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Original Research Article

The practices and philosophies of cartilage tympanoplasty in difficult and challenging circumstances: audiological and morphological perspectives

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ABSTRACT

Background: The main objective of the study was to assess the anatomical and functional results of cartilage tympanoplasty using full thickness cartilage graft (with or without perichondrium) reinforced with fascia in high risk situations.
Methods: This prospective non-controlled, non-randomized study included 124 cases of chronic otitis media who underwent cartilage (reinforcement) tympanoplasty (underlay) and ossicular reconstruction with or without mastoidectomy in following seven groups: revision cases, atelectatic cases, subtotal perforation (dry), larger anterior perforations (dry), tympanosclerosis, cholesteatomatous ear, and wet (discharging) ears . Graft success was accepted labelled as an intact graft at the end of six month postoperatively. At the same time, hearing results were also assessed by comparing pre- and post-operative pure tone average air-bone gap (PTA-ABG) of each group using Student "t" test and $p<0.05$ was considered statistically significant for the hearing outcomes.
Results: Anatomical success rate in this series was 94.36%. The overall mean pre- and post- operative pure tone average air-bone gap (PTA-ABG) were 31.33±10.41 dB and 19.55±12.04 dB, respectively and the difference was statistically significant ($p<0.05$). Best take up rates were observed in atelectatic and tympanosclerotic group i.e., 100% and 96.55% respectively.
Conclusions: This study discusses the results of cartilage tympanoplasty in specifically indicated seven situation and reveals good anatomic results in each group (minimum success rate was 86.66% in wet ears) and statistically significant differences in mean pre- and post op PTA-ABG in groups except cholesteatoma and wet ear group.

Keywords: Cartilage tympanoplasty, Chronic suppurative otitis media, Intact canal wall mastoidectomy, Middle ear, Tragal cartilage; Tympanic membrane

INTRODUCTION

The principal objective of tympanoplasty is to establish a healthy well ventilated tympanum along with reconstruction of perforated tympanic membrane and restoration of the sound conducting mechanism. A number of graft materials, techniques and approaches have been invented, popularized and reinforced by various authors. In the last twenty years there has been an increasing trend of using cartilage grafts in primary reconstruction of middle ear. In a meta-analytic study it was demonstrated that cartilage graft, as an independent variable, proves to be a better graft choice as compared with temporalis fascia in children and adult cases in context of graft take rates.[1] At present cartilage tympanoplasty is indicated in cases having subtotal or bilateral perforations, coexisting cranio-facial abnormalities, revision tympanoplasty, atelectatic ears

and cholesteatoma, for the reason cartilage graft offers a tough neo-membrane to counteract negative middle ear pressure.[2] As opposed to other grafting materials, cartilage grafts do not adhere to promontory/tympanic walls or pose danger to exposed/dehiscent facial nerve. It is a robust and thick graft material which effectively counteracts resorption, retraction, inflammatory reaction and infections during the healing process.

Success in tympanoplasty depends on the type of graft used, surgical technique and patient related reasons. Low success rate is due to Eustachian tube dysfunction, atelectasis, tympanosclerosis, revision surgery, and condition of middle ear mucosa. Austin cited a morphological success rate of 98.4% using cartilage shield graft in high risk cases i.e. atelectatic ears, total perforation, tympanoplasty failure and cholesteatomatous ears.[3] Various techniques have been described in the literature where different ways and positions of cartilage grafts were used to reconstruct tynmpano-ossicular complex. It can be sculpted into fragments of variable size and shapes and can be laid as a graft with partial/full thickness and with/without perichondrium in the reconstructed middle ear. Establishing the free flow of air in the middle ear and mastoid determines the success of reconstructive surgery and functioning of this vibrating neo-tympano-ossicular mechanism.

The aim of the study was to analyse the anatomical and functional results of cartilage tympanoplasty in high risk situations and to interpret our results with respect to the disease/indications instead of surgery performed.

METHODS

This study was carried out during the period from January 2015 to December 2018, and compromised 124 cases of cartilage tympanoplasty (±ossicular reconstruction or mastoidectomy) were that done at a tertiary care center. The cases included in this prospective, non-controlled, non-randomized study were divided in seven high risk groups and which were subtotal, large anterior perforation, atelectasis, wet perforations, tympanosclerosis, revision cases and cholesteatoma ears. Pre-operative evaluation of the cases included history, bilateral clinical examination, pure tone audiometry, x-ray mastoids and CT scan of the temporal bone (in selected cases of revision and cholesteatoma group). Preoperative air conduction and bones conduction thresholds (for frequencies 0.5, 1, and 2 kHz) and air-bone gap were calculated and recorded. A written informed consent was taken from all patients or parents (in case of children <16 years of age) before surgery. Follow up was done at 1st, 3rd, 6th and 12 month (wherever possible) postoperatively. Average follow up period was six months.

