1): p. 92-99.

87. van Weissenbruch, R., et al., *Chemoprophylaxis of fungal deterioration of the Provox silicone tracheoesophageal prosthesis in postlaryngectomy patients.* Ann. Otol. Rhinol. Laryngol, 1997. **106**(4): p. 329-337.

88. Ameye, D., et al., *Effect of a buccal bioadhesive nystatin tablet on the lifetime of a Provox silicone tracheoesophageal voice prosthesis.* Acta Otolaryngol, 2005. **125**(3): p. 304-306.

89. Schwandt, L.Q., et al., *Effect of dairy products on the lifetime of Provox2 voice prostheses in vitro and in vivo.* Head Neck, 2005. **27**(6): p. 471-477.

90. Holmes, A.R., et al., *Yeast colonization of voice prostheses: pilot study investigating effect of a bovine milk product containing anti-Candida albicans immunoglobulin A antibodies on yeast colonization and valve leakage.* Ann. Otol. Rhinol. Laryngol, 2012. **121**(1): p. 61-66.

91. Ol'shanskii, V.O., et al., *[Microflora of the voice prostheses] in Russian.* Vestn. Otorinolaringol, 2004(1): p. 61-63.

92. Somogyi-Ganss, E., et al., *Biofilm on the tracheoesophageal voice prosthesis: considerations for oral decontamination.* Eur Arch Otorhinolaryngol, 2016. **274**(1): p. 405-413.

93. Rodrigues, L., et al., *Strategies for the prevention of microbial biofilm formation on silicone rubber voice prostheses.* J. Biomed. Mater. Res. B Appl. Biomater, 2007. **81**(2): p. 358-370.

94. Brasnu, D., et al., *[Results of the treatment of spontaneous widening of tracheo-esophageal punctures after laryngeal implant] in French.* Ann. Otolaryngol. Chir Cervicofac, 1994. **111**(8): p. 456-460.

95. Luff, D.A., S. Izzat, and W.T. Farrington, *Viscoaugmentation as a treatment for leakage around the Provox 2 voice rehabilitation system.* J. Laryngol. Otol, 1999. **113**(9): p. 847-848.

96. Lorincz, B.B., et al., *Therapy of periprosthetical leakage with tissue augmentation using Bioplastique around the implanted voice prosthesis.* Eur. Arch. Otorhinolaryngol, 2005. **262**(1): p. 32-34.

97. Rokade, A.V., J. Mathews, and K.T. Reddy, *Tissue augmentation using Bioplastique as a treatment of leakage around a Provox 2 voice prosthesis.* J. Laryngol. Otol, 2003. **117**(1): p. 80-82.

98. Vollrath, M., *[Surgery of persisting tracheo-esophageal provox-fistula] in German.* Laryngorhinootologie, 2010. **89**(5): p. 262-264.

99. Hiltmann, O., M. Buntrock, and R. Hagen, *[Mechanical ileus caused by a Provox voice prosthesis -- an "iatrogenic" enteral complication in voice prosthesis rehabilitation of laryngectomees] in German.* Laryngorhinootologie, 2002. **81**(12): p. 890-893.

100. Scheuermann, K. and K.W. Delank, *[Perforation of the esophagus with a mediastinal abscess] in German.* HNO, 2005. **53**(1): p. 66-70.

101. Bozzo, C., et al., *Mediastinal abscess and esophageal stricture following voice prosthesis insertion.* Auris Nasus Larynx, 2014. **41**(2): p. 229-233.

102. Counter, P., et al., *Unusual complication of surgical voice restoration.* J. Laryngol. Otol, 2004. **118**(2): p. 148-149.

103. Smith, W.K. and A.G. Pfleiderer, *The use of the KTP laser in the management of hypertrophic tracheal mucosa and granulation tissue around Provox valve protheses.* J. Laryngol. Otol, 2003. **117**(1): p. 60-62.

104. Gonzalez-Garcia, J.A. and J.I. Aguirregaviria, *Total voice prosthesis incarceration in the trachaeo-oesophageal mucosa. Report of a new complication when using phonatory prostheses.* Acta Otorrinolaringol. Esp, 2010. **61**(3): p. 220-224.

105. Hadzibegovic, A.D., et al., *Analysis of saliva pepsin level in patients with tracheoesophageal fistula and voice prosthesis complications.* Coll. Antropol, 2012. **36 Suppl 2**: p. 93-97.

106. Lorenz, K.J., et al., *Role of reflux-induced epithelial-mesenchymal transition in periprosthetic leakage after prosthetic voice rehabilitation.* Head Neck, 2015. **37**(4): p. 530-536.

107. Lorenz, K.J. and S. Nolte, *[Solving problems after rehabilitation with voice prostheses : Two rare cases of fistula-related complications] in German.* Hno, 2016. **64**(7): p. 508-14.

108. Calkovsky, V. and A. Hajtman, *Primary prosthetic voice rehabilitation in patients after laryngectomy: applications and pitfalls.* Adv. Exp. Med. Biol, 2015. **852**: p. 11-16.

109. Cocuzza, S., et al., *Relationship between radiotherapy and gastroesophageal reflux disease in causing tracheoesophageal voice rehabilitation failure.* J Voice, 2014. **28**(2): p. 245-249.

110. Scherl, C., et al., *Secondary Tracheoesophageal Puncture After Laryngectomy Increases Complications With Shunt and Voice Prosthesis.* Laryngoscope, 2020.

111. Apert, V., et al., *Speech restoration with tracheoesophageal prosthesis after total laryngectomy: An observational study of vocal results, complications and quality of life.* Eur Ann Otorhinolaryngol Head Neck Dis, 2021.

112. Parrilla, C., et al., *A one-year time frame for voice prosthesis management. What should the physician expect? Is it an overrated job?* Acta Otorhinolaryngol Ital, 2020. **40**(4): p. 270-276.

113. Dragicevic, D.M., et al., *Complications following secondary voice prosthesis insertion and impact of previous irradiation on their appearance.* Niger J Clin Pract, 2021. **24**(4): p. 470-475.

114. Parrilla, C., et al., *Regenerative Strategy for Persistent Periprosthetic Leakage around Tracheoesophageal Puncture: Is It an Effective Long-Term Solution?* Cells, 2021. **10**(7).

115. Baumann, A., M.A. Hotz, and P. Zbaren, *[Results of voice rehabilitation with Provox prostheses] in German.* Schweiz. Med. Wochenschr. Suppl, 2000. **116**: p. 77S-79S.

116. Yamada, H., et al., *[Voice rehabilitation after total laryngectomy using the Provox voice prosthesis] - Abstract only, article in Japanese.* Nippon Jibiinkoka Gakkai Kaiho, 2003. **106**(11): p. 1093-1099.

117. Gultekin, E., et al., *Effects of neck dissection and radiotherapy on short-term speech success in voice prosthesis restoration patients.* J Voice, 2011. **25**(2): p. 245-248.

118. Lukinovic, J., et al., *Overview of 100 patients with voice prosthesis after total laryngectomy--experience of single institution.* Coll. Antropol, 2012. **36 Suppl 2**: p. 99-102.

119. Kummer, P., et al., *[Prosthetic voice rehabilitation after laryngectomy. Failures and complications after previous radiation therapy] in German.* HNO, 2006. **54**(4): p. 315-322.

120. Gonzalez, P.N., et al., *Phonation fistulas today.* Acta Otorrinolaringol. Esp, 2007. **58**(3): p. 110-112.

121. Serra, A., et al., *Post-laryngectomy voice rehabilitation with voice prosthesis: 15 years experience of the ENT Clinic of University of Catania. Retrospective data analysis and literature review.* Acta Otorhinolaryngol Ital, 2015. **35**(6): p. 412-419.

122. Yang, S., et al., *The Dynamic Tracheoesophageal Prosthesis Length.* J Voice, 2021.

123. Iype, E.M., et al., *Voice Rehabilitation After Laryngectomy: A Regional Cancer Centre Experience and Review of Literature.* Indian J Otolaryngol Head Neck Surg, 2020. **72**(4): p. 518-523.

124. Benazzo, M., et al., *Voice restoration after circumferential pharyngolaryngectomy with free jejunum repair.* Eur. Arch. Otorhinolaryngol, 2001. **258**(4): p. 173-176.

125. Panarese, A., et al., *Vocal rehabilitation after pharyngo-laryngectomy--the Provox valve.* Clin. Otolaryngol. Allied Sci, 1994. **19**(5): p. 427-429.

126. Hilgers, F.J.M., et al., *Prosthetic voice rehabilitation with Provox system after extensive pharyngeal resection and reconstruction*. 1996.

127. Baijens, L.W., et al., *Rehabilitation program for prosthetic tracheojejunal voice production and swallowing function following circumferential pharyngolaryngectomy and neopharyngeal reconstruction with a jejunal free flap.* Dysphagia, 2011. **26**(1): p. 78-84.

128. Reumueller, A., et al., *Pharyngolaryngectomy with free jejunal autograft reconstruction and tracheoesophageal voice restoration: Indications for replacements, microbial colonization, and indwelling times of the Provox 2 voice prostheses.* Head Neck, 2011. **33**(8): p. 1144-1153.

129. Tsao, C.K., et al., *Comprehensive Evaluation of Vocal Outcomes and Quality of Life after Total Laryngectomy and Voice Restoration with J-Flap and Tracheoesophageal Puncture.* Cancers (Basel), 2022. **14**(3).

130. Heaton, J.M. and A.J. Parker, *In vitro comparison of the Groningen high resistance, Groningen low resistance and Provox speaking valves.* J. Laryngol. Otol, 1994. **108**(4): p. 321-324.

131. Hilgers, F.J., M.W. Cornelissen, and A.J. Balm, *Aerodynamic characteristics of the Provox low-resistance indwelling voice prosthesis.* Eur. Arch. Otorhinolaryngol, 1993. **250**(7): p. 375-378.

132. Chung, R.P., et al., *In vitro and in vivo comparison of the low-resistance Groningen and the Provox tracheosophageal voice prostheses.* Rev. Laryngol. Otol. Rhinol. (Bord.), 1998. **119**(5): p. 301-306.

133. Miani, C., et al., *Dynamic behavior of the Provox and Staffieri prostheses for voice rehabilitation following total laryngectomy.* Eur. Arch. Otorhinolaryngol, 1998. **255**(3): p. 143-148.

134. Belforte, G., et al., *Staffieri tracheo-oesophageal prosthesis for voice rehabilitation after laryngectomy: an evaluation of characteristics.* Med. Biol. Eng Comput, 1998. **36**(6): p. 754-760.

135. van den Hoogen, F.J., et al., *A prospective study of speech and voice rehabilitation after total laryngectomy with the low-resistance Groningen, Nijdam and Provox voice prostheses.* Clin. Otolaryngol. Allied Sci, 1998. **23**(5): p. 425-431.

136. Heaton, J.M., et al., *Speech assessment of patients using three types of indwelling tracheo-oesophageal voice prostheses.* J. Laryngol. Otol, 1996. **110**(4): p. 343-347.

137. Dabholkar, J.P., N.M. Kapre, and H.K. Gupta, *Results of Voice Rehabilitation With Provox Prosthesis and Factors Affecting the Voice Quality.* J. Voice, 2015. **29**(6): p. 777 e1-8.

138. Schwandt, L.Q., et al., *Differences in aerodynamic characteristics of new and dysfunctional Provox 2 voice prostheses in vivo.* Eur. Arch. Otorhinolaryngol, 2006. **263**(6): p. 518-523.

139. Kress, P., et al., *Measurement and comparison of in vitro air-flow characteristics of the most frequently used European indwelling voice prostheses types*. 2007.

140. Santos, F.H.T., et al., *Influence of position and angulation of a voice prosthesis on the aerodynamics of the pseudo-glottis.* J Biomech, 2021. **125**: p. 110594.

141. Balm, A.J., et al., *The indwelling voice prosthesis for speech rehabilitation after total laryngectomy: a safe approach.* Otolaryngol. Pol, 2011. **65**(6): p. 402-409.

