

## Evaluation of Distortion Product Otoacoustic Emissions before and after Stapes Surgery

**Giuseppe Attanasio, M.D., Elio De Seta, M.D., Angela Musacchio, M.D., Roberto Filipo, M.D.**

---

From the Department of Neurology  
and Otolaryngology, University of  
Rome "La Sapienza", Rome, Italy.

Correspondence:

Prof. Roberto Filipo.  
Department of Neurology and  
Otolaryngology,  
University "La Sapienza",  
Viale del Policlinico 155,  
00161 Rome, Italy.  
Tel: +39 06 445 46 07  
Fax: +39 06 445 48 64  
e-mail: roberto.filipo@uniroma1.it

**OBJECTIVES:** The aim of the study was to investigate changes in middle ear dynamic characteristics caused by both otosclerosis and stapes surgery (platinotomy, prosthesis positioning, ossicular chain maneuver) and to evaluate distortion product otoacoustic emissions (DPOAEs) before and following surgery.

**PATIENTS AND METHODS:** The study included 15 patients (12 women, 3 men; mean age 51 years; range 32 to 69 years) with advanced otosclerosis. All the patients were evaluated with the use of pure tone audiograms (preoperatively, 5 and 30 days after surgery), stapedial reflexes (preoperatively), and DPOAE recordings (preoperatively, at the end of surgery, and 5 and 30 days after surgery). Changes in the hearing thresholds and in the DPOAE amplitudes were compared.

**RESULTS:** Preoperative tests showed conductive hearing loss, with a mean air-bone gap of 36.6 dB HL ranging from 0.25 to 1 kHz frequencies, and no stapedial reflexes were detected. DPOAEs were not measurable preoperatively, and they were detected only in two patients at the end of surgery, with low amplitudes in a narrow frequency range. No significant changes occurred in DPOAEs five days postoperatively. A month after surgery, improvement in conductive hearing loss was observed; the mean air-bone gap from 0.25 to 1 kHz was 12.9 dB HL, whereas the higher frequencies were still affected by the disease. DPOAEs increased in amplitude in four patients, but this was not significant.

**CONCLUSION:** It remains unclear why DPOAEs are not detected despite a subjective hearing improvement and a sufficiently closed air-bone gap at least in middle and low frequencies. The results of our study show that DPOAEs cannot replace behavioral threshold tests, they may only be included in a battery of tests for a complete clinical follow-up for efficiency monitoring after stapes surgery.

*Submitted:* April 10, 2005  
*Accepted:* May 31, 2005

Mediterr J Otol 2005;2:00-00.

Copyright 2005 © The Mediterranean  
Society of Otolaryngology and Audiology

Otoacoustic emissions (OAEs) are produced specifically by the cochlea and, most probably, by the cochlear outer hair cells as they expand and contract.

The primary purpose of OAE tests is to determine cochlear status, specifically hair cell function. This information can be used to (i) screen hearing (particularly in neonates), (ii) partially estimate hearing sensitivity within a limited range, (iii) differentiate between the sensory and neural components of sensorineural hearing loss, and (iv) test functional hearing loss.<sup>[1]</sup>

Distortion product otoacoustic emissions (DPOAEs) occur because of the nonlinear nature of outer hair cells. They are produced when two tones of different, but related, frequencies (F1 and F2) are presented to the cochlea simultaneously; in response to these two tones, a normal cochlea will generate tones related to F1 and F2.

Otoacoustic emissions are usually used to evaluate, analyze and check several diseases that may involve the cochlea, including otosclerosis.<sup>[2-4]</sup>

Otosclerosis is a primary localized disease of the bony otic capsule. It has a predilection for the oval window and is localized to the stapedial footplate, but it may involve all the otic capsule, with a conductive or sensorineural hearing loss. Usually stapes surgery, and among them, stapedotomy, is the first choice treatment.

The aim of the study was to investigate changes in dynamic characteristics of the middle ear caused by both the disease and stapes surgery (platinotomy, prosthesis positioning, ossicular chain maneuver) and to evaluate their influence on DPOAE responses in patients with otosclerosis.

---

## PATIENTS AND METHODS

---

The study included 15 patients (12 women, 3 men; mean age 51 years; range 32 to 69 years) with advanced otosclerosis. The patients were admitted to the ENT Clinic and were candidates for stapedotomy. Preoperatively, pure tone audiograms, stapedial reflexes, and DPOAEs were recorded.

