



# Comparison of Eustachian Tube Function Before and After Septoplasty: A Systematic Review and Meta-Analysis

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## 비중격교정술 전후의 유스타키오관 기능 비교: 체계적 문헌 고찰 및 메타 분석

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**Background and Objectives** The middle ear, eustachian tube, and nasal cavity are anatomically adjacent, so the middle ear pressure (MEP), eustachian tube function (ETF), and nasal cavity condition are highly correlated. In this study, the effect of nasal septal deviation (NSD) on ETF and the effects of septoplasty on ETF and MEP were meta-analyzed using the results of tympanogram.

**Subjects and Method** A systematic search was conducted using the PubMed, Embase, the Web of Science, and the Cochrane Central Register of Controlled Trials. The MEP and ETF were compared before and after septoplasty. We also compared eustachian tube dysfunction observed from the deviated side and from the non-deviated side of the ear. Heterogeneity was analyzed within the subgroups.

**Results** Eustachian tube dysfunction was about twice as high in the narrowed side of NSD patients than in other patients. The tympanogram results did not show any significant difference when subgroups were observed before, within 1 month after, or 3 months after septoplasty. Eustachian tube dysfunction before septoplasty was about 4.5 times higher than after septoplasty (when followed up for more than 1 month). From the subgroup analysis of deviated and non-deviated sides, MEP before septoplasty was significantly lower than after septoplasty and eustachian tube dysfunction was approximately 4 times higher in the narrowed nasal cavity.

**Conclusion** The narrowed side of the nasal cavity in NSD can be related to eustachian tube dysfunction. Septoplasty may help restore ETF in the ears of narrowed side of the nasal cavity.

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**Keywords** Auditory tube; Ear, Eustachian tubes; Middle; Middle ear ventilation; Nasal septum.

## Introduction

The eustachian tube is a passage from the nasopharynx to the middle ear, and takes a role in the ventilation of the middle ear.<sup>1-3)</sup> The eustachian tube function (ETF) regulates the

pressure in the middle ear.<sup>2,4)</sup> Middle ear pressure (MEP) applied through the eustachian tube can influence the middle ear mucosa. Since the middle ear, eustachian tube, and nasal cavity are anatomically adjacent, the status of the MEP, ETF, middle ear mucosa, and nasal cavity are highly correlated. Many studies have commonly interpreted that inflammation in the middle ear may persist if the aeration of the middle ear is not good. Inflammation of the nasopharynx, nasal cavity,

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and paranasal sinuses may also affect the ETF. Among them, nasal cavity obstruction and sinus infection due to nasal septal deviation (NSD) can cause eustachian tube dysfunction.<sup>2)</sup> However, there is controversy as to whether NSD has a direct effect on ETF. A study reported that prior septoplasty for NSD was related with favorable results of ear surgery.<sup>5)</sup> Alternatively, there have been studies showing that combining septoplasty and ear surgery improved the success rate of ear surgery.<sup>1,3,6)</sup>

Although there is no gold standard to evaluate the ETF,<sup>3,7,8)</sup> there are many different methods. The sonotubometry or manometric test measures and confirms sound waves.<sup>9,10)</sup> Also, the tympanometry and inflation test with Valsalva or Toynbee maneuver is widely used.<sup>1-3,8)</sup> It is also screened through questionnaires such as eustachian tube dysfunction questionnaire-7 (ETDQ-7).<sup>11)</sup> Tympanometry is a commonly used method for measuring MEP.

In this study, 1) the effect of NSD on ETF and 2) the effect of septoplasty on ETF and MEP were meta-analyzed using the studies (data) based on the tympanometry typically used for ETF evaluation.

## Subjects and Methods

### Search methods

Articles published by 21th, May 2022 were searched in PubMed, Embase, Web of Science, and Cochrane Central Register of Controlled Trials. Reviewers searched articles satisfying Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.<sup>12)</sup> All articles were original articles with at least an abstract published in English. The keywords “septoplasty,” “septal surgery,” “septum surgery,” “nasal surgery,” “nose surgery,” “nasal septal deviation,” “septal deviation,” “nasal deviation,” “nose deviation,” “middle ear function,” “eustachian tube function,” “eustachian function,” “tympanoplasty,” “myringoplasty,” and “ear surgery” were used.

### Eligibility criteria

#### Types of study

Prospective or retrospective design were included in this study.

#### Types of participants

We included 10 studies of patients who had been diagnosed with NSD. 521 ears underwent tympanometry to evaluate

MEP and ETF.