142. Tsikopoulos, A., et al., *In vitro Inhibition of Biofilm Formation on Silicon Rubber Voice Prosthesis: Alpha Systematic Review and Meta-Analysis.* ORL J Otorhinolaryngol Relat Spec, 2022. **84**(1): p. 10-29.

143. Spalek, J., et al., *Biofilm Growth Causes Damage to Silicone Voice Prostheses in Patients after Surgical Treatment of Locally Advanced Laryngeal Cancer.* Pathogens, 2020. **9**(10).

144. Galli, J., et al., *Biofilm in voice prosthesis: a prospective cohort study and laboratory tests using sonication and SEM analysis.* Clin Otolaryngol, 2018.

145. Ticac, B., et al., *Microbial colonization of tracheoesophageal voice prostheses (Provox2) following total laryngectomy.* Eur. Arch. Otorhinolaryngol, 2010. **267**(10): p. 1579-1586.

146. Nowak, M. and P. Kurnatowski, *[Candida biofilm formation on Provox 2 and Provox Acti Valve voice prosthesis] in Polish.* Otolaryngol. Pol, 2010. **64**(6): p. 358-364.

147. Pentland, D.R., et al., *Precision Antifungal Treatment Significantly Extends Voice Prosthesis Lifespan in Patients Following Total Laryngectomy.* Front Microbiol, 2020. **11**: p. 975.

148. Spalek, J., et al., *Assessment of Ceragenins in Prevention of Damage to Voice Prostheses Caused by Candida Biofilm Formation.* Pathogens, 2021. **10**(11).

149. Sarvestani, H.K., et al., *Molecular Characterization of Fungal Colonization on the Provox Tracheoesophageal Voice Prosthesis in Post Laryngectomy Patients.* Iran J Public Health, 2022. **51**(1): p. 151-159.

150. Lorenz, K.J., *The development and treatment of periprosthetic leakage after prosthetic voice restoration: a literature review and personal experience. Part II: conservative and surgical management.* Eur. Arch. Otorhinolaryngol, 2015. **272**(3): p. 661-672.

151. Free, R.H., et al., *Influence of the Provox Flush, blowing and imitated coughing on voice prosthetic biofilms in vitro.* Acta Otolaryngol, 2003. **123**(4): p. 547-551.

152. Brook, I., *The laryngectomee guide for Covid-19 pandemic*. 2020: Lulu.com.

153. Erdim, I., et al., *Treatment of large persistent tracheoesophageal peristomal fistulas using silicon rings.* Braz J Otorhinolaryngol, 2016. **83**(5): p. 536-540.

154. Balle, V.H. and J.C. Thomsen, *[Speech rehabilitation after laryngectomy, primary insertion of a speech ventilator] in Danish.* Ugeskr. Laeger, 1993. **155**(14): p. 1053-1055.

155. Hilgers, F.J. and A.J. Balm, *Long-term results of vocal rehabilitation after total laryngectomy with the low-resistance, indwelling Provox voice prosthesis system.* Clin. Otolaryngol. Allied Sci, 1993. **18**(6): p. 517-523.

156. Heaton, J.M. and A.J. Parker, *Indwelling tracheo-oesophageal voice prostheses post-laryngectomy in Sheffield, UK: a 6-year review.* Acta Otolaryngol, 1994. **114**(6): p. 675-678.

157. Callanan, V., et al., *Provox valve use for post-laryngectomy voice rehabilitation.* J. Laryngol. Otol, 1995. **109**(11): p. 1068-1071.

158. van den Hoogen, F.J., et al., *The Groningen, Nijdam and Provox voice prostheses: a prospective clinical comparison based on 845 replacements.* Acta Otolaryngol, 1996. **116**(1): p. 119-124.

159. Toma, A., et al., *Provox valve use for postlaryngectomy voice rehabilitation*. 1996.

160. Oilas, J., et al., *Implantes Fonatórios. Revisão de 101 casos. Portugues.* Revista Portuguesa de Otorrinolaringologia, 1996. **34**(1): p. 21-29.

161. Slavicek, A., et al., *[Voice rehabilitation with the Provox system after total laryngectomy] in Czech.* Sb Lek, 1997. **98**(4): p. 287-299.

162. Laccourreye, O., et al., *In situ lifetime, causes for replacement, and complications of the Provox voice prosthesis.* Laryngoscope, 1997. **107**(4): p. 527-530.

163. Cavalot, A.L., et al., *[The use of indwelling phonatory valve in the rehabilitation of laryngectomized patients: preliminary results in 30 patients] in Italian.* Acta Otorhinolaryngol. Ital, 1997. **17**(2): p. 109-114.

164. Aust, M.R. and T.V. McCaffrey, *Early speech results with the Provox prosthesis after laryngectomy.* Arch. Otolaryngol. Head Neck Surg, 1997. **123**(9): p. 966-968.

165. Nasser, T., et al., *Réhabilitation vocale par prothèse phonatoire après laryngectomie*. 1997.

166. Delsupehe, K., et al., *Prospective randomized comparative study of tracheoesophageal voice prosthesis: Blom-Singer versus Provox.* Laryngoscope, 1998. **108**(10): p. 1561-1565.

167. Biacabe, B., et al., *[Replacement of tracheo-esophageal Provox prosthesis] in French.* Ann. Otolaryngol. Chir Cervicofac, 2000. **117**(1): p. 34-39.

168. Cornu, A.S., et al., *Voice rehabilitation after laryngectomy with the Provox voice prosthesis in South Africa.* J. Laryngol. Otol, 2003. **117**(1): p. 56-59.

169. Mayo-Yanez, M., et al., *Prevention of periprosthetic leakage with double flange voice prosthesis: a systematic review and management protocol proposal.* Logoped Phoniatr Vocol, 2022: p. 1-8.

170. Pribuisis, K., et al., *Factors Affecting the Lifetime of Third-Generation Voice Prosthesis After Total Laryngectomy.* J Voice, 2022.

171. de Raucourt, D., et al., *[Voice rehabilitation with a voice prosthesis. Study of 62 patients with 5 years follow-up] in French.* Rev. Laryngol. Otol. Rhinol. (Bord.), 1998. **119**(5): p. 297-300.

172. Imre, A., et al., *Complications of tracheoesophageal puncture and speech valves: retrospective analysis of 47 patients - Abstract only.* Kulak Burun Bogaz Ihtis Derg, 2013. **23**(1): p. 15-20.

173. Polat, B., et al., *The effects of indwelling voice prosthesis on the quality of life, depressive symptoms, and self-esteem in patients with total laryngectomy.* Eur. Arch. Otorhinolaryngol, 2015. **272**(11): p. 3431-3437.

Internal References

[1] "Voice Prosthesis Literature Inventory_2022"

[2] "Piecharts Voice Prosthesis Literature Inventory_2022"

Appendix 1

The Provox® voice prosthesis

The first Provox® voice prosthesis was bi-flanged and made of medical grade silicone rubber. The esophageal flange was more rigid than the tracheal flange. The outer diameter was 22.5 French and the prosthesis was available in several lengths. The valve was molded in one piece with the prosthesis and was supported by a fluoroplastic valve seat (blue ring that is tightly secured into the shaft of the prosthesis and that is radiopaque). This first Provox® prosthesis was (re)placed retrograde through the oral cavity by means of a Provox® GuideWire, see Figure 13. The Provox® voice prosthesis was discontinued in 2016, however the Provox® Guidewire remains available for retrograde replacement of indwelling Provox® voice prostheses.

A surgical set consisting of a Provox® Trocar and Cannula and Provox® Pharynx Protector was available for creating a tracheoesophageal puncture and the Provox® Guidewire was then threaded through the Trocar for retrograde placement of the voice prosthesis. This surgical set was discontinued in 2016 when the Provox® Vega™ Puncture Set became the method of choice.

In addition to the Provox® voice prostheses, a surgical TE puncture system consisting of a Pharynx protector, Cannula, and Trocar, a cleaning Brush, and a Plug to temporarily prevent leakage through the prosthesis were developed [155].

Figure 13 Picture of the first Provox® voice prosthesis with Provox® GuideWire insertion system.

Device Life, Success Rates, and Complications

The first results with the Provox® voice prosthesis were described by Hilgers and Schouwenburg [6] who reported on 79 laryngectomized patients. Sixty-seven of them used a Groningen prosthesis that was replaced by the new Provox® prosthesis, in nine of them the prosthesis was placed during a secondary puncture, and in 12 the prosthesis was placed at the time of laryngectomy. *In vitro* and *in vivo* airflow characteristics were favorable; all 67 patients whom previously used the Groningen prosthesis experienced lower airflow resistance. Ninety-one percent of the patients achieved good voice quality. Eighty percent kept using the prosthesis successfully in the long-term (9% died, 6.7% had the fistula closed, and in 3.5% the correct size was not available during the trial). The mean device life was 154 days. Replacement was successfully carried out in the outpatient setting, but in 3 patients it was complicated due to severe hypopharyngeal stenosis. Complications were short-term enlarged fistula in eight patients (solved with shrinkage of the puncture tract by removing the prosthesis for some days),

fistula closure in three patients due to hypertrophic scarring, and fistula closure in three due to intractable leakage around the prosthesis. The prosthesis was found to be easy to maintain.

Balle and Thomsen [154], in a paper in Danish, state that the Provox® voice prosthesis had several advantages over their previously routinely used Bivona Duckbill prosthesis. They found it advantageous that the prosthesis retained well in the fistula, that the lumen was larger, and that the device life was longer (6 to 18 months as compared to 1 to 3 months).

Van Weissenbruch and Albers [78] prospectively studied 37 laryngectomized patients (who used 72 Provox® prostheses) during the period of February 1991 and February 1993. After 1 year, functional TE speech was obtained in 95% of the patients that had received primary puncture, and in 78% that received a secondary puncture. Average device lifetime was 5.4 months. Complications were leakage through prosthesis (35%), leakage around (11%), granulation (8%), displacement of prosthesis (4%), postoperative fistula (8%), fungal colonization (68%), obstruction valve part (16%), hypopharyngeal stenosis (5%), tracheostoma stenosis (5%), dysphagia (14%), and gastric reflux complaints (5%).

A 6-year retrospective review from the UK (1986-1990) of different types of indwelling voice prostheses (Groningen High Resistance (N=83), Groningen Low Resistance (N=71), and Provox® (N=16) showed that there was no statistically significant difference in the *in situ* device life time for the devices. They also found that with the Groningen prostheses relatively more valves were replaced for increased speaking resistance than with the Provox® prosthesis [156].

Callanan et al. [157], reported about a cohort of 28 patients using the Provox® voice prosthesis, the average device life was 148 days (median 120 days). Speech intelligibility was found to be good and no major surgical complications were associated with valve insertion or use. Two patients needed downsizing due to leakage around with a too long prosthesis, three patients showed migration of the esophageal mucosa around the valve housing which was solved by inserting a longer prosthesis, one patient ingested the prosthesis.

Van den Hoogen et al. [158] prospectively compared the Provox® voice prosthesis with the Groningen and Nijdam prosthesis. 845 consecutive replacements (prostheses were placed at random) were evaluated in 158 patients. The replacement indications for the prostheses differed; the Provox® was more often replaced for leakage, whereas the Groningen and Nijdam were more often replaced for increased speaking resistance. Although the average device life of the Nijdam prosthesis was longer (19 weeks) than that of the Provox® (13 weeks) and Groningen (15.8 weeks), there were other prosthesis-related issues with the Nijdam prosthesis that warranted replacement by another type of prosthesis. Granulation tissue and hypertrophic scar tissue formation were the most frequent complications.

Toma et al. [159] describe their results with the Provox® prosthesis in a cohort of 31 patients. Long-term success rate was 88%. Average device life was 148 days. Complications were inferolateral migration of the fistula in one patient, migration of esophageal mucosa around the valve in three, and prosthesis ingestion in one.

