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Hearing evaluation after successful myringoplasty

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Abstract

Objectives: To assess postoperative hearing level, and factors that may have influence hearing improvement after myringoplasty.
Methods: Twenty six cases of successful myringoplasty were included in this prospective study. Patient parameters including age, gender, size and site of the perforation, mastoid status, and etiology were evaluated. Hearing levels were assessed as the mean air conduction (AC), and air-bone gap (ABG) at 500, 1000, and 2000 Hz, and their relation with aforementioned parameters were analyzed.
Results: The mean AC hearing gain was 22.373 dB and mean ABG reduction was 20.733 dB. The maximum AC hearing gain was 25.93 dB for subtotal perforation and 26.24 dB for big central perforation, and the maximum ABG reduction was 25.63 dB for subtotal perforation and 24.20 for big central perforation. Mean AC hearing gain was 23.01 dB, 22.72 dB, and 21.39 dB for 500, 1000, and 2000 Hz, respectively, and mean ABG reduction was 21.52 dB, 20.79 dB, and 19.86 dB for 500, 1000, and 2000 Hz, respectively. Patient age, gender, mastoid status and etiology did not seem to have any bearing on postoperative hearing improvement.
Conclusion: While patient parameters do not seem to correlate with hearing improvement following myringoplasty, the size and location of perforation appear to have an impact on postoperative hearing outcomes. Most hearing improvement appears to occur at 500 Hz.

Keywords: Myringoplasty; Hearing loss; Tympanic membrane

1. Introduction

Myringoplasty is a common procedure in otology surgical practice, and refers to surgical repair of the tympanic membrane perforations. The most accepted indications are protection of the middle ear mucosa from the infection through external auditory canal, and hearing improvement. It was introduced by Berthold in 1878, but it was only in 1956 when Wullstein developed fundamental principles for modern practice (Wullstein, 1956). The underlay technique, described by Austin and Shea (1961) has become widely recognized as one of the most successful techniques. Hough modified this technique by utilizing temporalis fascia (Hough, 1970).

Different materials have been used to construct the tympanic membrane, the most accepted of which is temporalis fascia autograft and almost always the most favorable graft for its immunologically compatibility (Michael, 1972).

The most common surgical techniques used are underlay and overlay grafting, with transcanal or postauricular approach. The underlay technique is most preferred because, compared with the overlay technique, it gives a better access to middle ear and ossicles; while with regard to surgical approach, post-auricular approach is more preferable than transcanal route, because the grafting via ear canal through a speculum is regarded as more technically difficult (Jackson et al., 2010).

The tympanic membrane perforations mainly result from middle ear infections, trauma or iatrogenic causes (Sarker et al., 2011), and hearing loss from tympanic membrane perforation is usually less than 45 dB and of conductive type.

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More severe hearing loss more is usually associated with ossicular abnormalities (Browning, 2008).

There is no universal agreement regarding the standard criteria for reporting hearing results. A variety of methods have been applied by several researchers to record postoperative hearing assessment in the literature, and the parameters that are most often used are the mean (average) hearing gain, postoperative hearing level and air-bone gap (ABG). Hearing improvement is usually defined as hearing gain exceeding 10 dB or 20 dB, or reduction of ABG to within 10, 15, 20, or 30 dB, or achievement of the social hearing (0−30 dB HL). The American Academy of Ophthalmology and Otology recommend average hearing gain at frequencies of 500−2000 Hz, or a diminution of ABG, as measures of postoperative hearing outcomes (Gupta et al., 2016).

The aim of the current study was to assess postoperative hearing levels using different audiometric parameters and investigate factors that may influence outcomes after myringoplasty in term of hearing improvement.

2. Patients and methods

This was a prospective study involving 26 cases of successfully completed myringoplasty at ENT department of a private hospital from April 1st 2016 to April 1st 2017. All the operations were performed by a single surgeon under general anesthesia, through a postaural approach, using the underlay technique with autogenous temporalis fascia grafts.