### Types of intervention

We included 10 studies of patients received septoplasty to treat NSD. 521 ears underwent septoplasty and 48 ears of them underwent concurrent septoplasty and tympanoplasty.

### Types of outcomes

We included studies that evaluated the following outcomes: 1) MEP (daPa) from tympanogram to evaluate ETF, 2) eustachian tube dysfunction from the result of tympanogram, 3) tympanic membrane graft survival rate or success rate, and 4) the air bone gap from the audiometric function test.

### Study records

Similar search terms were included in the search. The two authors (KYJ, SSA) reviewed the titles and abstracts for each and identified article directly reporting on patients with NSD and the evaluated ETF. The articles were reviewed independently by the authors in accordance with the established eligibility criteria, and the details of the studies were extracted and analyzed. If the information in the paper was insufficient or not equivalent, the authors discussed and reviewed the data several times to resolve it.

The included studies were reviewed and extracted as follows: the author, year of publication, number of ears examined for MEP and ETF, diagnosing tools used to evaluate ETF, procedures and questionnaires to evaluate MEP, follow-up period after septoplasty, outcomes, and conclusions. The excluded studies were as follows: where patients underwent endoscopic sinus surgery only,<sup>13)</sup> where patients with NSD underwent no septoplasty or other MEP tests except tympanogram,<sup>14-16)</sup> insufficient data on MEP or ETF,<sup>7,17-19)</sup> and full text written by other languages than English. We evaluated the risk of bias of the studies included in the meta-analysis based on the Newcastle-Ottawa Scale criteria and Cochrane Handbook for Systematic Review of Interactions, and all included studies showed good or fair quality.

### Statistical analysis

The meta-analysis was carried out by inputting data into Revman Manager (RevMan) version 5.4.1 software (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). The weighted mean difference (MD) was expressed as 95% confidence interval (CI) range. Statistical heterogeneity was assessed by the *p*-value of chi-square test

results and the value of  $I^2$ .  $I^2$  was rated low, medium, or high heterogeneity on the basis of 40% and 60%. In addition, the random effects model was applied when it was evaluated as high heterogeneity. The fixed effects model was applied when it was evaluated as low or medium heterogeneity. A  $p$ -value less than 0.05 was considered statistically significant. If the results of included studies were continuous variables, the treatment effects were evaluated with either MD or standardized mean difference (SMD) with standard deviation and 95% CI. If the follow up periods after septoplasty was varied, the analysis was divided into each subgroup as short-term and long-term follow up. If these results were reliable without objection, the conclusions were extracted.

## Results

### Selection of studies

A total of 75 studies were identified through the title and abstract screening. Thirty-two of these studies were fully screened to evaluate the eligibility. After screening the full text, 12 studies were selected with qualitative synthesis. Of 22 excluded studies, 12 studies were excluded due to the lack of relevant data or no quantifiable data, and 2 studies were excluded due to the relationship with chronic otitis media only. One studies were excluded because they included patients who underwent endoscopic sinus surgery only. Seven studies were excluded due to the lack of a full text written by English. The remaining 10 studies satisfied our inclusion criteria.<sup>1-3,5,6,8,20-23</sup> A flowchart with PRISMA guidelines used to derive the included studies is presented in Fig. 1. In each study, the number of enrolled ears, the result of tympanogram, and follow up periods are summarized in Table 1.

### ETF depending on NSD

In 3 studies, eustachian tube dysfunction associated with NSD of 110 patients was compared in meta-analysis. Each study defined eustachian tube dysfunction using tympanometry: 1) tympanometric peak pressure (TPP) changes lower than 10 daPa analyzed at rest and after the Valsalva maneuver, 2) TPP changes lower than 10 daPa analyzed after the Valsalva and Toynbee maneuvers, 3) difference between Pmax and Pmin lower than 15 daPa, 4) MEP lower than -100 daPa (type C), or 5) no identifiable pressure peak (type B).