Ollas et al. [160] (article in Portuguese) retrospectively studied 101 laryngectomized patients using voice prostheses (95 Provox®, 4 Blom-Singer, 2 Groningen). The median device life was 327 days. In general, the first prosthesis lasted longer than the subsequent

ones. At the end of the study, of the 101 patients, 12 had died, 8 were lost to follow-up, 20 had their puncture surgically or spontaneously closed for a variety of reasons (ingestion (N=2), fistula (N=6), prefer esophageal speech (N=3), stenosis (N=2), extrusion (N=1), not motivated (N=4), unknown (N=2)). Of the remaining 63 patients, 95% had a fluent voice and average device life was 322 days.

Slavicek et al. [161] (article in Polish) describe the results of 53 patients (273 prostheses) using a Provox® voice prosthesis. All were placed during a secondary puncture procedure. Over 85% of the patients were able to produce satisfactory voice. Median device life was 98 days. Local inflammation or reaction occurred in 28.1%, resulting in removal or extrusion of the prosthesis in 14.2%.

Laccourreye et al. [162] (retrospective study Nov 1990-June 1994; 37 patients (100 Provox® prostheses) observed an average device life time of 311 days (including replacement for salivary leakage through (33%), salivary leakage around (27%) , deterioration of the prosthesis (24%), and increased airflow resistance with excessive crusting (16%). One early case of cellulites was seen and treated with antibiotics, late complications were uncommon and included granulation tissue formation treated with CO2 laser or electric cautery (N=6), tracheostoma stenosis (N=3), tracheoesophageal puncture necrosis due to ill-fitting voice prosthesis treated with insertion of a small diameter catheter and reinsertion of well fitted prosthesis (N=1), cervical cellulites (N=1), and swallowing impairment (N=1). No statistical relation was noted between the various complications and the *in situ* lifetime of the prosthesis.

In the UK, De Carpentier et al. [79] retrospectively studied device lifetime in 39 patients using 81 Provox® prostheses. Valve failure was determined as leakage around, through, or inability to produce voice. Median device life was 4.5 months. More detailed investigation showed that a small group of patients (7.7%) accounted for a substantial part of the replacements (24.7%) No particular patterns or conditions could be identified for this subgroup. The lifetime of the first valve was negatively affected by previous radiotherapy, subsequent prosthesis failures were neither affected by previous radiotherapy, nor by the length of previous prosthesis lifetimes.

A comparison between the Provox® and Blom-Singer indwelling voice prosthesis (article in Italian) showed that the average device life of the Provox® was 6 months (ranging from 2 to 18 months) and the average device life of the Blom-Singer was 5 months (range 3 to 15 months) [163]. This study was done in 30 patients, 16 received a Provox® and 14 a Blom-Singer, all punctures were made secondarily; the Provox® prosthesis was placed immediately and for the Blom-Singer prostheses first a catheter was placed and the prosthesis two days later. The Provox® patients were hospitalized 24 hours and the Blom-Singer patients 72 hrs. The overall success rate was 96%. Complications were pooled for both types of prostheses and included fistula dilation in 10%, cellulites in 6.6%, candida growth on prosthesis in 26.6%, and extrusion in 6.6%.

De Racourt et al. [171] (article in French) reported on voice rehabilitation in 62 laryngectomized patients, all with a 5 year follow-up, treated between December 1987 and February 1998. The prostheses used in these patients were Herrman (until 1993), Provox® (majority, but no specific numbers given), Traissac and Blom-Singer. Complications were pooled for all prostheses and were secondary pharyngostoma (N=1), pharyngeal stenosis (N=2), tracheostoma stenosis (N=3), enlarged fistula (16 patients, 37 episodes of which 28 were treated with shrinkage by placement of a narrow catheter, 2 healed spontaneously, 7 were surgically closed of which 4 were repunctured

later). Seventeen patients had the prosthesis permanently removed, 4 because of complications, 9 due to absence of motivation, 3 due to poor voice, 1 due to cancer recurrence.

Aust and McAffrey [164], in a retrospective study of 21 patients, found an average device life of the Provox® voice prosthesis of 166 days (24 replacements in 13 patients; leakage through as the cause in 3 valve changes and leakage around due to incorrect size in 21 changes). Success rate was 88% and complications were partial retraction of prosthesis into esophagus due to placement of too short prosthesis in 2 patients, granulation tissue in one, and cellulites in one.

Nasser et al. [165] (article in French) in a prospective study carried out from March 1994 until September 1996, report on 52 patients using Provox® voice prostheses. Device life varied from 2 – 19 months, with an average of about 8 months. Complications were leakage around (9 events), obstruction (30 events), and migration of prosthesis (17 events). 77% of the patients had good or excellent speech.

A prospective randomized controlled study compared the Provox® voice prosthesis to the Blom-Singer indwelling voice prosthesis [166]. Comparisons were made for device life and voice parameters. Fifty-two patients were randomly selected to receive Blom-Singer or Provox® and 113 prostheses were placed in total. Voice quality was overall good and comparable for both types of prostheses. Both prostheses lasted about 4 months (median 14.5 weeks for Provox® and 15 weeks for Blom-Singer).

Biacabe et al. [167] retrospectively studied device lifetime and compared cost of replacement for general or local anesthesia, they report an average device life of 241 days.

Cornu et al. [168], reported on the results of voice rehabilitation using the Provox® voice prosthesis in South Africa. A cohort of 128 patients, laryngectomized between 1995 and 1998 was studied. Average device life was 303 days. Complications (22 adverse events in 16 patients) were posterior displacement of the prosthesis (5), anterior displacement of prosthesis (9 events), granuloma formation (2 events), enlarged fistula (3 events), and leakage adjacent to the fistula (3 events).

Gultekin et al. [117] studied the effects of neck dissection and radiotherapy on short-term speech success. Thirty-two male patients treated for laryngeal squamous cell carcinoma were included. Nine patients underwent total laryngectomy and 23 underwent total laryngectomy combined with neck dissection, and 17 of the 23 with neck dissection were managed with postoperative radiotherapy. No complications were noted with intraoperative prosthesis placement. No prostheses were dislodged in the postoperative period. Authors conclude that neck dissection and postoperative radiotherapy have no significant influence on short-term speech success in VP restoration patients.

Imre et al. [172] conducted a retrospective study between 2006 and 2011 of 47 male laryngectomized patients fitted with Provox® indwelling voice prosthesis. Results showed that the overall complication rate was 42.6% during mean follow-up of 15.3 months. Tracheoesophageal puncture enlargement (n=9, 19.1%) was the most common minor complication and the most common cause of complete closure of TEP in this study.

Yenigun et al. 2015 [77] assessed the factors that influence the longevity and replacement frequency of Provox® voice prostheses. The records of 27 patients, attending follow-up between 1998 and 2012 were retrospectively reviewed. The success

rate was 85%. The average lifespan of the prosthesis was 17.1 months (range 1-36 months).

Quality of Life studies

Quality of life (QOL) is an important health domain to consider when evaluating the success of surgical voice restoration. Polat B, et al 2015 [173], found that patients who underwent total laryngectomy had seriously reduced QOL and self-esteem. In an uncontrolled single-arm study they compared patients' (n=30) psychosocial statuses pre- and post-voice prosthesis insertion (Provox®). Results indicated that placement of a voice prosthesis improved quality of life, self-esteem, and sexual function ($p < 0.05$). Additionally, symptoms of depression and anxiety decreased ($p < 0.05$).

Appendix 2

Literature Inventory

Reference list for publications used in Figure 4 for literature mentions of voice prostheses by manufacturer:

1. Pribuisis, K., et al., Factors Affecting the Lifetime of Third-Generation Voice Prosthesis After Total Laryngectomy. J Voice, 2022.

2. Sarvestani, H.K., et al., Molecular Characterization of Fungal Colonization on the Provox Tracheoesophageal Voice Prosthesis in Post Laryngectomy Patients. Iran J Public Health, 2022. 51(1): p. 151-159.

3. Mayo-Yanez, M., et al., Long-term outcomes and cost-effectiveness of a magnet-based valve voice prosthesis for endoprosthesis leakage treatment. Eur Arch Otorhinolaryngol, 2022.

4. Tsao, C.K., et al., Comprehensive Evaluation of Vocal Outcomes and Quality of Life after Total Laryngectomy and Voice Restoration with J-Flap and Tracheoesophageal Puncture. Cancers (Basel), 2022. 14(3).

5. Hanai, N., et al., A novel procedure of secondary voice prosthesis insertion from the inside out: The modified Fukuhara method. Auris Nasus Larynx, 2021.

6. Almeida, A.S., et al., Secondary tracheoesophageal puncture with a flexible transillumination device: a new technique and its outcomes. Braz J Otorhinolaryngol, 2021.

7. Parrilla, C., et al., Regenerative Strategy for Persistent Periprosthetic Leakage around Tracheoesophageal Puncture: Is It an Effective Long-Term Solution? Cells, 2021. 10(7).

8. Apert, V., et al., Speech restoration with tracheoesophageal prosthesis after total laryngectomy: An observational study of vocal results, complications and quality of life. Eur Ann Otorhinolaryngol Head Neck Dis, 2021.

9. Yang, S., et al., The Dynamic Tracheoesophageal Prosthesis Length. J Voice, 2021.

10. Dragicevic, D.M., et al., Complications following secondary voice prosthesis insertion and impact of previous irradiation on their appearance. Niger J Clin Pract, 2021. 24(4): p. 470-475.

11. Parrilla, C., et al., Periprosthetic Leakage in Tracheoesophageal Prosthesis: Proposal of a Standardized Therapeutic Algorithm. Otolaryngol Head Neck Surg, 2021: p. 194599820983343.

12. Ku, P.K.M., et al., Perceptual Voice and Speech Analysis after Supraglottic Laryngeal Closure for Chronic Aspiration in Head and Neck Cancer. Laryngoscope, 2021. 131(5): p. E1616-E1623.

13. Parrilla, C., et al., A one-year time frame for voice prosthesis management. What should the physician expect? Is it an overrated job? Acta Otorhinolaryngol Ital, 2020. 40(4): p. 270-276.

14. Iype, E.M., et al., Voice Rehabilitation After Laryngectomy: A Regional Cancer Centre Experience and Review of Literature. Indian J Otolaryngol Head Neck Surg, 2020. 72(4): p. 518-523.

15. Spalek, J., et al., Biofilm Growth Causes Damage to Silicone Voice Prostheses in Patients after Surgical Treatment of Locally Advanced Laryngeal Cancer. Pathogens, 2020. 9(10).

16. Jira, D., et al., [GERD and adjuvant radio-chemotherapy predespose to recurrent voice prosthesis leakage]. Laryngorhinootologie, 2020.

17. Longobardi, Y., et al., Patients with Voice Prosthesis Rehabilitation During the COVID-19 Pandemic: Analyzing the Effectiveness of Remote Triage and Management. Otolaryngol Head Neck Surg, 2020.

18. Pentland, D.R., et al., Precision Antifungal Treatment Significantly Extends Voice Prosthesis Lifespan in Patients Following Total Laryngectomy. Front Microbiol, 2020. 11: p. 975.

19. Scherl, C., et al., Secondary Tracheoesophageal Puncture After Laryngectomy Increases Complications With Shunt and Voice Prosthesis. Laryngoscope, 2020.

20. Mayo-Yanez, M., et al., Use of double flange voice prosthesis for periprosthetic leakage in laryngectomized patients: a prospective case-crossover study. Clin Otolaryngol, 2020.

21. Danic Hadzibegovic, A., et al., Influence of proton pump inhibitor therapy on occurrence of voice prosthesis complications. Eur Arch Otorhinolaryngol, 2020.

22. Meulemans, J., et al., Oncologic and Functional Outcomes After Primary and Salvage Laryngopharyngoesophagectomy With Gastric Pull-Up Reconstruction for Locally Advanced Hypopharyngeal Squamous Cell Carcinoma. Front Oncol, 2019. 9: p. 735.