The diagnosis was established after a relevant history, proper ENT examination with special attention to the ear of concern under a Carl Zeiss microscope with a 200 mms lens. The size of the tympanic membrane perforation was evaluated using the computer Auto CAD software Aperio Image Scope 11, in which the entire tympanic membrane (TM) and the area of perforation (P) were calculated, and the percentage area of perforation (P/TM × 100%) for each ear was measured. The perforation size was categorized as “small” (percentage perforation less than 25%), “medium” (25%−50%), “large” (50%−75%), or “subtotal” (more than 75%). Location of the perforation in the pars-tensa was documented in relation to the handle of the malleolus, as: “anterior central” (anterior to the handle), “posterior central” (posterior to handle), “central malleolor” (involving both halves), or “big central” (involving all quadrants of the tympanic membrane).

The study was dealing with selected cases of inactive mucosal chronic otitis media with persistent tympanic membrane perforations that fulfilled the following specific criteria;

Inclusion criteria

1. Age >18 years.
2. Dry central perforation for more than 12 weeks.
3. Normal hearing in the contralateral ear.
4. Functioning Eustachian tube and ossicular chain.
5. Duration of perforation or disease process <1 year.
6. Conductive hearing loss not exceeding 45 dB, with good cochlear reserve.

Exclusion criteria

1. Previous middle ear surgery or revision myringoplasty.
2. Tympanosclerosis or diseases of the external ear.
3. Mixed hearing loss on pure tone audiogram.
4. Pathological changes in the mucosa of the middle ear, such as polypoidal, atrophic mucosa, cholesteatoma, or granulation tissue.
5. Septic foci in the nose or paranasal sinuses; other relevant systemic medical conditions such as diabetes mellitus, tuberculosis, malignancy or pregnancy.

All the patients received CT scanning of the temporal bones for better evaluation of the middle ear mucosa clefts and the mastoid air cells.

The hearing level was assessed 1 week before the operation and at third month postoperatively, in an acoustically treated sound proof room, with a MI-300 clinical diagnostic pure tone audiometer recently calibrated “according to the international organization of standardization”. The Carhart and Jerger's technique was followed, and the mean air conduction (AC) threshold and air-bone gaps (ABG) over 500, 1000, and 2000 Hz were calculated.

The study was approved by the institutional ethical and scientific review board, and informed consents were obtained from all participating patients, as well as the hospital registration number.

Routine postoperative care and follow up were provided, weekly in the first month and then monthly up to 3 months, or longer as required by the patient's condition.

The operation was considered successful at three months postoperatively if the following criteria were met: intact, dry, and normal positioned graft under otoscopy, mean hearing level improvement by air conduction pure tone audiometry of 15 dB or more, or an ABG closure to within 15 dB.

2.1. Statistical analysis

Statistical analysis was done with the SPSS version 18 software (Statistical Package for Social Sciences, SPSS Inc, Chicago, Illinois, USA). Measurements were expressed as mean and standard deviation (SD±) for parametric data and as numbers and percentage for non-parametric data. The paired t test was used for comparison between pre and postoperative results within each group. The level of significance was set at $p < 0.05$.

3. Results

Of the 26 patients, 12 (46.15%) were male and 14 (53.84%) were female, with a mean age of 32.44 (±7.66) years.

The size, site and etiology of the perforations, as well as mastoid status are recorded in Table 1.

Mean hearing levels before and after the myrinoplasty are shown in Table 2, showing a mean postoperative air conduction hearing gain of 22.37 dB, and a mean air-bone gap reduction of 20.73 dB.

Table 1
Distribution of perforation parameters, etiology and mastoid status.

Site of [a]TM perforation	Number and percentage	Size of TM perforation	Number and percentage	Etiology	Number and percentage	Mastoid status	Number and percentage
Anterior central	5 ears (19.23%)	Small	3 ears (11.53%)	[b]CSOM	16 ears (61.53%)	pneumatic	13 ears (50%)
Posterior central	6 ears (23.07%)	Medium	8 ears (30.76%)	[c]TTMP	10 ears (38.46%)	Sclerotic	13 ears (50%)
Malleolar central	7 ears (26.92%)	Large	6 ears (23.07%)				
Big central	8 ears (30.76%)	Subtotal	9 ears (34.61%)				

[a] TM = tympanic membrane.
[b] CSOM = chronic suppurative otitis media.
[c] TTMP = traumatic tympanic membrane perforation.

Table 2
Pre and postoperative mean hearing levels (dB HL).

Hearing level	Preoperative dB[a]	Postoperative dB	P value
Air conduction	37.933	15.560	0.0001#
Air-bone gap	30.719	9.986	0.0001

#Statistically significant ($p < 0.05$).
[a] dB = decibel.