Anatomic success was labeled when the post-operative graft was intact at three months postoperatively. Anatomical failure was considered in cases where there was re-perforation, lateralization/medialization of graft, ossicular prosthesis displacement/extrusion and recurrence of cholesteatoma. Hearing outcomes were assessed by comparing the means of pre- and post-operative pure tone average-air bone gap (PTA-ABG) (using Student "t" test) at third month post-operatively and statistical significance was assigned to a value of $p<0.05$. Statistical analysis was done using SPSS software. This study was approved by the Ethics Committee of the Institute.

Operative technique

All surgical cases were done by the first author and performed under general anesthesia using a post-auricular approach. Temporalis fascia and tragal cartilage graft with perichondrium were harvested at the beginning of the operation. In cases of narrow canal, anterior canal bulge, or where exposure of ossicles was not proper and in pediatric cases (wherever required) adequate canaloplasty was done. Except in cholesteatoma cases, indications of mastoid exploration were recalcitrant wet ears, hypertrophic middle ear mucosa, glue in middle ear, granulations, impaired tubal function and changes in x-ray mastoid. In all cases full thickness tragal cartilage was used. Perichondrium was preserved on the cartilage side facing external ear canal. A wedge shaped piece of cartilage was cut from superior part to accommodate handle of malleus. In cases, where foreshortened handle of malleus and adhesions between malleus and promontory were seen, trimming of handle of malleus or sectioning of tensor tympani was done to make adequate middle ear space. Cartilage graft was placed medial to handle of malleus in these cases to make the whole complex springier.

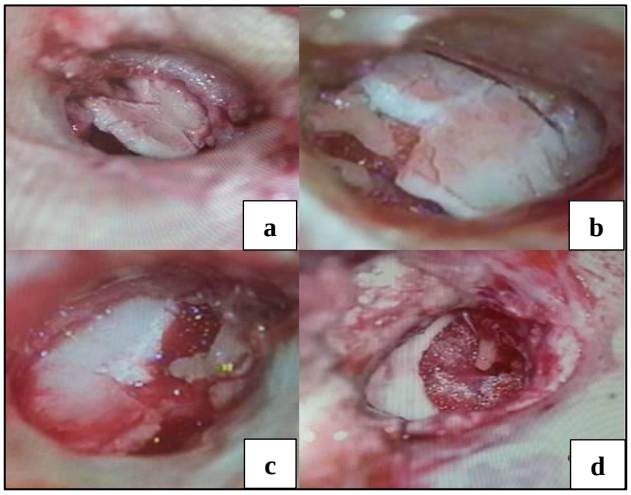

Figure 1. Cartilage graft kept in various situations: a) graft in large perforation; b) graft in subtotal perforation; c) graft in anterior half; d) graft as anterior rim only.

In all other cases, cartilage graft was placed lateral to handle of malleus but medial to annulus. Gelfoam was

placed medial to cartilage graft for stabilization and it was reinforced with temporalis fascia graft. The ear canal was packed with gelfoam and antibiotic soaked wick and kept for 10 days. Cartilage grafting was done as mosaic pattern, as anterior rim only, shield type, and as palisade pattern (in few cases) (Figure 1a, b, c, d).

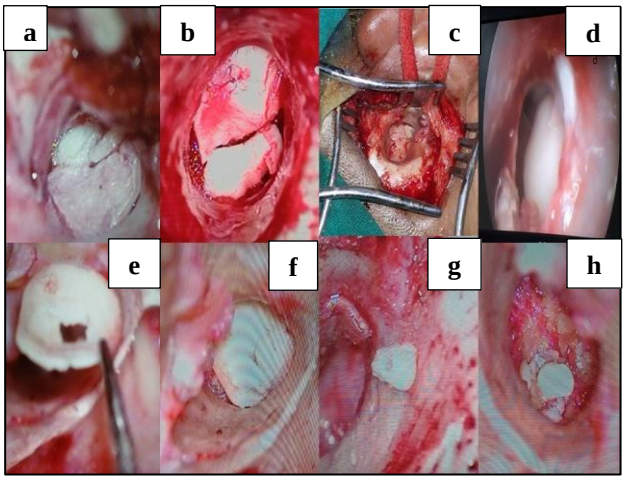

Figure 2: Cartilage grafts: a) graft having groove for handle of malleus; b) mosaic type pattern; c) graft in canal wall down mastoidectomy; d) graft failure after cartilage tympanoplasty in one case (anterior detachment); e) cartilage graft to be kept over stapes head; f) graft over stapes head; g) remodelled incus with groove; h) remodelled incus over stapes head (ossiculoplasty).