23. Petersen, J.F., et al., Postlaryngectomy prosthetic voice rehabilitation outcomes in a consecutive cohort of 232 patients over a 13-year period. Head Neck, 2019. 41(3): p. 623-631.

24. Petersen, J.F., et al., Solving periprosthetic leakage with a novel prosthetic device. Laryngoscope, 2018. 129(10): p. 2299-2302.

25. Krishnamurthy, A. and S. Khwajamohiuddin, Analysis of Factors Affecting the Longevity of Voice Prosthesis Following Total Laryngectomy with a Review of Literature. Indian J Surg Oncol, 2018. 9(1): p. 39-45.

26. Mayo-Yanez, M., et al., Provox 2((R)) and Provox Vega((R)) device life-time: a case-crossover study with multivariate analysis of possible influential factors and duration. Eur Arch Otorhinolaryngol, 2018. 275(7): p. 1827-1830.

27. Galli, J., et al., Biofilm in voice prosthesis: a prospective cohort study and laboratory tests using sonication and SEM analysis. Clin Otolaryngol, 2018.

28. Coffey, M.M., et al., Double Blind Study Investigating the Effect of Different Voice Prostheses on Ease of Swallowing and Residue Post Laryngectomy. Dysphagia, 2018.

29. Ishikawa, Y., et al., A questionnaire to assess olfactory rehabilitation for laryngectomized patients (Provox voice prosthesis users) in Japan. Auris Nasus Larynx, 2018.

30. Fukushima, H., et al., Indwelling voice prosthesis insertion after total pharyngolaryngectomy with free jejunal reconstruction. Laryngoscope Investigative Otolaryngology, 2017. 2(1): p. 30-35.

31. Serra, A., et al., Multicenter prospective crossover study on new prosthetic opportunities in post-laryngectomy voice rehabilitation. J Biol Regul Homeost Agents, 2017. 31(3): p. 803-809.

32. Robinson, R.A., et al., Total laryngectomy with primary tracheoesophageal puncture: Intraoperative versus delayed voice prosthesis placement. Head Neck, 2017. 39(6): p. 1138-1144.

33. Lewin, J.S., et al., Device Life of the Tracheoesophageal Voice Prosthesis Revisited. JAMA Otolaryngol Head Neck Surg, 2017. 143(1): p. 65-71.

34. Erdim, I., et al., Treatment of large persistent tracheoesophageal peristomal fistulas using silicon rings. Braz J Otorhinolaryngol, 2016. 83(5): p. 536-540.

35. Friedlander, E., et al., Practical management of periprosthetic leakage in patients rehabilitated with a Provox(R) 2 voice prosthesis after total laryngectomy. Acta Otorrinolaringol. Esp, 2016. 67(6): p. 301-305.

36. Jiang, N., A. Kearney, and E.J. Damrose, Tracheoesophageal fistula length decreases over time. Eur. Arch. Otorhinolaryngol, 2016. 273(7): p. 1819-24.

37. Thylur, D.S., et al., Device Life of Two Generations of Provox Voice Prostheses. Ann Otol Rhinol Laryngol, 2016. 125(6): p. 501-7.

38. Salturk, Z., et al., How do voice restoration methods affect the psychological status of patients after total laryngectomy? HNO, 2016. 64(3): p. 163-168.

39. Serra, A., et al., Post-laryngectomy voice rehabilitation with voice prosthesis: 15 years experience of the ENT Clinic of University of Catania. Retrospective data analysis and literature review. Acta Otorhinolaryngol Ital, 2015. 35(6): p. 412-419.

40. Yenigun, A., et al., Factors influencing the longevity and replacement frequency of Provox voice prostheses. Singapore. Med. J, 2015. 56(11): p. 632-636.

41. Noel, D., et al., Secondary tracheoesophageal puncture using transnasal esophagoscopy in gastric pull-up reconstruction after total laryngopharyngoesophagectomy. Head Neck, 2016. 38(3): p. E61-E63.

42. Dabholkar, J.P., N.M. Kapre, and H.K. Gupta, Results of Voice Rehabilitation With Provox Prosthesis and Factors Affecting the Voice Quality. J. Voice, 2015. 29(6): p. 777 e1-8.

43. Wasano, K., et al., Closure of tracheoesophageal puncture with pedicled fascia flap of the sternocleidomastoid muscle. Auris. Nasus. Larynx, 2015. 42(4): p. 318-321.

44. Sirin, A.A., et al., Detection of ideal reservoir level after laryngectomy using endoilluminator in voice rehabilitation. Laryngoscope, 2015. 125(7): p. E239-E244.

45. Kelkar, D.S., S.S. Gandhi, and G.A. Oka, Surgical treatment of glottic cancer: retrospective analysis of 192 cases in a multidisciplinary tertiary care centre in Pune, India. J. Laryngol. Otol, 2015. 16(3): p. 1-6.

46. Timmermans, A.J., et al., Biofilm formation on the Provox ActiValve: Composition and ingrowth analyzed by Illumina paired-end RNA sequencing, fluorescence in situ hybridization and confocal laser scanning microscopy. Head Neck, 2015. 38 Suppl 1: p. E432-40.

47. Calkovsky, V. and A. Hajtman, Primary prosthetic voice rehabilitation in patients after laryngectomy: applications and pitfalls. Adv. Exp. Med. Biol, 2015. 852: p. 11-16.

48. Lorenz, K.J., The development and treatment of periprosthetic leakage after prosthetic voice restoration. A literature review and personal experience part I: the development of periprosthetic leakage. Eur. Arch. Otorhinolaryngol, 2015. 272(3): p. 641-659.

49. Messing, B.P., et al., Evaluation of prophylaxis treatment of Candida in alaryngeal patients with tracheoesophageal voice prostheses. Laryngoscope, 2015. 125(5): p. 1118-1123.

50. Kilic, C., U. Tuncel, and E. Comert, [Provox 2 use for voice restoration after total laryngectomy] in Turkish. Kulak. Burun. Bogaz. Ihtis. Derg, 2014. 24(6): p. 339-343.

51. Polat, B., et al., The effects of indwelling voice prosthesis on the quality of life, depressive symptoms, and self-esteem in patients with total laryngectomy. Eur. Arch. Otorhinolaryngol, 2015. 272(11): p. 3431-3437.

52. Bertl, K., et al., Oral cavity anaerobic pathogens in biofilm formation on voice prostheses. Head Neck, 2015. 37(4): p. 524-9.

53. Damrose, E.J., D.Y. Cho, and R.L. Goode, The hybrid tracheoesophageal puncture procedure: indications and outcomes. Ann. Otol. Rhinol. Laryngol, 2014. 123(8): p. 584-590.

54. Lorenz, K.J., et al., Role of reflux-induced epithelial-mesenchymal transition in periprosthetic leakage after prosthetic voice rehabilitation. Head Neck, 2015. 37(4): p. 530-536.

55. Iqueda, A.P., et al., Nasalance and nasality of tracheoesophageal speech in total laryngectomee. Codas, 2013. 25(5): p. 469-74.

56. Lewin, J.S., et al., Clinical application of the Provox NiD voice prosthesis: a longitudinal study. Laryngoscope, 2014. 124(7): p. 1585-1591.

57. Guttman, D., et al., Post-laryngectomy voice rehabilitation: comparison of primary and secondary tracheoesophageal puncture. Isr. Med. Assoc. J, 2013. 15(9): p. 565-567.

58. Fusconi, M., et al., Degradation of silicone rubber causes provox 2 voice prosthesis malfunctioning. J Voice, 2014. 28(2): p. 250-254.

59. Cocuzza, S., et al., Relationship between radiotherapy and gastroesophageal reflux disease in causing tracheoesophageal voice rehabilitation failure. J Voice, 2014. 28(2): p. 245-249.

60. Kress, P., et al., Are modern voice prostheses better? A lifetime comparison of 749 voice prostheses. Eur. Arch. Otorhinolaryngol, 2014. 271(1): p. 133-140.

61. Bertl, K., et al., Oral microbial colonization in laryngectomized patients as a possible cofactor of biofilm formation on their voice prostheses. J Clin Periodontol, 2013. 40(9): p. 833-840.

62. Singer, S., et al., Speech rehabilitation during the first year after total laryngectomy. Head Neck, 2013. 35(11): p. 1583-1590.

63. Hancock, K.L., N.R. Lawson, and E.C. Ward, Device life of the Provox Vega voice prosthesis. Eur. Arch. Otorhinolaryngol, 2013. 270(4): p. 1447-1453.

64. Lorenz, K.J., F.M. Hilgers, and H. Maier, [A novel puncture instrument: the Provox-Vega(R) puncture set : Its use in voice prosthesis insertion following laryngectomy] in German. HNO, 2013. 61(1): p. 30-37.

65. Hilgers, F.J., et al., Development and (pre-) clinical assessment of a novel surgical tool for primary and secondary tracheoesophageal puncture with immediate voice prosthesis insertion, the Provox Vega Puncture Set. Eur. Arch. Otorhinolaryngol, 2013. 270(1): p. 255-262.

66. Imre, A., et al., Complications of tracheoesophageal puncture and speech valves: retrospective analysis of 47 patients - Abstract only. Kulak Burun Bogaz Ihtis Derg, 2013. 23(1): p. 15-20.

67. Pedisic, D., et al., The use of ultrasound in determining the length of the Provox II voice prosthesis. Coll. Antropol, 2012. 36 Suppl 2: p. 103-106.

68. Lukinovic, J., et al., Overview of 100 patients with voice prosthesis after total laryngectomy--experience of single institution. Coll. Antropol, 2012. 36 Suppl 2: p. 99-102.

69. Hadzibegovic, A.D., et al., Analysis of saliva pepsin level in patients with tracheoesophageal fistula and voice prosthesis complications. Coll. Antropol, 2012. 36 Suppl 2: p. 93-97.

70. Zimmer-Nowicka, J. and A. Morawiec-Sztandera, [Causes and indwelling times of multiple voice prosthesis replacements in patients after total laryngectomy - analysis of 184 replacements in 42 patients] in Polish. Otolaryngol. Pol, 2012. 66(5): p. 322-327.

71. Boci, B., R. Isufi, and K. Thomai, Postlaryngectomy vocal rehabilitation in Albania. J. BUON, 2012. 17(3): p. 478-482.

72. Hancock, K., et al., A prospective, randomized comparative study of patient perceptions and preferences of two types of indwelling voice prostheses. Int. J. Lang Commun. Disord, 2012. 47(3): p. 300-309.

73. Takeshita, T.K., et al., Relation between the dimensions and intraluminal pressure of the pharyngoesophageal segment and tracheoesophageal voice and speech proficiency. Head Neck, 2013. 35(4): p. 500-504.

74. Holmes, A.R., et al., Yeast colonization of voice prostheses: pilot study investigating effect of a bovine milk product containing anti-Candida albicans immunoglobulin A antibodies on yeast colonization and valve leakage. Ann. Otol. Rhinol. Laryngol, 2012. 121(1): p. 61-66.

75. Harms, K., et al., A prospective randomized multicenter clinical trial of the Provox2 and Groningen Ultra Low Resistance voice prostheses in the rehabilitation of post-laryngectomy patients: a lifetime and preference study. Oral. Oncol, 2011. 47(9): p. 895-899.

76. Reumueller, A., et al., Pharyngolaryngectomy with free jejunal autograft reconstruction and tracheoesophageal voice restoration: Indications for replacements, microbial colonization, and indwelling times of the Provox 2 voice prostheses. Head Neck, 2011. 33(8): p. 1144-1153.

77. Hutcheson, K.A., et al., Outcomes and adverse events of enlarged tracheoesophageal puncture after total laryngectomy. Laryngoscope, 2011. 121(7): p. 1455-1461.

78. Wierzchowska, M. and P.K. Burduk, [Early and late complications after implantation of the Provox 2 voice prosthesis in patients after total laryngectomy] - Abstract only, article in Polish. Otolaryngol. Pol, 2011. 65(3): p. 184-187.