Postoperative hearing gain was between 11 and 20 dB in 6 ears (23.08%), and between 20 and 30 dB in 20 ears (76.92%); while ABG was completely closed in 2 ears (7.69%), reduced to less than 10 dB in 20 ears (76.92%), and less than 20 dB in 4 ears (15.38%).

Pre and postoperative mean air conduction hearing levels and air-bone gaps are compared in Table 3 in relation with various patient parameters.

Pre and postoperative mean air conduction hearing levels at different speech frequencies are listed in Table 4, and show mean postoperative hearing gain of 23.01, 22.72, and 21.39 dB at 500, 1000 and 2000 Hz, respectively, irrelevant to patient parameters.

Postoperative air-bone gap reduction at 500, 1000 and 2000 Hz was 21.52 dB, 20.79 dB, and 19.86 dB, respectively, irrespective to all patient's parameters (Table 5).

4. Discussion

As hearing restoration forms a critical matter for the rehabilitation in patients suffering from tympanic membrane perforation, the surgeons is more interested in recovering or at least improving their hearing capacity while treating ears pathologies. Myringoplasty is therefore considered an important surgical tool widely used in this field.

The current study used two pure tone audiometric parameters for the assessment/confirmation of hearing gain after myringoplasty at 500, 1000 and 2000 Hz, which represent critical frequencies for understanding speech. The author also chose to limit the scope of the study to a purpose criterion based assessment, with a precisely selected non-probabilistic sampling technique, in order to avoid any possibility of confounding factors impacting the results.

In the current study the mean patient age was 32.44 (±7.66) years, with a female predominance. Most patients presented with subtotal and big central perforations, with CSOM being the most common etiology, these observations are essentially comparable with the findings by Rasha and Ahmed (2015), although the location of perforation was not assessed in their study. The largest preoperative hearing loss was seen with the subtotal and big central perforations in this study with CSOM

Table 3
Pre and postoperative mean hearing levels (dB[a] HL[b]) and ABGs (dB) in relation to patient parameters.

Parameters		Preoperative hearing level	Postoperative hearing level	Preoperative air-bone gap	Postoperative air-bone gap
Gender	Male	36.831	14.563	31.569	9.857
	Female	37.857	15.714	30.857	9.341
Age groups	18−29 years	38.27	15.54	29.351	10.625
	30−39 years	39.62	17.58	29.531	10.67
	40−49 years	36.860	14.637	27.27	8.34
Etiology	CSOM[c]	39.875	16.25	31.598	13.125
	TTMP[d]	33.49	10.42	27.473	8.845
Size of the perforation	Small	31.837	13.53	26.96	6.659
	Medium	38.425	15.648	28.53	8.74
	Large	41.26	16.27	31.47	11.871
	Subtotal	44.58	18.65	38.98	13.35
Site of the perforation	Anterior central	30.653	13.327	26.679	6.17
	Posterior central	38.751	16.75	32.258	10.761
	Malleolor central	40.862	15.58	33.832	10.324
	Big central	44.56	18.32	36.74	12.54
Mastoid status	Sclerotic	38.25	18.486	31.25	10.75
	Pneumatic	32.893	13.269	27.89	7.8

[a] dB = decibel.
[b] HL = hearing level.
[c] CSOM = chronic suppurative otitis media.
[d] TTMP = traumatic tympanic membrane perforation.

Table 4
Pre [b] and postoperative[c] mean hearing levels (dB[d] HL[e]) at different speech frequencies in relation to patient parameters.