It was also used to reconstruct attic/postero-superior bony defects (surgical/pathological). In certain cases, where incus was removed or ossicular reconstruction was done, cartilage graft was placed medial both handle of malleus and annulus. Partial/total ossicular replacement prostheses (PORP/TORP), cartilage plates technique or sculpted incus over stapes head were used for ossiculoplasty (Figure 2a, b, c, d, e, f, g, h).

RESULTS

In this study of 124 cases, who underwent cartilage tympanoplasty, there were sixty five males and fifty nine females with male to female ratio of 1.1:1. Mean age observed was 28.31±11.15 years and age ranged from 6 to 62 years. The overall anatomical success rate was 94.36%. Functionally the difference between pre- (31.33±10.41 dB) and post-operative PTA-ABG (19.55±12.04 dB) was statistically significant ($p<0.05$). There were total seven failures in this series.

In Atelectatic group there were total sixteen cases (6 males and 10 females). Surgical correction was done on left ear in seven cases and on right ear in nine cases. In twelve cases, closed mastoidectomy and tympanoplasty (I or III) was done and in four cases tympanoplasty alone (I or III) was done. 100% anatomical success rate was achieved in this group (Table 1).

Table 1: Graft take- up rate (anatomical results) in all groups.

	Atelectasis	Cholesteatoma	Large anterior	Revision	Subtotal	Tympanosclerosis	Wet ear	
Success	16	13	19	10	18	28	13	
Failure	0	1	1	1	1	1	2	
Total	16	14	20	11	19	29	15	124
Complications	2	6	6	2 (in same patient)	2	1	3	
Success rate	100%	92.85%	95%	90.90%	94.73%	96.55%	86.66	

Table 2: Functional outcome. Changes in pre- and post-operative mean ABG calculated at three frequencies (0.5, 1, 2 kHz) for all seven groups are shown ($p<0.05$, Student "t" test).

	Atelectasis mean±SD	Cholesteatoma mean±SD	Large anterior mean±SD	Revision mean±SD	Subtotal mean±SD	Tympanosclerosis mean±SD	Wet ear mean±SD
Preop PTA-AB gap	32.43 (10.46)	32.07 (11.02)	27.7 (10.95)	28.9 (8.92)	34.42 (9.42)	29.68 (10.10)	32.73 (12)
Postop PTA-AB gap	22.4 (14.39)	30.78 (9.88)	12.55 (5.74)	18.09 (12.09)	19.42 (10.84)	15.58 (10.69)	25.2 (12.90)
	P <0.05 significant	p>0.05 not significant	P<0.05 significant	P<0.05 significant	P<0.05 significant	P<0.05 significant	P>0.05 not significant

Functionally, there was statistically significant difference ($p<0.05$) between pre- and post-operative PTA-ABG (Table 2).

In three cases there was no hearing improvement despite intact neo-membrane. The only complication observed in this group was post-operative otorrhoea (two cases) and it responded to conservative treatment with successful outcomes.

In cholesteatoma group of fourteen cases, right ear surgery was done in seven cases and seven cases had had left ear surgery. Graft success rate in this group was 92.85% with one failure (perforation observed) and the complications noticed with retraction (one case), worsening of hearing (two cases), discharge (one case), tinnitus (one case) and perichondritis (one case). In one case there was no hearing improvement even with an intact graft. In total, five canal wall down mastoidectomies and nine intact wall mastoidectomies with cartilage grafting were performed. Single stage middle ear reconstruction was done in all cases. The difference between pre- and post-operative PTA-ABG was not statistically significant ($p>0.05$) (Table 2).

In large anterior perforation group of twenty cases, right ear surgery was done in eleven cases and left ear surgery was done in nine cases. In nine cases mastoidectomy with tympanoplasty (I/II/III) was done alone and in eleven cases tympanoplasty (I/II) was done. In this group there was 95% anatomical success rate with one failed case (Table 1). There was a statistically significant difference ($p<0.05$) observed between pre- and post-operative PTA-ABG (Table 2). Six cases developed postoperative ear discharge which was managed conservatively. In two cases with intact graft, there was no hearing improvement.