79. Lorenz, K.J., et al., The management of periprosthetic leakage in the presence of supra-oesophageal reflux after prosthetic voice rehabilitation. Eur. Arch. Otorhinolaryngol, 2011. 268(5): p. 695-702.

80. Dragicevic, D., et al., Comparison of Voice Handicap Index in Patients with Esophageal and Tracheoesophageal Speech after Total Laryngectomy. Folia Phoniatr Logop, 2019: p. 1-7.

81. Graville, D.J., et al., Determining the efficacy and cost-effectiveness of the ActiValve: results of a long-term prospective trial. Laryngoscope, 2011. 121(4): p. 769-776.

82. Gultekin, E., et al., Effects of neck dissection and radiotherapy on short-term speech success in voice prosthesis restoration patients. J Voice, 2011. 25(2): p. 245-248.

83. Sokal, W., M. Kordylewska, and W. Golusinski, [An influence of some factors on the logopedic rehabilitation of patients after total laryngectomy] in Polish. Otolaryngol. Pol, 2011. 65(1): p. 20-25.

84. Ward, E.C., et al., Perceptual characteristics of tracheoesophageal speech production using the new indwelling Provox Vega voice prosthesis: a randomized controlled crossover trial. Head Neck, 2011. 33(1): p. 13-19.

85. Giordano, L., et al., Satisfaction and Quality of Life in Laryngectomees after Voice Prosthesis Rehabilitation. Folia Phoniatr. Logop, 2011. 63(5): p. 231-236.

86. Bock, J.M., et al., Analysis of pepsin in tracheoesophageal puncture sites. Ann. Otol. Rhinol. Laryngol, 2010. 119(12): p. 799-805.

87. Lorenz, K.J. and H. Maier, [Voice rehabilitation after laryngectomy : Initial clinical experience with the Provox-Vega(R) voice prosthesis and the SmartInserter(R) system.] in German. HNO, 2010. 58(12): p. 1174-1183.

88. Terada, T., et al., [Voice restoration and long-term progress in voice rehabilitation using the Provox2 voice prosthesis after total laryngectomy] Abstract only, article in Japanese. Nihon Jibiinkoka Gakkai Kaiho, 2010. 113(11): p. 838-843.

89. Aguiar-Ricz, L., et al., Intraluminal esophageal pressures in speaking laryngectomees. Ann. Otol. Rhinol. Laryngol, 2010. 119(11): p. 729-735.

90. Lorenz, K.J., et al., Role of reflux in tracheoesophageal fistula problems after laryngectomy. Ann. Otol. Rhinol. Laryngol, 2010. 119(11): p. 719-728.

91. Takeshita, T.K., et al., Correlation between tracheoesophageal voice and speech and intraluminal pharyngoesophageal transition pressure. Pro. Fono, 2010. 22(4): p. 485-490.

92. Schuldt, T., et al., [Time course of microbial colonization of different voice prostheses] in German. Laryngorhinootologie, 2010. 89(10): p. 606-611.

93. Dayangku Norsuhazenah, P.S., et al., Complications following tracheoesophageal puncture: a tertiary hospital experience. Ann. Acad. Med. Singapore, 2010. 39(7): p. 565-4.

94. Bozec, A., et al., Results of vocal rehabilitation using tracheoesophageal voice prosthesis after total laryngectomy and their predictive factors. Eur. Arch. Otorhinolaryngol, 2010. 267(5): p. 751-758.

95. Hilgers, F.J., et al., Clinical phase I/feasibility study of the next generation indwelling Provox voice prosthesis (Provox Vega). Acta Otolaryngol, 2010. 130(4): p. 511-519.

96. Bien, S., et al., The effect of a Heat and Moisture Exchanger (Provox HME) on pulmonary protection after total laryngectomy: a randomized controlled study. Eur. Arch. Otorhinolaryngol, 2010. 267(3): p. 429-435.

97. So, Y.K., et al., Speech outcome of supracricoid partial laryngectomy: comparison with total laryngectomy and anatomic considerations. Otolaryngol. Head Neck Surg, 2009. 141(6): p. 770-775.

98. Lorenz, K.J., et al., [Coincidence of fistula enlargement and supra-oesophageal reflux in patients after laryngectomy and prosthetic voice restoration] in German. HNO, 2009. 57(12): p. 1253-1261.

99. Krause, E., J.M. Hempel, and R. Gurkov, Botulinum toxin A prolongs functional durability of voice prostheses in laryngectomees with pharyngoesophageal spasm. Am. J. Otolaryngol, 2009. 30(6): p. 371-375.

100. Ng, M.L., et al., Long-term average spectral characteristics of Cantonese alaryngeal speech. Auris Nasus Larynx, 2009. 36(5): p. 571-577.

101. Leonhard, M., et al., [Examination of biofilm related material deterioration on 20 PROVOX2 voice prostheses by scanning electron microscopy] in German. Laryngorhinootologie, 2009. 88(6): p. 392-397.

102. Tammam, N., Voice Rehabilitation using Provox following Total Laryngectomy in Bahrain. A preliminary Report on 5 Cases, in Journal of Bahrain Medical Society, A. MM, Editor. 2009. p. 275-279.

103. Albirmawy, O.A., et al., Effect of primary neopharyngeal repair on acoustic characteristics of tracheoesophageal voice after total laryngectomy. J. Laryngol. Otol, 2009. 123(4): p. 426-433.

104. Torrejano, G. and I. Guimaraes, Voice quality after supracricoid laryngectomy and total laryngectomy with insertion of voice prosthesis. J. Voice, 2009. 23(2): p. 240-246.

105. van Rossum, M.A., et al., Quality of 'glottal' stops in tracheoesophageal speakers. Clin. Linguist Phon, 2009. 23(1): p. 1-14.

106. Minovi, A., et al., [Quality of life in long-term survivors after laryngectomy] in German. Laryngorhinootologie, 2009. 88(1): p. 18-22.

107. Kotby, M.N., et al., Aerodynamics of the pseudo-glottis. Folia. Phoniatr. Logop, 2009. 61(1): p. 24-28.

108. Mastronikolis, N.S., et al., Voice restoration after total laryngectomy using provox 2 (generation II) prosthesis. Eur. Rev. Med. Pharmacol. Sci, 2008. 12(5): p. 327-330.

109. Boscolo-Rizzo, P., et al., The impact of radiotherapy and GERD on in situ lifetime of indwelling voice prostheses. Eur. Arch. Otorhinolaryngol, 2008. 265(7): p. 791-796.

110. Hilgers, F.J., et al., A thin tracheal silicone washer to solve periprosthetic leakage in laryngectomies: direct results and long-term clinical effects. Laryngoscope, 2008. 118(4): p. 640-645.

111. Jacobs, K., P.R. Delaere, and P. Vander, V, Submucosal purse-string suture as a treatment of leakage around the indwelling voice prosthesis. Head Neck, 2008. 30(4): p. 485-491.

112. Grolman, W., et al., Vocal efficiency in tracheoesophageal phonation. Auris Nasus Larynx, 2008. 35(1): p. 83-88.

113. Soolsma, J., et al., Long-term results of Provox ActiValve, solving the problem of frequent candida- and "underpressure"-related voice prosthesis replacements. Laryngoscope, 2008. 118(2): p. 252-257.

114. Padhya, T.A., et al., An alternative approach for secondary tracheoesophageal puncture in the difficult laryngectomy neck. Laryngoscope, 2008. 118(2): p. 266-269.

115. Boscolo-Rizzo, P., et al., Long-term quality of life after total laryngectomy and postoperative radiotherapy versus concurrent chemoradiotherapy for laryngeal preservation. Laryngoscope, 2008. 118(2): p. 300-306.

116. Ratajczak, J., A. Wojdas, and D. Jurkiewicz, [Results of rehabilitation of voice and speeches after implantation of valve vocal prosthesis at ill after total removal of larynx] in Polish. Otolaryngol. Pol, 2008. 62(6): p. 727-730.

117. Gehrking, E., M. Raap, and K.D. Sommer, Classification and management of tracheoesophageal and tracheopharyngeal fistulas after laryngectomy. Laryngoscope, 2007. 117(11): p. 1943-1951.

118. Gonzalez, P.N., et al., Phonation fistulas today. Acta Otorrinolaringol. Esp, 2007. 58(3): p. 110-112.

119. Terada, T., et al., Voice rehabilitation with Provox2 voice prosthesis following total laryngectomy for laryngeal and hypopharyngeal carcinoma. Auris Nasus Larynx, 2007. 34(1): p. 65-71.

120. Lorenz, K.J., et al., Hands-free speech after surgical voice rehabilitation with a Provox voice prosthesis: experience with the Provox FreeHands HME tracheostoma valve system. Eur. Arch. Otorhinolaryngol, 2007. 264(2): p. 151-157.

121. Murray, D.J., et al., Functional outcomes and donor site morbidity following circumferential pharyngoesophageal reconstruction using an anterolateral thigh flap and salivary bypass tube. Head Neck, 2007. 29(2): p. 147-154.

122. Bilewicz, R., et al., [The surgery voice rehabilitation after total laryngectomy with the Provox system] in Polish. Otolaryngol. Pol, 2007. 61(3): p. 265-270.

123. Ramalingam, W., et al., Tracheo-esophageal Puncture (TEP) for Voice Rehabilitation in Laryngectomised Patients Blom-singer Vs Provox Prosthesis: Our Experience. MJAFI, 2007. 63(1): p. 15-18.

124. Grolman, W., et al., Aerodynamic and sound intensity measurements in tracheoesophageal voice. ORL J. Otorhinolaryngol. Relat Spec, 2007. 69(2): p. 68-76.

125. Kress, P., et al., Measurement and comparison of in vitro air-flow characteristics of the most frequently used European indwelling voice prostheses types. 2007.

126. Calder, N., C. MacAndie, and F. MacGregor, Tracheoesophageal voice prostheses complications in north Glasgow. J. Laryngol. Otol, 2006. 120(6): p. 487-491.

127. Albirmawy, O.A., et al., Managing problems with tracheoesophageal puncture for alaryngeal voice rehabilitation. J. Laryngol. Otol, 2006. 120(6): p. 470-477.

128. Schwandt, L.Q., et al., Differences in aerodynamic characteristics of new and dysfunctional Provox 2 voice prostheses in vivo. Eur. Arch. Otorhinolaryngol, 2006. 263(6): p. 518-523.

129. Kummer, P., et al., [Prosthetic voice rehabilitation after laryngectomy. Failures and complications after previous radiation therapy] in German. HNO, 2006. 54(4): p. 315-322.

130. Stajner-Katusic, S., et al., Voice and speech after laryngectomy. Clin. Linguist Phon, 2006. 20(2-3): p. 195-203.

131. Bien, S. and S. Okla, [Analysis of complications after surgical voice and speech rehabilitation in laryngectomized patients. Problems related to implantation and change of voice prosthesis] in Polish. Otolaryngol. Pol, 2006. 60(2): p. 129-134.

132. Lam, P.K., et al., Long-term performance of indwelling tracheoesophageal speaking valves in Chinese patients undergoing laryngectomy. Arch. Otolaryngol. Head Neck Surg, 2005. 131(11): p. 954-958.

133. Hancock, K., et al., First clinical experience with a new non-indwelling voice prosthesis (Provox NID) for voice rehabilitation after total laryngectomy. Acta Otolaryngol, 2005. 125(9): p. 981-990.

134. Op de Coul, B.M., et al., Compliance, quality of life and quantitative voice quality aspects of hands-free speech. Acta Otolaryngol, 2005. 125(6): p. 629-637.

135. Schwandt, L.Q., et al., Effect of dairy products on the lifetime of Provox2 voice prostheses in vitro and in vivo. Head Neck, 2005. 27(6): p. 471-477.

136. Ameye, D., et al., Effect of a buccal bioadhesive nystatin tablet on the lifetime of a Provox silicone tracheoesophageal voice prosthesis. Acta Otolaryngol, 2005. 125(3): p. 304-306.