Parameters		500 Hz[a] Pre/post-op	1000 Hz Pre/post-op	2000 Hz Pre/post-op
Gender	Male	37.731/13.642	36.831/14.463	35.931/15.584
	Female	37.829/14.912	38.755/15.814	36.987/16.416
Age groups	18–29 years	39.25/15.63	38.29/14.56	37.27/16.43
	30–39 years	38.63/16.28	40.91/17.69	39.32/18.77
	40–49 years	37.73/15.926	36.89/13.239	35.96/14.746
Etiology	CSOM[f]	40.985/16.21	38.878/17.38	39.762/15.16
	TTMP[g]	33.69/10.31	34.49/10.52	32.29/10.43
Size of the perforation	Small	31.826/13.47	30.967/12.61	32.718/14.51
	Medium	39.113/14.858	38.327/15.959	37.835/16.127
	Large	41.17/15.14	42.35/16.29	40.26/17.38
	Subtotal	44.47/18.51	45.68/17.75	43.59/19.69
Site of the perforation	Anterior central	30.742/12.316	29.563/13.339	31.654/14.327
	Posterior central	39.640/15.65	38.862/16.87	37.751/17.73
	Malleolor central	40.964/15.47	41.781/14.69	39.841/16.58
	Big central	44.23/18.02	44.47/18.11	44.98/18.83
Mastoid status	Sclerotic	38.17/18.379	39.37/19.593	37.21/17.486
	Pneumatic	32.891/13.259	31.995/13.279	33.793/13.269

[a] Hz = Hertz.
[b] HL = hearing level, media.
[c] Pre = preoperative.
[d] Post-op = postoperative.
[e] dB = decibel.
[f] CSOM = chronic suppurative otitis.
[g] TTMP = traumatic tympanic membrane perforation.

as the etiology, and these are comparable to finding in other studies (Yung, 1983; Shetty, 2012).

The mean air conduction hearing gain in the current study was 22.37 dB, and mean air-bone gap reduction was 20.73 dB, comparable to the result of some studies (Shetty, 2012; Sangavi, 2015; Patil et al., 2014), while different from others (Rasha and Ahmed, 2015; Maroto et al., 2010; Singh et al., 2014), which report less hearing threshold gain. The explanation for the difference may involve status of the ossicular chain or scar tissue in the middle ear cavity in CSOM, which can be the responsible factor for incomplete restoration of the hearing after myringoplasty (Koch et al., 1990).

Some reports state that the degree of hearing improvement depends upon many factors, such as the site and size of

Table 5
Pre[b] and postoperative[c] air–bone gaps (dB[d]) at different speech frequencies.

Parameters		500 Hz[a] Pre/post-op	1000 Hz Pre/post-op	2000 Hz Pre/post-op
Gender	Male	32.459/9.737	31.669/9.857	30.579/9.977
	Female	31.956/8.241	30.757/9.380	29.858/10.402
Age groups	18–29 years	28.310/9.914	30.492/11.316	29.251/10.645
	30–39 years	30.551/9.95	29.521/10.69	28.521/11.37
	40–49 years	28.05/8.13	27.29/8.34	26.47/8.55
Etiology	CSOM[e]	30.197/12.247	32.899/14.016	31.698/13.112
	TTMP[f]	28.291/8.721	27.452/8.845	26.676/8.969
Size of the perforation	Small	26.99/6.659	26.96/5.879	26.93/7.439
	Medium	32.13/10.993	31.49/11.860	30.79/12.760
	Large	32.99/11.760	31.27/11.861	30.15/11.992
	Subtotal	38.97/12.79	38.98/13.24	38.99/14.02
Site of the perforation	Anterior central	27.359/5.39	26.999/6.08	25.679/7.04
	Posterior central	33.078/10.641	32.037/10.751	31.659/10.891
	Malleolor central	34.702/11.012	32.983/10.117	33.811/9.843
	Big central	37.31/12.21	36.92/12.43	35.99/12.98
Mastoid status	Sclerotic	32.01/10.41	31.15/10.85	30.59/10.99
	Pneumatic	26.99/7.70	27.79/7.80	28.89/7.90

[a] Hz = Hertz.
[b] Pre = preoperative.
[c] Post-op = postoperative.
[d] dB = decibel.
[e] CSOM = chronic suppurative otitis media.
[f] TTMP = traumatic tympanic membrane perforation.

perforation, ossicular chain status, pneumatization of mastoid air cells, and surgeon experiences, in addition to the surgical technique applied, type of graft used, and functioning status of the Eustachian tube (Black and Wormald, 1995; Blakley et al., 1998).