In revision group there were a total of eleven cases out of which right side revision surgery was done in nine cases and left ear revision surgery alone was done in two cases. Mastoidectomy with tympanoplasty (I/II/III) was done in five cases, whereas tympanoplasty (I/II) were done in remaining cases. Anatomical success rate in this group was 90.90% with one failed case (Table 1) and there was a statistically significant difference ($p<0.05$) between pre- and post-operative PTA-ABG (Table 2). Observed complications were worsening of hearing and tinnitus in same patient despite intact graft.

In subtotal perforation group of nineteen cases, right ear was operated was operated in nine cases and ten cases were operated for left ear disease. There was 94.73% (18 cases). A success rate of 94.73% was achieved in this group with one failure (anterior re-perforation) (Table 1). The only complication observed was postoperative discharge in two cases and it was managed successfully with medications. There was no hearing improvement in one case (graft intact). Functionally, there was a statistically significant difference ($p<0.05$) between pre- and post-operative PTA-ABG (Table 2).

In tympanosclerosis group of twenty nine cases, right ear surgery was done in eighteen cases and eleven cases had had left ear surgery. In fourteen cases, tympanoplasty I/III was done whereas, mastoidectomy with type I/III was done in 15 cases. Anatomical success rate achieved in this group was 96.55% with one failed case (Table 1). There was a statistically significant difference ($p<0.05$) between pre- and post-operative PTA-ABG (Table 2). No hearing improvement was observed in four cases despite intact graft. Only complication noted was postoperative ear discharge in one case which was managed conservatively.

In fifteen cases of the discharging ear (wet ear) group right ear was operated in six cases and in nine cases left ear was operated. Mastoidectomy coupled with tympanoplasty (I/II/III) was done in thirteen cases whereas tympanoplasty alone was done in two cases. Morphologically there was 86.6% (13 cases) success rate with two failed cases. There was no statistically significant ($p>0.05$) difference between pre- and post-operative PTA-ABG (Table 2). Complication observed in this group was postoperative discharge in three cases which was successfully managed with no sequelae. In three cases there was no hearing improvement despite intact graft.

Assessment of the difference between pre- and postoperative PTA-ABG revealed that closure of ABG to 10 dB or less was seen in 27 cases postoperatively and closure between 11-20 dB was seen in 51 cases postoperatively (Table 3).

Table 3: Comparison of pre- and post-operative PTA-ABG.

	Preop PTA-ABG Case (%)	Postop PTA-ABG Cases (%)
0-10 dB	3 (2.42)	27 (21.77)
11-20 dB	22 (17.74)	51 (41.13)
21-30 dB	26 (20.97)	21 (16.94)
31-40 dB	52 (41.94)	16 (12.90)
>40 dB	21 (16.93)	9 (7.26)
Total	124	124

DISCUSSION

With the passage of time various grafting materials including skin, temporalis fascia, fascia lata, vein, dura, perichondrium and cartilage have been introduced with variable success to reconstruct tympanic membrane (TM). In literature, various techniques of cartilage tympanoplasty such as cartilage butterfly inlay technique, palisade technique, mosaic technique, composite chondro-perichondrial island technique and cartilage reinforcement technique have been described.[2] Cartilage graft is easy to harvest, is hard and thick, opposes resorption and retraction, and is expedient for sculpting in accordance to the size of the perforation. Cartilage can be used to close perforations, to reconstruct the ossicles and for reconstruction of bony walls as well. The first ear surgeon to use cartilage in middle ear surgery was Utech. He is also credited as the first surgeon for using a cartilage stapes columella in cases with a missing stapes.[4]

In tympanosclerotic cases, cartilage grafting plays an important role. Migirov et al cited that removal of all

plaques from membrane remnant and adequate freshening of perforation margins is necessary for better success rates in patients with myringosclerosis.[5] Graft take-up rates are generally low in tympanosclerotic or atelectatic ears.[6] Pertaining to outcomes in the atelactatic/retracted group two potential shortcomings may arise; first is the medially rotated malleus which renders insertion of the graft quite difficult, second is related to management of atrophic TM.[7] In a study cartilage tympanoplasty was done in cases of grade III and IV retraction pockets of pars flaccida with 90% successful graft take-up rate.[8] In our study**,** cartilage was used in tympanosclerotic and atelectatic groups with an anatomical success rate of 96.55% and 100% respectively.