137. Markowski, J., et al., [The use of the vocal prosthesis Provox 2 for speech rehabilitation after total laryngectomy] in Polish. Otolaryngol. Pol, 2005. 59(3): p. 373-377.

138. Morshed, K., et al., [Speech rehabilitation using Provox voice prosthesis] in Polish. Otolaryngol. Pol, 2005. 59(2): p. 225-228.

139. Schuster, M., et al., Voice handicap of laryngectomees with tracheoesophageal speech. Folia Phoniatr. Logop, 2004. 56(1): p. 62-67.

140. Demir, D., et al., [Factors that affect in situ lifetime of Provox voice prosthesis] in Turkish. Kulak. Burun. Bogaz. Ihtis. Derg, 2004. 13(5-6): p. 126-131.

141. Boscolo-Rizzo, P., et al., Long-term results with tracheoesophageal voice prosthesis: primary versus secondary TEP. Eur. Arch. Otorhinolaryngol, 2008. 265(1): p. 73-77.

142. Bergquist, H., et al., Functional long-term outcome of a free jejunal transplant reconstruction following chemoradiotherapy and radical resection for hypopharyngeal and proximal oesophageal carcinoma. Dig. Surg, 2004. 21(5-6): p. 426-431.

143. Olszanski, W., et al., [Acoustic analysis of tracheoesophageal speech in comparison to esophageal speech after total laryngectomy]. Otolaryngol Pol, 2004. 58(3): p. 473-7.

144. Globlek, D., et al., Comparison of alaryngeal voice and speech. Logoped. Phoniatr. Vocol, 2004. 29(2): p. 87-91.

145. Globlek, D., et al., Speech and voice analysis after near-total laryngectomy and tracheoesophageal puncture with implantation of Provox 2 prosthesis. Logoped. Phoniatr. Vocol, 2004. 29(2): p. 84-86.

146. Ol'shanskii, V.O., E.N. Novozhilova, and V.V. Dvornichenko, [Clinical and acoustic characteristics of tracheoesophageal bypass with prosthesis] in Russian. Vestn. Otorinolaringol, 2004(2): p. 17-19.

147. Trussart, C., G. Lawson, and M. Remacle, Voice prostheses: long-term follow-up retrospective study (three- to sixteen-year follow-up of 22 patients). Rev. Laryngol. Otol. Rhinol. (Bord.), 2003. 124(5): p. 299-304.

148. Luczaj, J. and B. Kosztyla-Hojna, [Voice prosthesis in patients after total laryngectomy] in German. Otolaryngol. Pol, 2003. 57(6): p. 897-903.

149. Makitie, A.A., et al., Postlaryngectomy voice restoration using a voice prosthesis: a single institution's ten-year experience. Ann. Otol. Rhinol. Laryngol, 2003. 112(12): p. 1007-1010.

150. Yamada, H., et al., [Voice rehabilitation after total laryngectomy using the Provox voice prosthesis] - Abstract only, article in Japanese. Nippon Jibiinkoka Gakkai Kaiho, 2003. 106(11): p. 1093-1099.

151. Lequeux, T., et al., A comparison of survival lifetime of the Provox and the Provox2 voice prosthesis. J. Laryngol. Otol, 2003. 117(11): p. 875-878.

152. Vlantis, A.C., et al., Conversion from a non-indwelling to a Provox2 indwelling voice prosthesis for speech rehabilitation: comparison of voice quality and patient preference. J. Laryngol. Otol, 2003. 117(10): p. 815-820.

153. Hilgers, F.J., et al., A new problem-solving indwelling voice prosthesis, eliminating the need for frequent Candida- and "underpressure"-related replacements: Provox ActiValve. Acta Otolaryngol, 2003. 123(8): p. 972-979.

154. Schuster, M., et al., Quality of life in laryngectomees after prosthetic voice restoration. Folia. Phoniatr. Logop, 2003. 55(5): p. 211-219.

155. Olthoff, A., et al., Assessment of irregular voices after total and laser surgical partial laryngectomy. Arch. Otolaryngol. Head Neck Surg, 2003. 129(9): p. 994-999.

156. Tisch, M., et al., [Quality of life for patients after laryngectomy and surgical voice rehabilitation. Experience with the Provox prosthesis] in German. HNO, 2003. 51(6): p. 467-472.

157. Schuster, M., et al., [Coping strategies in laryngectomy patients] in German. HNO, 2003. 51(4): p. 337-343.

158. Cornu, A.S., et al., Voice rehabilitation after laryngectomy with the Provox voice prosthesis in South Africa. J. Laryngol. Otol, 2003. 117(1): p. 56-59.

159. Ozkul, M.D., et al., Ten-year experience with voice prosthesis. 2003.

160. Perie, S., et al., Autologous fat injection to treat leakage around tracheoesophageal puncture. Am J Otolaryngol, 2002. 23(6): p. 345-350.

161. Fajdiga, I., I.H. Boltezar, and M. Zargi, Voice prostheses - ten years after. 2002.

162. Elving, G.J., et al., The influence of radiotherapy on the lifetime of silicone rubber voice prostheses in laryngectomized patients. Laryngoscope, 2002. 112(9): p. 1680-1683.

163. Hotz, M.A., et al., Success and predictability of provox prosthesis voice rehabilitation. Arch. Otolaryngol. Head Neck Surg, 2002. 128(6): p. 687-691.

164. Cavalot, A.L., et al., Qualitative and quantitative evaluation of some vocal function parameters following fitting of a prosthesis. J. Voice, 2001. 15(4): p. 587-591.

165. Schafer, P., N. Klutzke, and F.P. Schwerdtfeger, [Voice restoration with voice prosthesis after total laryngectomy. Assessment of survival time of 378 Provox-1, Provox-2 and Blom-Singer voice prosthesis] in German. Laryngorhinootologie, 2001. 80(11): p. 677-681.

166. Arweiler-Harbeck, D., et al., Does metal coating improve the durability of silicone voice prostheses? Acta Otolaryngol, 2001. 121(5): p. 643-646.

167. Issing, W.J., S. Fuchshuber, and M. Wehner, Incidence of tracheo-oesophageal fistulas after primary voice rehabilitation with the Provox or the Eska-Herrmann voice prosthesis. Eur. Arch. Otorhinolaryngol, 2001. 258(5): p. 240-242.

168. Benazzo, M., et al., Voice restoration after circumferential pharyngolaryngectomy with free jejunum repair. Eur. Arch. Otorhinolaryngol, 2001. 258(4): p. 173-176.

169. Op de Coul, B.M., et al., A decade of postlaryngectomy vocal rehabilitation in 318 patients: a single Institution's experience with consistent application of provox indwelling voice prostheses. Arch. Otolaryngol. Head Neck Surg, 2000. 126(11): p. 1320-1328.

170. Ahmad, I., et al., Surgical voice restoration following ablative surgery for laryngeal and hypopharyngeal carcinoma. J. Laryngol. Otol, 2000. 114(7): p. 522-525.

171. Neumann, A. and H.J. Schultz-Coulon, [Management of complications after prosthetic voice rehabilitation] in German. HNO, 2000. 48(7): p. 508-516.

172. Koscielny, S. and B. Brauer, [What is the best system for changing of voice prosthesis - Provox1 or Provox2?] in German. Otorhinolaryngol Nova, 2000. 10(April): p. 5.

173. van Weissenbruch, R., et al., Cineradiography of the pharyngoesophageal segment in postlaryngectomy patients. Ann. Otol. Rhinol. Laryngol, 2000. 109(3): p. 311-319.

174. Biacabe, B., et al., [Replacement of tracheo-esophageal Provox prosthesis] in French. Ann. Otolaryngol. Chir Cervicofac, 2000. 117(1): p. 34-39.

175. Balle, V.H., L. Rindso, and J.C. Thomsen, Primary speech restoration at laryngectomy by insertion of voice prosthesis--10 years experience. Acta Otolaryngol. Suppl, 2000. 543: p. 244-245.

176. Baumann, A., M.A. Hotz, and P. Zbaren, [Results of voice rehabilitation with Provox prostheses] in German. Schweiz. Med. Wochenschr. Suppl, 2000. 116: p. 77S-79S.

177. Graville, D., et al., The long-term indwelling tracheoesophageal prosthesis for alaryngeal voice rehabilitation. Arch. Otolaryngol. Head Neck Surg, 1999. 125(3): p. 288-292.

178. Ackerstaff, A.H., et al., Multi-institutional assessment of the Provox 2 voice prosthesis. Arch. Otolaryngol. Head Neck Surg, 1999. 125(2): p. 167-173.

179. Finizia, C., et al., Acoustic and perceptual evaluation of voice and speech quality: a study of patients with laryngeal cancer treated with laryngectomy vs irradiation. Arch. Otolaryngol. Head Neck. Surg, 1999. 125(2): p. 157-163.

180. van den Hoogen, F.J., et al., A prospective study of speech and voice rehabilitation after total laryngectomy with the low-resistance Groningen, Nijdam and Provox voice prostheses. Clin. Otolaryngol. Allied Sci, 1998. 23(5): p. 425-431.

181. Finizia, C., et al., Quality of life and voice in patients with laryngeal carcinoma: a posttreatment comparison of laryngectomy (salvage surgery) versus radiotherapy. Laryngoscope, 1998. 108(10): p. 1566-1573.

182. Delsupehe, K., et al., Prospective randomized comparative study of tracheoesophageal voice prosthesis: Blom-Singer versus Provox. Laryngoscope, 1998. 108(10): p. 1561-1565.

183. Van As, C.J., et al., Acoustical analysis and perceptual evaluation of tracheoesophageal prosthetic voice. J. Voice, 1998. 12(2): p. 239-248.

184. Daniilidis, I., et al., [Voice rehabilitation after total laryngectomy. Voice prostheses or esophageal replacement voice?] in German. Laryngorhinootologie, 1998. 77(2): p. 89-92.

185. Ackerstaff, A.H., et al., Long-term compliance of laryngectomized patients with a specialized pulmonary rehabilitation device: Provox Stomafilter. Laryngoscope, 1998. 108(2): p. 257-60.

186. Chung, R.P., et al., In vitro and in vivo comparison of the low-resistance Groningen and the Provox tracheosophageal voice prostheses. Rev. Laryngol. Otol. Rhinol. (Bord.), 1998. 119(5): p. 301-306.

187. de Raucourt, D., et al., [Voice rehabilitation with a voice prosthesis. Study of 62 patients with 5 years follow-up] in French. Rev. Laryngol. Otol. Rhinol. (Bord.), 1998. 119(5): p. 297-300.

188. Miani, C., et al., Dynamic behavior of the Provox and Staffieri prostheses for voice rehabilitation following total laryngectomy. Eur. Arch. Otorhinolaryngol, 1998. 255(3): p. 143-148.

189. van den Hoogen, F.J., et al., In vivo aerodynamic characteristics of the Nijdam voice prosthesis. Acta Otolaryngol, 1997. 117(6): p. 897-902.

190. Hilgers, F.J.M., et al., Development and clinical evaluation of a second-generation voice prosthesis (Provox 2), designed for anterograde and retrograde insertion. Acta Otolaryngol, 1997. 117(6): p. 889-896.

191. Aust, M.R. and T.V. McCaffrey, Early speech results with the Provox prosthesis after laryngectomy. Arch. Otolaryngol. Head Neck Surg, 1997. 123(9): p. 966-968.

192. van Weissenbruch, R., et al., Deterioration of the Provox silicone tracheoesophageal voice prosthesis: microbial aspects and structural changes. Acta Otolaryngol, 1997. 117(3): p. 452-458.

193. Cavalot, A.L., et al., [The use of indwelling phonatory valve in the rehabilitation of laryngectomized patients: preliminary results in 30 patients] in Italian. Acta Otorhinolaryngol. Ital, 1997. 17(2): p. 109-114.