The forest plot is shown in Fig. 2. The eustachian tube dysfunction rate was 1.94 times higher in the deviated side than in the non-deviated side (odds ratio [OR], 1.94; 95% CI,

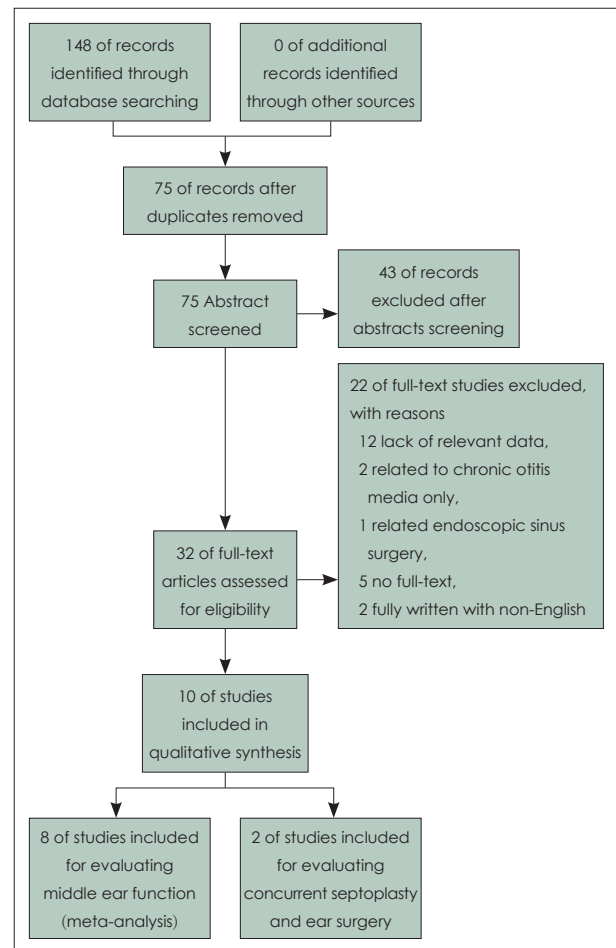


Fig. 1. Summary of the search strategy.

1.03–3.64;  $p=0.04$ ) and there was no heterogeneity ( $I^2=0\%$ ).

### ETF before and after septoplasty

A total of 8 studies tested ETF by tympanogram before and after septoplasty. Among these, two studies with only median values and one study using tubomanometry were excluded. In 2 of the remaining 5 studies, tympanograms were measured separately in the deviated and non-deviated sides of the nasal cavity, and in 3 studies, the right, left, and both sides were measured regardless of septal deviation.

### ETF on the right, left, or both sides before and after septoplasty

In 3 studies including 288 ears, the ETF was checked by tympanogram in the right, left, and both sides before and within 1 month after septoplasty. The forest plot is shown in Fig. 3A. The MEP before surgery was 0.05 (SMD) lower than after surgery without statistical significance ( $p=0.57$ ) and there was no heterogeneity ( $I^2=0\%$ ). In 2 studies includ-

**Table 1.** Summary of the clinical characteristics of 8 studies which documented the ETF or tympanogram results after septoplasty

Author	Year	Type	Number of ears underwent tympanogram (preop, postop)	Parameters of ETF	Side of ears underwent tympanogram	Definition of Eustachian tube dysfunction	Follow-up periods after septoplasty
Low and Willatt <sup>8)</sup>	1993	Prospective	55, 55	Tympanometry	Deviated side	Not mentioned	6–10 months (median 7.5)
Salvinelli, et al. <sup>3)</sup>	2005	Prospective	43, 43	Tympanometry: Valsalva and Toynbee tubal function tests	Both ear	Not a shift of at least 10 daPa on both tests	2 weeks, 1 month, 3 months
Yilmaz, et al. <sup>22)</sup>	2012	Prospective	51, 51	Tympanometry (Impedance Audiometer AZ26, Interacoustics, Assens, Denmark)	Left or right ear	Not mentioned	1 week
Eyigör, et al. <sup>23)</sup>	2013	Prospective	25, 25	Tympanometry (Madsen Capella, GN Otometrics, USA)	Left or right ear	Not mentioned	1 week, 1 month, 3 months
Akyildiz, et al. <sup>5)</sup>	2017	Prospective	25, 25	Tympanometry (Impedance Audiometer AZ26)	Deviated or non-deviated side	P1–P2 < 10 daPa or Pmax–Pmin ≤ 15 daPa	1, 3 months
Doğan, et al. <sup>21)</sup>	2019	Prospective	156, 156	Tympanometry (Impedance Audiometry AC40, Interacoustics): Toynbee test	Both ear	P1–P2 < 10 daPa or Pmax–Pmin < 15 daPa	6 months
Kaya, et al. <sup>1)</sup>	2018	Prospective	50, 50	Tympanometry (Impedance Audiometer AZ26): Basal, after Valsalva and Toynbee maneuvers	Deviated or non-deviated side	TPP changes (analyzed after the Valsalva and Toynbee) < 10 daPa	8 weeks
Fontes Lima, et al. <sup>2)</sup>	2022	Prospective	35, 35	Tympanometry, tubomanometry, ETDQ-7	Deviated or non-deviated side	MEP was lower than - 100 daPa (type C) or with no identifiable pressure peak (type B)	3–6 months