The repair of subtotal perforation remains a challenge for the otologists. Low success rates are expected in cases of large central perforation due to anterior detachment of graft, shrinkage of fascial graft, improper anterior visualization and sliding of the graft posteriorly during manipulation. In a study by Ghosh et al, composite graft of tragal perichondrium supported by a ring of cartilage peripherally was used for closure of big central and subtotal perforations and a 93.33% graft take rate was observed in that study.[9] Similarly repairing large anterior perforation seems difficult than the repair of posterior quadrant perforation because of graft's viability, anterior canal wall bulge and medialization of the graft.[10] Various theories support or negate the relation between the location of perforation and surgical success. Particularly, anterior perforations affect the surgical outcome negatively due to technical difficulty in surgical manipulation and weak capillary feed.[11]

Even though success rates of 90% or greater after primary tympanoplasty have been claimed, successful results in revision cases avail no such privilege.[12] In a series of 135 revision cases, Ruhl et al performed tympanoplasty coupled with mastoidectomy, even in wet cases, achieving 90% graft take up rate supporting the role of mastoidectomy in conjunction with tympanoplasty. However they lacked a control group without mastoidectomy.[13] On the other hand, Boone et al concluded that mastoidectomy may not be required in revision tympanoplasty surgery, done for non-cholesteatomatous ear cases, if reconstruction made with cartilage.[12] Sahan et al studied the contributory factors to success and results in cases of revision tympanoplasty using cartilage-perichondrium island graft and concluded that large perforation, adhesive changes and hypertrophic middle ear mucosa adversely affect the graft take rates.[11] In our study of eleven cases in revision surgery group, successful graft uptake was observed in ten cases (90.90%). Mastoid exploration was done in five cases and the single failure case had had tympanoplasty coupled with mastoidectomy.

Pradhan et al in a series of 80 cases, of active squamous disease with conductive hearing loss, who underwent retrograde canal wall down mastoidectomy with type III cartilage (palisade grafting) tympanoplasty reported 95% success rate in closure of tympanic membrane defects. At the end of one year, 35.08% of new cases and 25% of revision cases had had significant improvement in hearing.[14] In our study, we achieved 92.85% success rate in cholesteatoma group (14 cases) with one failure. Functionally, there was no statistically significant ($p>0.05$) difference between pre- and post-op PTA-ABG.

In discharging ear group, we achieved 86.66% success rate with 2 graft failures. Functionally there was no significant difference ($p>0.05$) between pre-and post-operative PTA-ABG. In a study it was observed that there is better healing of TM after surgery in a wet ear with 100% success rate whereas, there was only 75% success rate in dry ears.[15] In a meta-analysis studying the effect of ear discharge on anatomical success rates, it was observed that tympanoplasty in such ears is equally successful as in a dry ear.[16]

Concerns have been raised in context of hearing outcomes due to mass, thickness and rigidity of cartilage graft which mechanically reduce vibratory pattern of neo-membrane. Other issues such as decreased middle ear space, difficulty in postoperative middle ear surveillance due to its opacity and increased risk of complications due to occurrence of acute middle ear infection have also been described. In a systematic review of randomized controlled trial (RCT), retrospective studies and literature reviews to compare the effectiveness of the use of cartilage (with or without perichondrium) with temporalis fascia used in tympanoplasty, it was concluded that tympanoplasty using cartilage shows better morphological outcomes than fascia tympanoplasty.[17] Nevertheless, there was no statistically significant difference in hearing outcomes between two graft materials.[18] It is reported that achieving postoperative AB closure (ABG) within 20 dB ranges from 60-90% in various individual studies, and our results (62%) are favourably consistent with the above (Table 3).[1]

A potential disadvantage of this method is the graft opacity, which may mask middle ear residual cholesteatoma**.** This opaque neo-membrane (graft) may hinder in detecting the underlying recidivism, otitis media with effusion, adhesions and/or displaced ossicular grafts.[17,19] Uslu et al, in his study, used cartilage in anterior most part of the reconstructed ear drum and also (used it posteriorly when scutum was drilled) to overcome this problem and found that it is easy to observe the middle ear to check recidivism or tympanic effusion developing postoperatively.[2]