194. Laccourreye, O., et al., In situ lifetime, causes for replacement, and complications of the Provox voice prosthesis. Laryngoscope, 1997. 107(4): p. 527-530.

195. van Weissenbruch, R., et al., Chemoprophylaxis of fungal deterioration of the Provox silicone tracheoesophageal prosthesis in postlaryngectomy patients. Ann. Otol. Rhinol. Laryngol, 1997. 106(4): p. 329-337.

196. Slavicek, A., et al., [Voice rehabilitation with the Provox system after total laryngectomy] in Czech. Sb Lek, 1997. 98(4): p. 287-299.

197. Balle, V.H., L. Rindso, and J. Thomsen, Speech rehabilitation by Provox voice prosthesis combined with heat and moisture exchange filters. Acta Otolaryngol. Suppl, 1997. 529: p. 251-253.

198. Nasser, T., et al., Réhabilitation vocale par prothèse phonatoire après laryngectomie. 1997.

199. Heaton, J.M., et al., In vivo measurements of indwelling tracheo-oesophageal prostheses in alaryngeal speech. Clin. Otolaryngol. Allied Sci, 1996. 21(4): p. 292-296.

200. van den Hoogen, F.J., et al., The Groningen, Nijdam and Provox voice prostheses: a prospective clinical comparison based on 845 replacements. Acta Otolaryngol, 1996. 116(1): p. 119-124.

201. van den Hoogen, F.J., et al., The Blom-Singer tracheostoma valve as a valuable addition in the rehabilitation of the laryngectomized patient. Eur. Arch. Otorhinolaryngol, 1996. 253(3): p. 126-129.

202. de Carpentier, J.P., et al., Survival times of Provox valves. J. Laryngol. Otol, 1996. 110(1): p. 37-42.

203. Hilgers, F.J.M., et al., Prosthetic voice rehabilitation with Provox system after extensive pharyngeal resection and reconstruction. 1996.

204. Callanan, V., et al., Provox valve use for post-laryngectomy voice rehabilitation. J. Laryngol. Otol, 1995. 109(11): p. 1068-1071.

205. Kischk, B.T. and M. Gross, [Comparative evaluation of the voice prosthesis after laryngectomy] in German. HNO, 1995. 43(5): p. 304-310.

206. Grolman, W., et al., First results with the Blom-Singer adjustable tracheostoma valve. ORL J. Otorhinolaryngol. Relat Spec, 1995. 57(3): p. 165-170.

207. Kollbrunner, J., et al., [Voice rehabilitation after laryngectomy with tracheoesophageal prosthesis. Analysis with special reference to psychosocial factors] in German. HNO, 1995. 43(4): p. 216-222.

208. Prichard, A.J., et al., Surgical voice restoration: the Sunderland experience. J. R. Coll. Surg. Edinb, 1994. 39(6): p. 355-359.

209. Heaton, J.M. and A.J. Parker, Indwelling tracheo-oesophageal voice prostheses post-laryngectomy in Sheffield, UK: a 6-year review. Acta Otolaryngol, 1994. 114(6): p. 675-678.

210. Panarese, A., et al., Vocal rehabilitation after pharyngo-laryngectomy--the Provox valve. Clin. Otolaryngol. Allied Sci, 1994. 19(5): p. 427-429.

211. Ackerstaff, A.H., et al., Communication, functional disorders and lifestyle changes after total laryngectomy. Clin. Otolaryngol. Allied Sci, 1994. 19(4): p. 295-300.

212. Natarajan, B., et al., The Provox voice prosthesis and Candida albicans growth: a preliminary report of clinical, mycological and scanning electron microscopic assessment. J. Laryngol. Otol, 1994. 108(8): p. 666-668.

213. Debruyne, F., et al., Acoustic analysis of tracheo-oesophageal versus oesophageal speech. J. Laryngol. Otol, 1994. 108(4): p. 325-328.

214. Brasnu, D., et al., [Results of the treatment of spontaneous widening of tracheo-esophageal punctures after laryngeal implant] in French. Ann. Otolaryngol. Chir Cervicofac, 1994. 111(8): p. 456-460.

215. Hilgers, F.J. and A.J. Balm, Long-term results of vocal rehabilitation after total laryngectomy with the low-resistance, indwelling Provox voice prosthesis system. Clin. Otolaryngol. Allied Sci, 1993. 18(6): p. 517-523.

216. Ackerstaff, A.H., et al., Improvements in respiratory and psychosocial functioning following total laryngectomy by the use of a heat and moisture exchanger. Ann. Otol. Rhinol. Laryngol, 1993. 102(11): p. 878-883.

217. van Weissenbruch, R. and F.W. Albers, Vocal rehabilitation after total laryngectomy using the Provox voice prosthesis. Clin. Otolaryngol. Allied Sci, 1993. 18(5): p. 359-364.

218. Balle, V.H. and J.C. Thomsen, [Speech rehabilitation after laryngectomy, primary insertion of a speech ventilator] in Danish. Ugeskr. Laeger, 1993. 155(14): p. 1053-1055.

219. Hilgers, F.J. and P.F. Schouwenburg, A new low-resistance, self-retaining prosthesis (Provox) for voice rehabilitation after total laryngectomy. Laryngoscope, 1990. 100(11): p. 1202-1207.

220. Heaton, J.M., et al., Speech assessment of patients using three types of indwelling tracheo-oesophageal voice prostheses. J. Laryngol. Otol, 1996. 110(4): p. 343-347.

221. Liu, J.X., et al., [Aerodynamic study of the low-resistance Groningen button in voice prosthesis]. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi, 2007. 42(8): p. 589-93.

222. Furuta, Y., et al., Voice restoration by primary insertion of indwelling voice prosthesis following circumferential pharyngolaryngectomy with free jejunal graft. Auris Nasus Larynx, 2005. 32(3): p. 269-274.

223. Hanai, N., et al., [Long-term outcomes and complications associated with the use of a Groningen voice prosthesis]. Nihon Jibiinkoka Gakkai Kaiho, 2004. 107(10): p. 943-8.

224. Iwai, H., M. Adachi, and T. Yamashita, Front-loading of Groningen voice prosthesis in alaryngeal patients requiring prosthetic replacement. J. Laryngol. Otol, 2003. 117(8): p. 633-636.

225. Schutte, H.K. and G.J. Nieboer, Aerodynamics of esophageal voice production with and without a Groningen voice prosthesis. Folia Phoniatr. Logop, 2002. 54(1): p. 8-18.

226. Chung, R.P., et al., The ultra-low resistance Groningen voice prosthesis: clinical experiences. Rev. Laryngol. Otol. Rhinol. (Bord.), 2001. 122(2): p. 129-133.

227. Everaert, E.P., et al., Biofilm formation in vivo on perfluoro-alkylsiloxane-modified voice prostheses. Arch. Otolaryngol. Head Neck Surg, 1999. 125(12): p. 1329-1332.

228. Izdebski, K., et al., Problems with tracheoesophageal fistula voice restoration in totally laryngectomized patients. A review of 95 cases. Arch. Otolaryngol. Head Neck Surg, 1994. 120(8): p. 840-845.

229. Neu, T.R., et al., Microflora on explanted silicone rubber voice prostheses: taxonomy, hydrophobicity and electrophoretic mobility. J Appl Bacteriol, 1994. 76(5): p. 521-8.

230. O'Leary, I.K., et al., Acceptability and intelligibility of tracheoesophageal speech using the Groningen valve. Folia Phoniatr. Logop, 1994. 46(4): p. 180-187.

231. Parker, A.J., et al., Characteristics of Groningen tracheo-oesophageal speaking valves prior to insertion and after removal for failure. J. Laryngol. Otol, 1992. 106(6): p. 521-524.

232. Parker, A.J., et al., The Groningen valve voice prosthesis in Sheffield: a 4-year review. J. Laryngol. Otol, 1992. 106(2): p. 154-156.

233. van Lith-Bijl, J.T., et al., Clinical experience with the low-resistance Groningen button. Eur. Arch. Otorhinolaryngol, 1992. 249(6): p. 354-357.

234. Rosingh, H.J., et al., [Voice rehabilitation following larynx extirpation using the Groningen button] in Dutch. Ned. Tijdschr. Geneeskd, 1991. 135(29): p. 1315-1318.

235. Manni, J.J. and P. Van den Broek, Surgical and prosthesis-related complications using the Groningen button voice prosthesis. Clin. Otolaryngol. Allied Sci, 1990. 15(6): p. 515-523.

236. Gazzini, L., et al., Secondary tracheoesophageal puncture with the blind technique: 10 years' experience. Eur Arch Otorhinolaryngol, 2021. 278(11): p. 4459-4467.

237. Keyser, B., J.E. Lubek, and J.F. Caccamese, Jr., Self-Retained Voice Prosthesis in the Decompression of the Odontogenic Keratocyst: A Technical Note. J Oral Maxillofac Surg, 2020. 78(10): p. 1754-1758.

238. Brownlee, B., et al., Selective patient experience with the Blom-Singer Dual Valve voice prosthesis. Laryngoscope, 2017. 128(2): p. 422-426.

239. Naunheim, M.R., et al., The Effect of Initial Tracheoesophageal Voice Prosthesis Size on Postoperative Complications and Voice Outcomes. Ann. Otol. Rhinol Laryngol, 2015. 125(6): p. 478-84.

240. Naunheim, M.R., et al., Placement of a 16-French voice prosthesis at the time of secondary tracheoesophageal voice restoration. Am. J. Otolaryngol, 2015. 36(4): p. 509-512.

241. Sethi, R.K., et al., Primary tracheoesophageal puncture with supraclavicular artery island flap after total laryngectomy or laryngopharyngectomy. Otolaryngol. Head Neck Surg, 2014. 151(3): p. 421-423.

242. Choussy, O., et al., Management of voice prosthesis leakage with Blom-Singer large esophage and tracheal flange voice prostheses. Eur. Ann. Otorhinolaryngol. Head Neck Dis, 2012. 130(2): p. 49-53.

243. Deore, N., et al., Acoustic analysis of tracheo-oesophageal voice in male total laryngectomy patients. Ann. R. Coll. Surg. Engl, 2011. 93(7): p. 523-527.

244. Deschler, D.G., et al., Simplified technique of tracheoesophageal prosthesis placement at the time of secondary tracheoesophageal puncture (TEP). Laryngoscope, 2011. 121(9): p. 1855-1859.

245. Sinclair, C.F., et al., Primary versus delayed tracheoesophageal puncture for laryngopharyngectomy with free flap reconstruction. Laryngoscope, 2011. 121(7): p. 1436-1440.

246. Divi, V., et al., Primary TEP placement in patients with laryngopharyngeal free tissue reconstruction and salivary bypass tube placement. Otolaryngol. Head Neck Surg, 2011. 144(3): p. 474-476.

247. Sayed, S.I., et al., Tracheo-oesophageal party wall thickness in laryngectomised patients in India: implications for surgical voice restoration. J. Surg. Oncol, 2010. 101(1): p. 78-83.

248. Pighi, G.P., et al., Secondary tracheoesophageal puncture: blind technique with a rigid hysterometer. Laryngoscope, 2009. 119(7): p. 1431-1434.

249. Deschler, D.G., et al., Evaluation of voice prosthesis placement at the time of primary tracheoesophageal puncture with total laryngectomy. Laryngoscope, 2009. 119(7): p. 1353-1357.

250. Chone, C.T., et al., Computerized manometry use to evaluate spasm in pharyngoesophageal segment in patients with poor tracheoesophageal speech before and after treatment with botulinum toxin. Braz. J. Otorhinolaryngol, 2009. 75(2): p. 182-187.

251. Alam, D.S., P.P. Vivek, and J. Kmiecik, Comparison of voice outcomes after radial forearm free flap reconstruction versus primary closure after laryngectomy. Otolaryngol. Head Neck Surg, 2008. 139(2): p. 240-244.