ETF, eustachian tube function; TPP, tympanometric peak pressure; ETDQ-7, eustachian tube dysfunction questionnaire-7; MEP, middle ear pressure

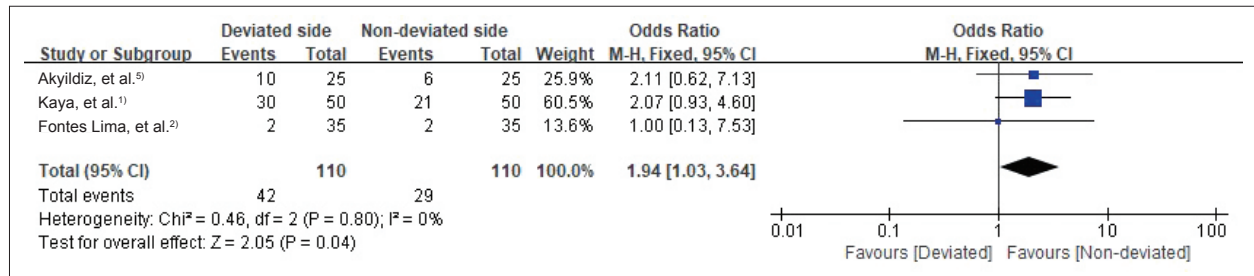
ing 118 ears, the ETF was checked by tympanogram in the right, left, and both sides before and 3 months after septoplasty. The forest plot is shown in Fig. 3B. The MEP before surgery was 0.21 (SMD) lower than after surgery without statistical significance ( $p=0.11$ ) and there was no heterogeneity ( $I^2=0\%$ ).

In 3 studies including 275 ears, the eustachian tube dysfunction was checked by tympanogram in both ears before and after septoplasty. Salvinelli, et al.<sup>3)</sup> reported eustachian tube

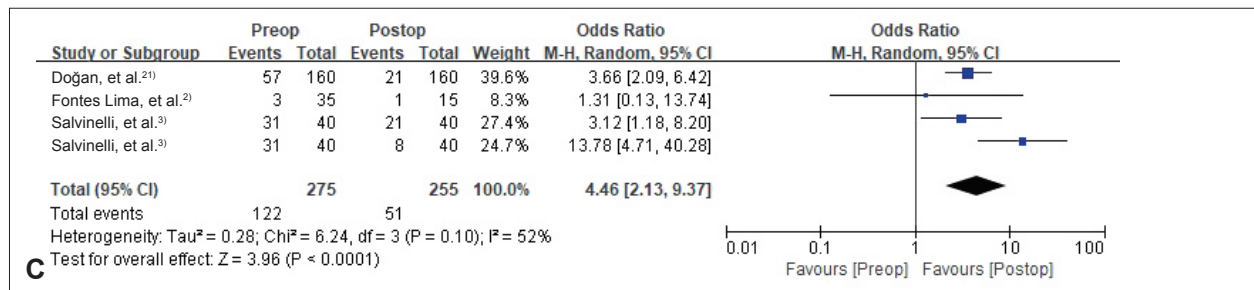
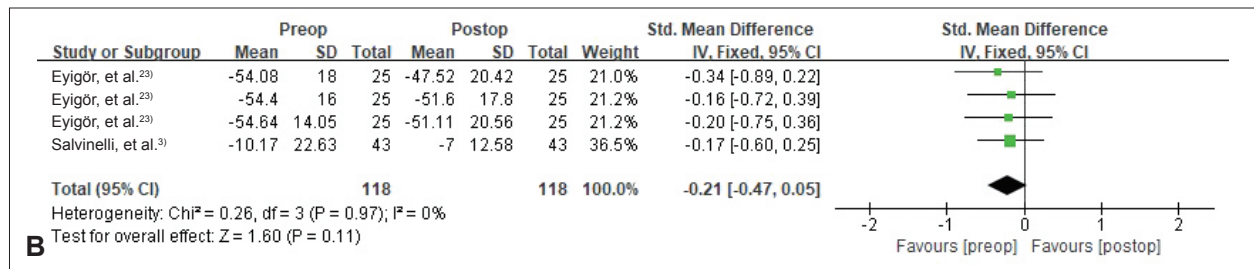
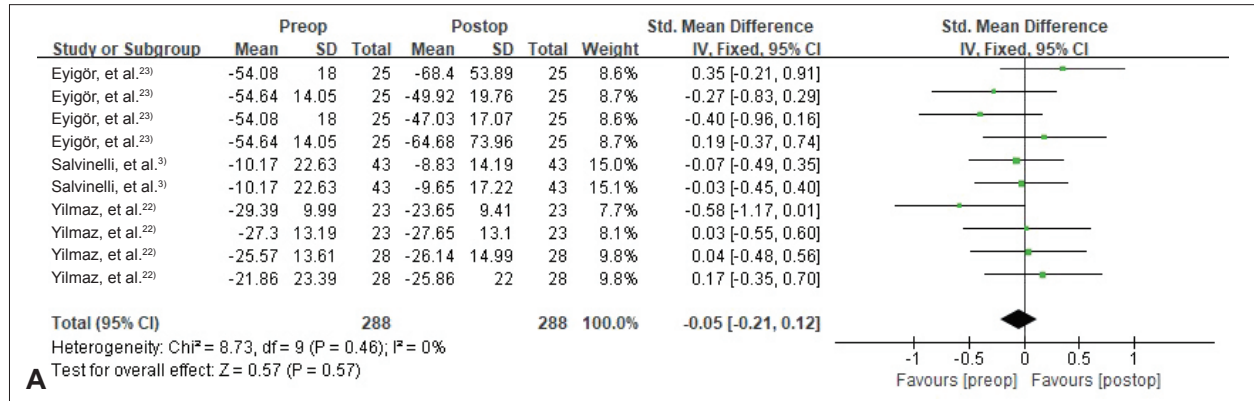
dysfunction 1 month and 3 months after septoplasty. The forest plot is shown in Fig. 3C. The eustachian tube dysfunction before septoplasty was 4.46 times higher than after septoplasty with statistical significance (OR, 4.46; 95% CI, 2.13–9.37;  $p<0.001$ ), but there was high heterogeneity ( $I^2=52\%$ ).