Failure of tympanoplasty can be attributed to severe ear disease, diseased ossicles, cholesteatoma, tympanosclerosis, atelectasis, large and anterior perforations, tobacco smoke exposure and disease in both ears.[20,21] Other causes can possibly be attributed to the properties of graft take-up rate, tubal function, incomplete clearance of mucosal disease, surgical

experience/ expertise and host's factors. Bernal-Sprekelsen, in his study of 362 cases of type III cartilage palisade (partial/total) tympanoplasty (with ossicular reconstruction, CWD and CWU mastoidectomy), reported two cases of total hearing loss and five cases of sensorineural hearing loss with successful take rate in 98.3% of cases with complications such as re-perforation (1.7%), retraction pockets (2.5%), and recurrent cholesteatoma (2.2%).[22] In our study seven cases (5.64% failure rate) presented with re-perforation (Table 1). The most common complications reported in literature are re-perforation (11.9%), revision surgery (11.4%), blunting (6.7%) and lateralization (4.2%).[1] The most common complications observed in our series were postoperative ear discharge (15 cases), followed by worsening of hearing (3 cases), tinnitus (2 cases), recurrence of cholesteatoma (1 case), perichondritis (1 case). Highest number of complications were observed in cholesteatoma and large anterior perforation groups (6 each). Complications such as wound site infection or hematoma, facial palsy/paresis, extrusion of prostheses, blunting of anterior canal wall angle, external canal stenosis, and labyrinthitis, were not observed in the study. No hearing improvement despite successful graft take- up was observed in 12.09 % (n=15) cases. Solmaz et al in their series of 191 cases (194 ears), who underwent type I, II, III perichondrium attached island graft tympanoplasty, claimed overall 91.24% (Table 4) graft take rate after 13 months postoperatively with a graft failure rate of 8.76%.[23] In their series improvement in hearing was seen in 76.29%, no change in 18.04% and deterioration of hearing was observed in 5.67% of cases.

Table 4: Comparison with other studies.

Series	Cases	Success rate	Mean follow up	Technique	Duration of study	Pre-operative ABG	Postoperative ABG
Yurttas et al[24]	87 cases	93%	15.3 months	Cartilage island graft	Dec 2007-Oct 2011	37.27±12.35 dB	27.58±9.84 dB
Boone et al[12]	95 cases	94.7%	12 months	Tragal cartilage perichondrial island graft/conchal palisaded pattern cartilage	July 1994-June 2001	24.6±13.8 dB	12.2±7.3 dB
Cavaliere et al[19]	304 cases	99.35%	37 months	Tragal cartilage shield	4.5 years	43.79±7.07 dB	10.43± 5.25 dB after 1 year
Aidonis et al[25]	62 cases	98.4%	23 months	Cartilage shield	1998-2003	32.4±14.1 dB	24±13.7dB at 7 months
Sahan et al[11]	33 revision cases	87.9%	1 year	Cartilage perichondrium island graft	Jan 2009-Aug 2012	24.5± 7.2dB	12.8± 5.6 dB
Uslu et al[2]	60 cases	78.3%	-	Cartilage reinforcement method	Nov 2006- Oct 2008	38.76± 11.24dB HL in dB	25.36±10.55 dB (HL in dB)
Yilmaj et al[26]	42 paediatric cases	88.6%	17 months	Type I cartilage tympanoplasty	3 years 6 months	27.4 ± 5.2 dB	16.5± 6.6 dB
Nevoux et al[27]	268 paediatric cases	Very satisfactory in 80% of cases	At 1, 2, 5 years	Cartilage shield with ossiculoplasty	April 1997-January 2008	25± 1.8dB	18.9±10.3 dB
Solmaz et al[23]	191 cases	91.24%	13 months	Type I/II/III perichondrium attached cartilage island tympanoplasty		I-33.74±9.6 II- 52.58±9.07 III-56.58±10.27	18.55±9.25 31.21±4.36 44.84±12.45
Our series	124 cases	94.36%	1, 6, 12 months	Cartilage tympanoplasty (reinforced)	Jan 2015 to Dec 2018	31.33±10.41	19.55±12.04 dB

Small sample size, heterogeneity of various middle ear pathologies and surgeries, lack of longer follow-up and serial hearing evaluation, were the limiting factors in our study. To our best of knowledge this is one of the few studies where the morphological success of cartilage tympanoplasty was assessed and correlated with the disease present (indications of surgery) instead of the type of surgery done.

CONCLUSION

The history and evolution of tympanoplasty has evidenced the continuous change in approach, technique and materials used for grafting adopted by various surgeons from time to time. Cartilage possesses properties of an ideal and stable graft in progressive and advanced middle ear disorders with minimal complications. It is a reliable and well tolerated grafting source and resists infection and negative intratympanic pressure effectively and provides longevity. The routine use of cartilage grafting in all cases is still debatable.

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