252. Chone, C.T., et al., Botulinum toxin in speech rehabilitation with voice prosthesis after total laryngectomy. Braz. J. Otorhinolaryngol, 2008. 74(2): p. 230-234.

253. Attieh, A.Y., et al., Voice restoration following total laryngectomy by tracheoesophageal prosthesis: effect on patients' quality of life and voice handicap in Jordan. Health Qual. Life Outcomes, 2008. 6: p. 26.

254. Singh, A., et al., Does flexible videostroboscopy compare with rigid videostroboscopy in the assessment of the neoglottis? A preliminary report. Clin. Otolaryngol, 2008. 33(1): p. 60-63.

255. Lundstrom, E., et al., The pharyngoesophageal segment in laryngectomees--videoradiographic, acoustic, and voice quality perceptual data. Logoped. Phoniatr. Vocol, 2008. 33(3): p. 115-125.

256. Kazi, R., et al., Multidimensional assessment of female tracheoesophageal prosthetic speech. Clin. Otolaryngol, 2006. 31(6): p. 511-517.

257. Kress, P., P. Schafer, and F.P. Schwerdtfeger, [Clinical use of a voice prosthesis with a flap valve containing silver oxide (Blom-Singer Advantage), biofilm formation, in-situ lifetime and indication] in German. Laryngorhinootologie, 2006. 85(12): p. 893-896.

258. Kress, P., P. Schafer, and F.P. Schwerdtfeger, [The custom-fit voice prosthesis, for treatment of periprothetic leakage after tracheoesophageal voice restoration] in German. Laryngorhinootologie, 2006. 85(7): p. 496-500.

259. Nyquist, G.G., et al., Stricture associated with primary tracheoesophageal puncture after pharyngolaryngectomy and free jejunal interposition. Head Neck, 2006. 28(3): p. 205-209.

260. Li, Q.M., et al., [Complications of tracheoesophageal puncture for Blom-Singer voice restoration after total laryngectomy]. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi, 2005. 40(12): p. 925-8.

261. Awan, M.S., et al., Speech results with tracheoesophageal voice prosthesis after total laryngectomy. J. Pak. Med. Assoc, 2005. 55(12): p. 540-542.

262. Leder, S.B., et al., Voice restoration with the advantage tracheoesophageal voice prosthesis. Otolaryngol. Head Neck Surg, 2005. 133(5): p. 681-684.

263. Schindler, A., et al., Intensity and fundamental frequency control in tracheoesophageal voice. Acta Otorhinolaryngol. Ital, 2005. 25(4): p. 240-244.

264. Shah, R.K. and E.E. Rebeiz, Tracheoesophageal voice restoration following laryngotracheal separation procedure. Ann. Otol. Rhinol. Laryngol, 2005. 114(8): p. 634-637.

265. Chone, C.T., et al., Primary versus secondary tracheoesophageal puncture for speech rehabilitation in total laryngectomy: long-term results with indwelling voice prosthesis. Otolaryngol. Head Neck Surg, 2005. 133(1): p. 89-93.

266. Li, Q., et al., [Long-term results of tracheoesophageal puncture for voice restoration after total laryngectomy]. Lin Chuang Er Bi Yan Hou Ke Za Zhi, 2005. 19(6): p. 241-3, 246.

267. Chone, C.T., et al., Speech rehabilitation after total laryngectomy: long-term results with indwelling voice prosthesis Blom-Singer. Rev. Bras. Otorrinolaringol. (Engl. Ed), 2005. 71(4): p. 504-509.

268. Akbas, Y. and G. Dursun, Voice restoration with low pressure blom singer voice prosthesis after total laryngectomy. Yonsei Med. J, 2003. 44(4): p. 615-618.

269. Jin, G.W., et al., [Acoustic analysis of the voice restored by using a tracheoesophageal slit-like fistula]. Zhonghua Er Bi Yan Hou Ke Za Zhi, 2003. 38(3): p. 225-8.

270. Ge, P.J., et al., [Pharyagoesophageal sphinoter myotomy for voice rehabilitation after total laryngectomy]. Zhonghua Er Bi Yan Hou Ke Za Zhi, 2003. 38(1): p. 12-4.

271. Fagan, J.J., et al., Tracheoesophageal speech in a developing world community. Arch. Otolaryngol. Head Neck Surg, 2002. 128(1): p. 50-53.

272. Desyatnikova, S., et al., Tracheoesophageal puncture in the office setting with local anesthesia. Ann. Otol. Rhinol. Laryngol, 2001. 110(7 Pt 1): p. 613-616.

273. Peng, Y., et al., [Pharyngeal plexus neurectomy for voice restoration of alaryngeal]. Zhonghua Er Bi Yan Hou Ke Za Zhi, 2000. 35(4): p. 298-9.

274. Deschler, D.G., et al., Effects of sound pressure levels on fundamental frequency in tracheoesophageal speakers. Otolaryngol. Head Neck Surg, 1999. 121(1): p. 23-26.

275. Dworkin, J.P., et al., Videostroboscopy of the pharyngoesophageal segment in total laryngectomees. Laryngoscope, 1998. 108(12): p. 1773-1781.

276. Kumazawa, H., et al., [Voice restoration and clinical outcome in patients undergoing laryngectomy with voice prostheses]. Nihon Jibiinkoka Gakkai Kaiho, 1998. 101(11): p. 1303-10.

277. Deschler, D.G., et al., Quantitative and qualitative analysis of tracheoesophageal voice after pectoralis major flap reconstruction of the neopharynx. Otolaryngol. Head Neck. Surg, 1998. 118(6): p. 771-776.

278. Kumazawa, H., et al., Magnetic resonance imaging of vocal failure in patients undergoing laryngectomy with tracheoesophageal fistula. Ann. Otol. Rhinol. Laryngol, 1997. 106(9): p. 795-798.

279. Leder, S.B. and M.C. Erskine, Voice restoration after laryngectomy: experience with the Blom-Singer extended-wear indwelling tracheoesophageal voice prosthesis. Head Neck, 1997. 19(6): p. 487-493.

280. Wong, S.H., et al., Long-term results of voice rehabilitation after total laryngectomy using primary tracheoesophageal puncture in Chinese patients. Am. J. Otolaryngol, 1997. 18(2): p. 94-98.

281. Lavertu, P., et al., Secondary tracheoesophageal puncture: factors predictive of voice quality and prosthesis use. Head Neck, 1996. 18(5): p. 393-398.

282. Geraghty, J.A., et al., Long-term follow-up of tracheoesophageal puncture results. Ann. Otol. Rhinol. Laryngol, 1996. 105(7): p. 501-503.

283. Stern, Y., et al., [Speech rehabilitation following total laryngectomy with tracheo-esophageal puncture]. Harefuah, 1996. 130(2): p. 77-81, 144.

284. Blom, E.D., B.R. Pauloski, and R.C. Hamaker, Functional outcome after surgery for prevention of pharyngospasms in tracheoesophageal speakers. Part I: Speech characteristics. Laryngoscope, 1995. 105(10): p. 1093-1103.

285. Leder, S.B. and C.T. Sasaki, Incidence, timing, and importance of tracheoesophageal prosthesis resizing for successful tracheoesophageal speech production. Laryngoscope, 1995. 105(8 Pt 1): p. 827-832.

286. Miralles, J.L. and T. Cervera, Voice intelligibility in patients who have undergone laryngectomies. J. Speech Hear. Res, 1995. 38(3): p. 564-571.

287. Labruna, A., et al., Tracheoesophageal puncture in irradiated patients. Ann. Otol. Rhinol. Laryngol, 1995. 104(4 Pt 1): p. 279-281.

288. Mehta, A.R., et al., The Indian experience with immediate tracheoesophageal puncture for voice restoration. Eur. Arch. Otorhinolaryngol, 1995. 252(4): p. 209-214.

289. Deschler, D.G., et al., Tracheoesophageal voice following tubed free radial forearm flap reconstruction of the neopharynx. Ann Otol Rhinol Laryngol, 1994. 103(12): p. 929-36.

290. Anthony, J.P., et al., Long-term functional results after pharyngoesophageal reconstruction with the radial forearm free flap. Am. J. Surg, 1994. 168(5): p. 441-445.

291. Ching, T.Y., R. Williams, and H.A. Van, Communication of lexical tones in Cantonese alaryngeal speech. J. Speech Hear. Res, 1994. 37(3): p. 557-563.

292. Wilson, P.S., et al., Speech restoration following total laryngo-pharyngectomy with free jejunal repair. Clin Otolaryngol Allied Sci, 1994. 19(2): p. 145-8.

293. Kao, W.W., et al., The outcome and techniques of primary and secondary tracheoesophageal puncture. Arch. Otolaryngol. Head Neck Surg, 1994. 120(3): p. 301-307.

294. Gerwin, J.M. and G.L. Culton, Prosthetic voice restoration with the tracheostomal valve: a clinical experience. Am. J Otolaryngol, 1993. 14(6): p. 432-439.

295. Kerr, A.I., et al., Blom-Singer prostheses--an 11 year experience of primary and secondary procedures. Clin Otolaryngol Allied Sci, 1993. 18(3): p. 184-7.

296. Mendelsohn, M., M. Morris, and R. Gallagher, A comparative study of speech after total laryngectomy and total laryngopharyngectomy. Arch Otolaryngol Head Neck Surg, 1993. 119(5): p. 508-10.

297. Deshmane, V.H., et al., Primary tracheo oesophageal puncture our initial experience. Indian J Cancer, 1992. 29(3): p. 114-6.

298. Callaway, E., et al., Predictive value of objective esophageal insufflation testing for acquisition of tracheoesophageal speech. Laryngoscope, 1992. 102(6): p. 704-708.

299. Ottaviani, F., [The restoration of the vocal possibilities for the laryngectomized patient with a tracheoesophageal prosthesis]. Acta Otorhinolaryngol Ital, 1992. 12(3): p. 265-71.

300. Cole, I. and S. Miller, TOTAL LARYNGECTOMY WITH PRIMARY VOICE RESTORATION. Australian and New Zealand Journal of Surgery, 1992. 62(4): p. 279-282.

301. Camilleri, A.E. and K. MacKenzie, The acceptability of secondary tracheo-oesophageal fistula creation in long standing laryngectomees. J. Laryngol. Otol, 1992. 106(3): p. 231-233.

302. St Guily, J.L., et al., Postlaryngectomy voice restoration. A prospective study in 83 patients. Arch Otolaryngol Head Neck Surg, 1992. 118(3): p. 252-5.

303. Wang, R.C., et al., Long-term problems in patients with tracheoesophageal puncture. Arch. Otolaryngol. Head Neck Surg, 1991. 117(11): p. 1273-1276.

304. Recher, G., et al., Italian experience of voice restoration after laryngectomy with tracheoesophageal puncture. Ann. Otol. Rhinol. Laryngol, 1991. 100(3): p. 206-210.

305. Fujimoto, P.A., C.L. Madison, and L.B. Larrigan, The effects of a tracheostoma valve on the intelligibility and quality of tracheoesophageal speech. J. Speech Hear. Res, 1991. 34(1): p. 33-36.

306. Julien, N., et al., [Vocal restoration by tracheo-esophageal fistula. Evaluation of a 5 years' experience]. Ann Otolaryngol Chir Cervicofac, 1991. 108(3): p. 164-8.

307. Williams, S.E., T.S. Scanio, and S.I. Ritterman, Perceptual characteristics of tracheoesophageal voice produced using four prosthetic/occlusion combinations. Laryngoscope, 1990. 100(3): p. 290-3.

308. Lacau St Guily, J., et al., [Patients excluded from voice restoration after total laryngectomy]. Ann Otolaryngol Chir Cervicofac, 1990. 107(3): p. 205-8.

Head office:
Atos Medical AB, Hyllie Boulevard 17, SE-215 32 Malmö, Sweden

Manufacturer:
Atos Medical AB, Kraftgatan 8, SE-242 35 Hörby, Sweden Tel: +46 (0) 415 198 00
Email: info@atosmedical.com