#### ETF on the deviated or non-deviated side before and after septoplasty

In 2 studies including 190 ears, the ETF was checked by



**Fig. 2.** Forest plots of eustachian tube dysfunction on the deviated or non-deviated side for patients with nasal septal deviation. Eustachian tube dysfunction using tympanometry was checked not depending on septoplasty. CI, confidence interval.



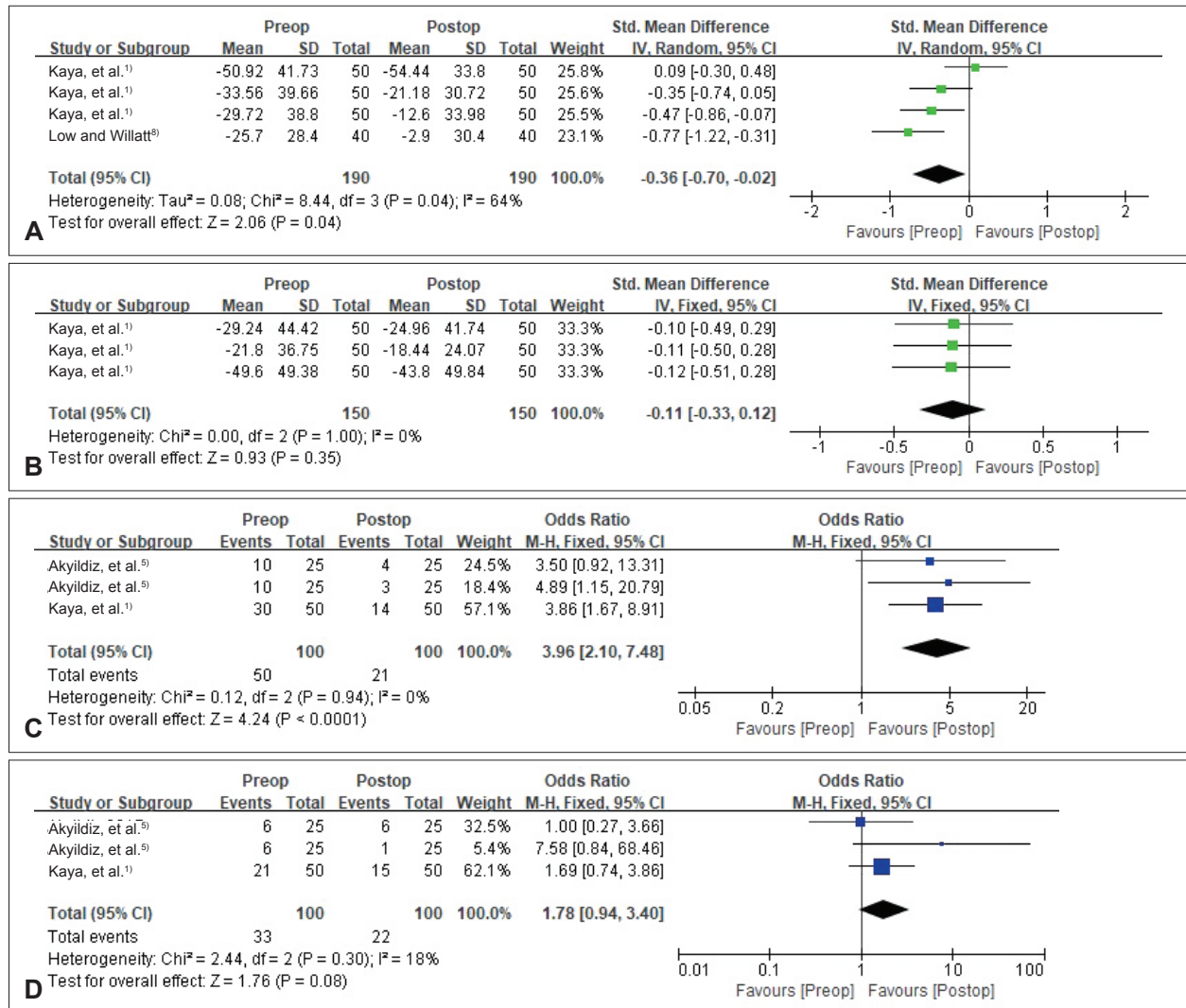
**Fig. 3.** Forest plots of eustachian tube function according to the direction of middle ear pressure measurement before and after septoplasty. A: Tympanometry results on the right, left or both sides before and within 1 month after septoplasty. B: Tympanometry results on the right, left or both sides before and 3 months after septoplasty. C: Eustachian tube dysfunction on the both sides before and after septoplasty. SD, standard deviation; CI, confidence interval.

tympanogram in septal deviation sided ears before and more than 1 month after septoplasty. Kaya, et al.<sup>1)</sup> presented the tympanogram results measured in different conditions: at rest, after the Valsalva and Toynbee maneuvers. The forest plot is shown in Fig. 4A. The MEP before surgery was 0.36 (SMD) lower than after surgery with statistical significance ( $p=0.04$ ), but there was high heterogeneity ( $I^2=64\%$ ). In 150 ears, the

