

# Dynamic characteristics of the middle ear after stapes surgery: a distortion product otoacoustic emission study

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## Background

Otosclerosis is a primary localized disease of the bony otic capsule that is mainly localized to the stapedial footplate. Stapedotomy is the treatment of choice. The effect of stapes surgery on otoacoustic emissions is not sufficiently known.

## Objectives

The aim of the present study was to assess changes in the middle ear dynamic characteristics, and to evaluate distortion product otoacoustic emissions (DPOAEs) in otosclerosis. Moreover, the study aimed to evaluate DPOAEs before and after stapes surgery.

## Patients and methods

A total of 20 patients with otosclerosis and undergoing stapedotomy surgery were included in the study. Assessment was performed preoperatively, 1 week, 1 month, and 6 months postoperatively by using pure-tone average, tympanometry, and DPOAE.

## Results

Significant improvement in the air–bone gap by pure-tone average was reported at 1 week and 1 month postoperatively, whereas 6 months postoperative hearing threshold remained the same as that of 1 month postoperative. The difference between preoperative and postoperative detection of DPOAE was not significant.

## Conclusion

Conventional pure-tone audiometry remains the choice for evaluation of stapes surgery in patients of otosclerosis. The use of DPOAEs in the evaluation of a successful stapes surgery requires further studies including a larger number of patients.

## Keywords:

distortion product otoacoustic emission, otosclerosis, pure-tone audiometry, stapedotomy

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## Introduction

Otosclerosis is a primary localized disease of the bony otic capsule that is mainly localized to the stapedial footplate [1]. Stapedotomy is the treatment of choice [1,2].

Otosclerosis is usually diagnosed by using audio-tympanometry, but a clear diagnosis is made during surgery because the surgeon can exclude the considerable rarer causes of conductive hearing impairment in the presence of normal mobile tympanic membrane [3].

Otoacoustic emissions (OAEs) are signals emitted by the cochlea (specifically outer hair cells) either spontaneously or evoked by an auditory stimulus. In clinical practice, the most commonly recorded OAEs are transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs). Kramer notes that TEOAEs are recorded during the silent intervals between brief broad-spectrum transient clicks, which activate a wide portion of the basilar

membrane. TEOAEs can (generally) be measured between 1000 and 4000 Hz [4].

DPOAEs are recorded during cochlear activation. DPOAEs are typically recorded from 1000 to 6000 Hz. The DPOAEs reflect the status of the cochlea at the representative cubic difference tone, not the primary tones [4].

The DPOAE is a noninvasive, objective, and extraordinarily sensitive method for evaluating outer hair cell function and detecting cochlear damage [4–6].

The effect of stapes surgery on OAEs is not sufficiently known. Transient OAEs have been previously detected

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in only a small number of patients after stapes surgery [5], whereas DPOAEs have been reported more after successful stapedectomy [5].

It remains unclear why DPOAEs are not detected despite a subjective hearing improvement and a sufficiently closed air–bone gap (ABG) at least at middle and low frequencies [1].

The aim of this research was to study the changes in the middle ear dynamic characteristics, and to evaluate DPOAEs in otosclerosis. The study also aimed to evaluate DPOAEs before and after stapes surgery.

### Patients and methods

This study was conducted on patients with otosclerosis, who were scheduled for stapedotomy surgery. Revision cases, patients unfit for general anesthesia, and patient lost from follow-up were excluded from the study. Informed consent was signed by all included patients and ethical committee approval was obtained.

All patients were subjected to preoperative assessment in the form of history taking, thorough examination, and audiological evaluation.

Audiological assessment consisted of pure-tone average (PTA) for air-conduction, bone-conduction, and ABG, which were calculated at 0.5, 1, 2, and 4 kHz, in addition to stapedial reflex, tympanometry, and speech reception threshold.

DPOAEs testing was also performed for all patients using otodynamics ILO V6 OAE. After inserting the ear tip into the ear canal, DPOAEs were obtained with primary tone level of L1 and L2 as 65 and 55 dB SPL, respectively, in ascending frequency order and frequency ratio F2/F1 of 1.22, which generates 2f1-f2 DP. The DPOAE amplitudes were recorded and plotted as DP gram as a function of F2 frequencies at 0.5, 1.0, 2.0, 4.0, 6.0, and 8.0 kHz.

Under general anesthesia, stapedotomy was carried out in all patients by using the common endoaural

approach and incudostapedial joint disarticulation, cutting of the stapedial tendon, fracture of posterior crus of stapes, and then perforation of the foot plate. A teflon piston prosthesis of appropriate length was inserted.

Postoperative assessment was carried out at 1 week, 1 month, and 6 months after the surgery by examination, PTA at 0.5, 1, 2, and 4 Hz, speech reception threshold, and DPOAE.