The current study shows that age and gender do not seem to have any bearing on the postoperative hearing improvement ($p = 0.78$ and $p = 0.63$, respectively), which are in agreement with the results of several other studies (Yung, 1983; Shrestha and Sinha, 2006; Karela et al., 2008). While postoperative hearing gain in this study showed a linear relation with increasing size of the perforation, with the largest hearing gain (25.93 dB) seen in subtotal perforation ($p = 0.034$), consistent with Wesson's study, which concluded that mean air conduction audiometric gain was directly correlated with preoperative perforation size (Wasson et al., 2009), and the study by Kumar (2015) which observed that when the perforation size increased, postoperative hearing gain also improved; but in contrast to few other studies (Rasha and Ahmed, 2015; Singh et al., 2009) which reported that, despite greater preoperative hearing loss in larger size perforations, postoperative hearing gain was mostly better with smaller size perforations.

The explanation for better hearing improvement in smaller size perforations, especially if associated with shorter disease duration, may be the less extent of pathological changes in the middle ear (Lee et al., 2002). However, it is worth to mention that, these two factors were taken into consideration by the author in advance in this study, as the inclusion/exclusion criteria required that the middle ear mucosa be without any pathological changes, and duration of perforation be less than 1 year. Other studies, however, have concluded that there is no correlation between the size of the perforation and postoperative hearing gain (Karela et al., 2008).

The current study also shows that postoperative hearing gain varies with site of the perforation, with better gain in posterior central perforations than anterior central perforations ($p = 0.04$), similar to a few other studies (Yung, 1983; Shrestha and Sinha, 2006), but different from the study by Karela et al. (2008) which concluded that hearing improvement was not dependent upon the site of tympanic membrane perforation.

The relation between postoperative hearing gain and mastoid status revealed a minor difference in favor of sclerotic mastoid in this study, although not statistically significant ($p = 0.59$), in spite of the greater preoperative hearing loss with the sclerotic mastoid, and this is confirmed by the study by Singh et al. (2014), which concluded that the mastoid air cell system had no effect on hearing outcomes.

Another interesting aspect of the postoperative hearing results in this study is the distribution of hearing thresholds across the speech frequencies (500, 1000 and 2000 Hz), showing largest mean postoperative air conduction hearing gain (23.01 dB) and ABG reduction (21.52 dB) at 500 Hz, almost comparable to the observation in other studies, such as the one by Maroto et al. (2010) which assessed hearing improvement after myringoplasty in 119 cases and concluded that greater hearing improvement was found at lower the frequency with the best results at 250 Hz.

Similarly, Choi et al. (2011) studied 559 chronic ear surgeries, and found that the air conduction threshold and ABG improvement was detected primarily in the low and mid frequencies.

In general, the results of myringoplasty in terms of hearing gain reveal a considerable variability when evaluated by various modalities in different studies. Therefore, postoperative hearing gain assessment needs a sustained effort to simultaneously take into consideration many parameters, including multiple audiometric parameters, preoperative hearing level, characteristics of the perforation, adjustment of the audiogram, patient's cooperation, surgical indications, as well as the type of surgical technique used, and of course the experience and skill of the operating surgeon.

It is not abnormal for some variance to be detected in the results of this kind of surgery. Researchers advise that the best approach is to look at all parameters simultaneously in order to come up with a satisfactory concept of the hearing status, and this requires conducting protocols based on scientific verification that would standardize the criteria in all aspects for more dependable results to be attained, with the actual possibility of an objective comparison among different set-ups.

5. Conclusions

In this study, the mean air conduction hearing gain was 22.37 dB and mean air-bone gap reduction was 20.73 dB after myringoplasty. Most patient parameters including age, gender, mastoid status and etiology did not seem to have any bearing on postoperative hearing improvement, while the size and site of the perforation were correlated with the level of hearing gain. The largest air conduction hearing gain (23.01 dB) and ABG reduction (21.52 dB), irrespective to patient parameters, were seen at 500 Hz.

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Conflicts of interest

None.

References

Austin, D.F., Shea Jr., J.J., 1961. A new system of tympanoplasty using vein graft. Laryngoscope 71, 596–611.

Black, J.H., Wormald, P.J., 1995. Myringoplasty-effects on hearing and contributing factors. S. Afr. Med. J. 85, 41–43.

Blakley, B.W., Kim, S., Vancamp, M., 1998. Preoperative hearing predicts postoperative hearing. J. Otolaryngol. Head Neck Surg. 119, 559–563.

Browning, G.G., 2008. Chronic otitis media. In: Gleeson, M., Browning, G.G., Burton, M.G., et al. (Eds.), Scott-Brown's Otorhinolaryngology Head and Neck Surgery, seventh ed., vol. 3. Hodder Arnold, London, pp. 3395–3445.