ETF was checked by tympanogram in different conditions in non-deviation sided ears before and 2 months after septoplasty.<sup>1)</sup> The forest plot is shown in Fig. 4B. The MEP before surgery was 0.11 lower than after surgery without statistical significance ( $p=0.35$ ). There was no heterogeneity ( $I^2=0\%$ ).

In 2 studies, the eustachian tube dysfunction was checked by tympanogram on the deviation sided or non-deviation sid-





**Fig. 4.** Forest plots of eustachian tube function according to the direction of nasal septal deviation before and after septoplasty. A: Tympanometry results on deviated side before and after septoplasty. B: Tympanometry results on non-deviated side before and after septoplasty. C: Eustachian tube dysfunction on deviated side before and after septoplasty. D: Eustachian tube dysfunction on non-deviated side before and after septoplasty. SD, standard deviation; CI, confidence interval.

ed ear before and after septoplasty. Akildiz, et al.<sup>(5)</sup> reported Eustachian tube dysfunction 1 month and 3 months after septoplasty. The forest plot of deviated and non-deviated sides was shown in Fig. 4C and D. The eustachian tube dysfunction of deviation sided ears before septoplasty was 3.96 times higher than after septoplasty with statistical significance (OR, 3.96; 95% CI, 2.10–7.48;  $p < 0.001$ ). There was no heterogeneity ( $I^2 = 0\%$ ). The eustachian tube dysfunction of non-deviation sided ears before septoplasty was 1.78 times higher than after septoplasty without statistical significance (OR, 1.78; 95% CI, 0.94–3.40;  $p = 0.08$ ). There was low heterogeneity ( $I^2 = 18\%$ ).