### Statistical analysis

All data were collected, tabulated, and statistically analyzed using the SPSS 18.0 for Windows (SPSS Inc., Chicago, Illinois, USA). All tests were two-tailed. A *P*-value of less than 0.05 was considered statistically significant (S).

### Results

This study included 20 patients (13 females and seven males, with a mean age of 34.6±6.4 years) with otosclerosis, who underwent primary stapedotomy surgery. The mean ABG was 37.5±5.25 preoperatively, 9±3.83 at 1 week postoperatively, 3.5±3.28 at 1 month postoperatively, and 3.5±3.28 at 6 months postoperatively. Thus, significant improvement in hearing was reported at 1 week and 1 month postoperatively, whereas 6 months postoperatively, hearing threshold remained the same as 1 month postoperatively (Table 1).

Overall, 20% of the patients showed ABG improvement within 11–20 dB, 60% of the patients within 21–30 dB, and 20% showed ABG improvement of more than 30 dB. One month postoperatively, ABG showed an improvement of 21–30 dB in 30% of the patients and more than 30 dB improvement in 70% of the patients.

As regards the preoperative DPOAEs response, it was absent in all cases. Postoperatively, DPOAEs could not be detected in most cases (80%), whereas it was only detected in four (20%) patients with significant differences from preoperative detection (Table 2).

**Table 1 Comparison between preoperative and postoperative air–bone gap (db)**

Air–bone gap (db)	Preoperative	One week postoperative	One month postoperative	6 months postoperative
Mean	37.5±5.25	9±3.83	3.5±3.28	3.5±3.28
t-Test		19.6129	4.8778	0
P-value		<0.0001 (HS)	<0.0001 (HS)	1

HS, highly significant.

**Table 2 Comparison between preoperative and postoperative distortion product otoacoustic emission**

Postoperative distortion product OAE	Preoperative (N=20) [n (%)]	1 week postoperative (N=20) [n (%)]	1 month postoperative (N=20) [n (%)]	6 months postoperative (N=20) [n (%)]
Absent	20 (100)	16 (80)	16 (80)	16 (80)
Detected	0 (0)	4 (20)	4 (20)	4 (20)
$\chi^2$ -Test	Reference		4.444	
P-value			0.035 (S)	

OAE, otoacoustic emission.

## Discussion

Stapes surgery is the only effective treatment of otosclerosis, with excellent functional results in more than 90% of the cases. However, failures and complications of the surgery may be observed [2].

The key measurement in otosclerosis remains PTA. The mean preoperative ABG in our cases was 37.5  $\pm$  5.25 dB, which is near to that obtained in some previous studies [7,8].

After stapedotomy, hearing improved significantly and sequentially till 1 month postoperatively, and then remained at the same improved level at 6 months postoperative PTA. Comparable results were obtained by House *et al.* [9], Quaranta *et al.* [10], and Filipino *et al.* [7].

The effect of stapes surgery on OAEs has not been sufficiently studied, with few preliminary studies with contradictory results.

As regards our results of the preoperative DPOAEs response, it was absent in 100% of our cases. This is similar to the findings of Ralli *et al.* [6]. One and 6 months postoperatively, valid DPOAEs could be detected in four out of 20 cases (20%) and group data did not reveal significant differences between preoperative and postoperative DPOAE amplitudes. In their study, House *et al.* [9] detected OAE in four out of 40 (10%) otosclerosis patients after stapes surgery, whereas Filipino *et al.* [7] detected DPOAEs in two out of 50 patients, taking in consideration that in both these studies ABG was significantly improved.

The reasons why OAEs cannot be detected in most cases after successful stapedotomy remain unclear despite satisfactory ABG closure and the hearing threshold within the measurable range for DPOAEs. In their study, Attanasio *et al.* [1] hypothesized that this could be due to (a) an increase in stiffness, and (b) a clinically inapparent perilymph leak. An increase in stiffness of the middle ear structures after stapedotomy can be attributed to scar formation around the inserted

piston and/or to the clamping of the prosthesis loop around the long process of the incus. The second factor could be a functionally incomplete coupling of the piston within the vestibule.

Therefore, PTA is still considered the main measurement of the stapedectomy results and OAEs cannot replace PTA. However, as some cases could be detected postoperatively after being undetectable preoperatively, OAEs need to be studied as part of battery of tests for a complete clinical follow-up for after stapedotomy on a large number of cases.

## Conclusion

Conventional PTA remains the choice for the evaluation of outcomes of stapes surgery in patients of otosclerosis. The use of DPOAEs in the evaluation of the outcome of successful stapes surgery requires further studies with a larger number of patients. Moreover, the measurement of OAEs in otosclerosis needs to be studied further to generate more normative values.

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## Conflicts of interest

There are no conflicts of interest.

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