Choi, H.G., Lee, D.H., Chang, K.H., Yeo, S.W., Yoon, S.H., Jun, B.C., 2011. Frequency-specific hearing results after surgery for chronic ear diseases. Clin. Exp. Otorhinolaryngol. 4, 126–130.

Gupta, S., Kalsotra, P., Sehgal, S., Gupta, N., 2016. Review of parameters used to assess hearing in improvement in tympanoplasty. IOSR-JDMS 2, 122–128.

Hough, J.V., 1970. Tympanoplasty with interior fascial graft technique and ossicular reconstruction. Laryngoscope 80, 1385–1401.

Jackson, C.G., Kaylie, D.M., Glasscock, M.E., Stransnick, B., 2010. Tympanoplasty-undersurface graft technique. In: Brackmann, D.E., Shelton, C., Moises, A.A. (Eds.), Otologic Surgery, third ed. Saunders, Philadelphia, pp. 149–152.

Karela, M., Berry, S., Watkins, A., Phillippis, J.J., 2008. Myringoplasty: surgical outcomes and hearing improvement: is it worth performing to improve hearing? Eur. Arch. Otorhinolaryngol. 265, 1039–1042.

Koch, W.M., Friedman, E., Mc Gill, T.J.I., Healy, G.B., 1990. Tympanoplasty type 1. Arch. Otolaryngol. Head Neck Surg. 116, 35–40.

Kumar, T.V.V.V., 2015. Evaluation of various graft materials in myringoplasty. Int. J. Pharm. Bio. Sci. 6, 700–723.

Lee, P., Kelly, G., Mills, R.P., 2002. Myringoplasty: does the size of the perforation matter? Clin. Otolaryngol. 27, 331–334.

Maroto, D.P., Gutiérrez, J.J.E., Jiménez, M.C., Rodríguez, V.P., Morente, J.C., Benítez-Parejo, N., 2010. Functional results in myringoplasties. Acta Otorrinolaryngol. Esp. 61, 94–99.

Michael, M.D., 1972. Homograft tympanic membrane in myringoplasty. Ann. Oto. Rhino. Laryngol. 81, 194–202.

Patil, B.C., Misale, P.R., Mane, R.S., Mohite, A.A., 2014. Outcome of interlay grafting in type 1 tympanoplasty for large central perforation. Indian J. Otolaryngol. Head Neck Surg. 66, 418–424.

Rasha, A., Ahmed, S.A.O., 2015. Outcome of hearing improvement in myringoplasty a study of fifty one sudanese patients. Int. J. Otorhinolaryngol. 1, 5–8.

Sangavi, A.K.B., 2015. Assessment of hearing improvement by myringoplasty. J. Sci. Inno. R. 4, 67–70.

Sarker, A.H., Ahmed, Z., Patwary, M., Islam, P., Joarder, R., 2011. Factors affecting surgical outcome of myringoplasty. Bangladish J. Otorhinolaryngol. 17, 82–87.

Shetty, S., 2012. Pre-operative and post-operative assessment of hearing following tympanoplasty. Indian J. Otolaryngol. Head Neck Surg. 64, 377–381.

Shrestha, S., Sinha, B.K., 2006. Hearing results after myringoplasty. Kathmandu Univ. M. J. 4, 455–459.

Singh, B.J., Sengupta, A., Sudip, D., Ghosh, D., Basak, B., 2009. A comparative study of different graft materials used in myringoplasty. Indian J. Otolaryngol. Head Neck Surg. 61, 131–134.

Singh, M.N., Hamam, D.P., Lyngdoh, N.C., Priyokumar, O.S., 2014. Evaluation of hearing status in pre and post-operative endoscopic type 1 tympanoplasty and its influencing factors. Med. Soci. J. 28, 166–170.

Wasson, J.D., Papadimitriou, C.E., Pau, H., 2009. Myringoplasty: impact of perforation size on closure and audiological improvement. J. Laryngol. Otol. 123, 973–977.

Wullstein, H., 1956. Theory and practice of tympanoplasty. Laryngoscope 66, 1076–1093.

Yung, M.W., 1983. Myringoplasty: hearing gain in relation to perforation site. J. Laryngol. Otol. 97, 11–17.