### Graft success and air bone gap after concurrent septoplasty and tympanoplasty

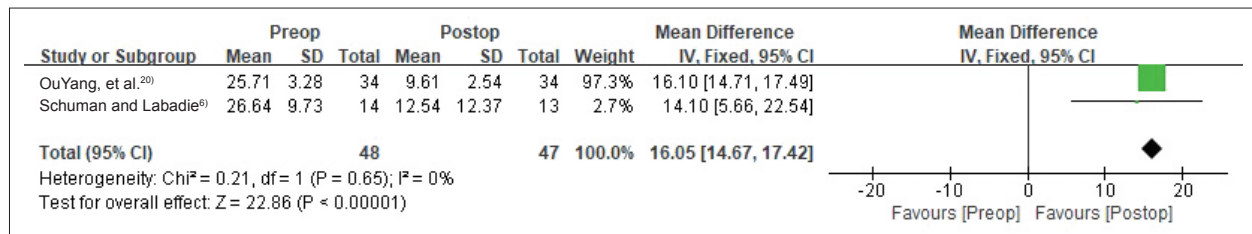
In 2 studies including 48 ears which underwent concurrent septoplasty and tympanoplasty, graft success rates were high (Table 2). The air bone gap was checked by pure tone audiometry in both ears before and after concurrent septoplasty and tympanoplasty. The forest plot is shown in Fig. 5. The air bone gap before surgery was 16.05 higher than after surgery with statistical significance ( $p < 0.001$ ). There was no heterogeneity ( $I^2 = 0\%$ ).

## Discussion

The prevalence of eustachian tube dysfunction identified

**Table 2.** Summary of the clinical characteristics of 2 studies which included patients who underwent concurrent septoplasty and tympanoplasty

Author	Year	Type	Patients who underwent concurrent surgery (n)	Parameters to evaluate the graft or surgical success	Other parameters for Eustachian tube function	Follow-up periods after concurrent surgery
Schuman and Labadie <sup>6)</sup>	2010	Retrospective	14	- Tympanic membrane grafts survival rates 92.9% - Surgical success 78.6% (achieved an aerated middle ear without the need for a pressure-equalization tube)	Air bone gap from audiograms	1.8–29.8 months (mean 12.8)
OuYang, et al. <sup>20)</sup>	2021	Retrospective	34	- Tympanic membrane graft success rates 100.0%, 85.3% (Postoperative 6 months, 24 months) - Re-perforation rates 15.5%	Eustachian tube score, eustachian tube dysfunction Questionnaire 7, tubomanometry, air-bone gap from audiograms	6, 24 months

**Fig. 5.** Forest plots of the air bone gaps before and after surgery in patients who underwent concurrent septoplasty and tympanoplasty. SD, standard deviation; CI, confidence interval.

in the United States is 4.6%.<sup>24)</sup> The prevalence of NSD reached 80%.<sup>25)</sup> In general, there are many patients who have nasal congestion and eustachian tube dysfunction simultaneously. Since the nasal cavity condition influences the mucosa around the eustachian tube, it can be a determining factor for ETF. That is, eustachian tube dysfunction can occur due to allergic rhinitis, chronic rhinosinusitis, or NSD.<sup>26)</sup> Several studies have suggested that NSD may be the cause of eustachian tube dysfunction. On the other hand, other studies have reported that there is no direct relationship between nasal congestion and ETF. To the best of our knowledge, this study is the first meta-analysis to analyze the effect of NSD and septoplasty on ETF and middle ear condition. Importantly, we considered the follow up periods and analyzed each nasal cavity (the narrow or broad side) separately if possible.

Many papers have shown that NSD and ETF are correlated.<sup>2,5)</sup> In our meta-analysis, it was confirmed that the deviated side was about twice as likely to have impaired eustachian tube dysfunction. The relationship between NSD and ETF can be explained as follows. NSD prevents smooth ciliary movement in the nasal cavity and nasal secretions may stagnate and

become inflamed. The airflow problems and inflammation also affect the eustachian tube opening causing inflammation and occlusion of the eustachian tube. In addition, NSD can result in changes in ETF by mucosal dryness, decreased viscosity of nasal mucus, and autonomic nerve dysfunction.<sup>27)</sup>

Low and Willatt<sup>8)</sup> reported that the mean TPP significantly increased after septoplasty in NSD patients. In addition, many papers have reported that septoplasty is related to the improvement of ETF.<sup>1-3,5,21,22)</sup> Specifically, Doğan<sup>21)</sup> reported that septoplasty only in type 4 and type 6 NSD patients could influence the middle ear. The possibility of MEP improvement after septoplasty has been documented in two papers, which were not included in this meta-analysis because they provided only the median value of the results of tympanometry.<sup>7,18)</sup>

However, the effect of septoplasty on ETF in the early postoperative period is not clear. Akyildiz, et al.<sup>5)</sup> suggested that eustachian tube dysfunction may be present in the early postoperative period. And Salvinelli, et al.<sup>3)</sup> reported no significant differences in tympanometry results at 1 month after surgery compared with the preoperative results. Eyigör, et al.<sup>23)</sup> reported that there was no significant correlation between the

success of septoplasty and MEP. Al Karaki, et al.<sup>16)</sup> suggested an association between eustachian tube dysfunction-related symptoms and NSD, but tympanometry results did not support it. Rahim Davari<sup>28)</sup> reported that there were no significant changes in MEP and ETF after septoplasty. Maier and Krebs<sup>29)</sup> reported that septoplasty prior to tympanoplasty is not always recommended, but it can be helpful in cases where ETF is decreased due to chronic inflammation in the nasal cavity.

In this study, when the tympanogram results before septoplasty and within 1 month after the surgery were analyzed, no significant differences were found. When analyzed before septoplasty and 3 months after the surgery, there were no significant differences in tympanogram results either. However, in the subgroup analysis with the results divided into the deviated and non-deviated sides, the ETF before surgery was significantly lower in the deviated side. When evaluated regarding the eustachian tube dysfunction rate, it was about 4.46 times higher before septoplasty than after 1 month. In addition, the preoperative eustachian tube dysfunction was significantly higher in the deviated side by about 4 times. These results were contrary to those reported by Akyildiz, et al.<sup>5)</sup> and Fontes Lima, et al.<sup>2)</sup> In these two papers, there were no significant correlations between the sides of NSD and eustachian tube dysfunction.

There is controversy on whether the concurrent tympanoplasty and septoplasty have a good effect on the outcome of middle ear condition. Tan, et al.<sup>19)</sup> reported that NSD may not influence the success of tympanoplasty and thus septoplasty prior to ear surgery is unnecessary. Akyildiz, et al.<sup>15)</sup> reported that NSD may affect ETF in chronic otitis media patients, but as a result of the study, NSD did not significantly affect ETF before and after the ear surgery, which does not support the need for concurrent septoplasty. On the other hand, Schuman and Labadie<sup>6)</sup> showed that when the septoplasty and tympanoplasty were administered simultaneously, the tympanic membrane graft survival was 92.9% and safe. OuYang, et al.<sup>20)</sup> suggested that endoscopic sinus surgery could help ETF improvement. However, these 4 studies were not included in this meta-analysis because the parameters and groups for evaluating ETF and MEP did not match up. From Schuman and Labadie<sup>6)</sup> and OuYang, et al.,<sup>20)</sup> it was confirmed that there was a significant improvement in the air bone gap after concurrent septoplasty and tympanoplasty compared with tympanoplasty alone.

Our study has several limitations. First, because there is no gold standard to check ETF, various tools such as tympanom-

etry and tubomanometry have been used in many studies, and the inflation test indicators of the Valsalva and Toynbee maneuvers also varied and could not be unified. Second, since the ETF were indirectly evaluated using MEP or TPP, it cannot be said that all included studies compared ETF and MEP equally. There was also no unified definition of eustachian tube dysfunction. Third, the studies evaluating the right ear, left ear, and both ears are mixed. However, the deviated and non-deviated sides were separated through subgroup analysis.

In conclusion, in our meta-analysis, it has been confirmed that the deviated side of NSD is about twice as likely to have impaired eustachian tube dysfunction. The tympanogram results showed a significant difference before and after septal surgery only in the deviated side. Eustachian tube dysfunction improved about 4 times or more 1 month after the surgery, especially in the deviated side.

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None

## Author Contribution

Conceptualization: Jin-Hee Cho, Yun Jin Kang. Data curation: Soo Ah Son, Youn Sun Park. Formal analysis: Yun Jin Kang. Investigation: Soo Ah Son, Youn Sun Park. Methodology: Yun Jin Kang. Project administration: Jin-Hee Cho, So Young Park. Software: Yun Jin Kang. Supervision: Jin-Hee Cho, So Young Park. Visualization: Yun Jin Kang. Writing—original draft: Soo Ah Son, Yun Jin Kang. Writing—review & editing: Jin-Hee Cho, So Young Park.

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