### Stapes surgery

Ear surgery was performed in all the patients under local anesthesia, using a transcanal approach to the middle ear. After tympanomeatal flap elevation, the scutum was partially removed by a curette to allow complete visualization of the oval window region.

Once fixation of the stapedial footplate was confirmed with a Rosen's needle, the platinotomy was performed using a manual perforator. The crural arch was removed after separating the incudostapedial joint and cutting the stapedius tendon. A piston Teflon platinum wire 0.5 mm in diameter was placed in 11 patients and 0.4 mm in diameter in four patients. The prosthesis loop was secured around the long process of the incus. The tympanomeatal flap was repositioned and the external canal was packed with Gelfoam and Merocel for five days. None of the patients had any complications during or after surgery.

### DPOAE measurements

Stimulus presentation, data recording, and spectrum analysis for DPOAEs were carried out using a Labat Otoacoustic Emission Test Instrument, Model Eclipse. The F1 and F2 levels were both 75 dB SPL, they were constant at all frequencies tested and DPOAEs were plotted for different frequencies (DP-gram). DP-grams were collected in 1 octave steps from 500 to 1 kHz and in 1/3 octave steps from 1 to 8 kHz.

DPOAEs were recorded at the end of the surgical time, after insertion of the piston prosthesis and tympanomeatal flap repositioning. Five days later, after removing the packing of the outer ear canal, DPOAE measurements were repeated.

The patients were asked to visit the outpatient clinic 30 days after surgery, where they underwent a pure tone audiogram and DPOAE measurements. Changes in the hearing thresholds and in the DPOAE amplitudes were statistically assessed with the t-test, and a *p* value of less than 0.05 was regarded as significant.

---

## RESULTS

---

Preoperative tests showed conductive hearing loss, with a mean air-bone gap of 36.6 dB HL ranging from 0.25 to 1 kHz frequencies, and no stapedial reflexes were detected.

DPOAEs were not measurable preoperatively, and they were detected only in two patients at the end of surgery, with low amplitudes in a narrow frequency range. No significant changes occurred in DPOAEs five days postoperatively.

A month after surgery, improvement in conductive hearing loss was observed; the mean air-bone gap from 0.25 to 1 kHz was 12.9 dB HL, whereas the higher frequencies were still affected by the disease.

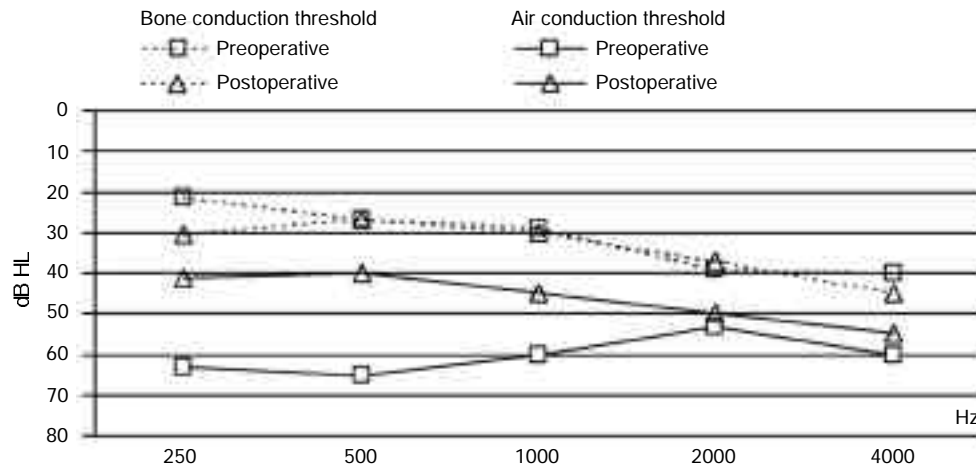


Fig. 1. The mean tonal audiograms of 15 patients the day before and 30 days after stapedotomy.

DPOAEs increased in amplitude in four patients, but this was not significant. The results of audiograms and DP-grams are shown in Fig. 1 and 2, respectively.

#### DISCUSSION

Stapes surgery is the treatment of choice in otosclerosis for hearing improvement. The effect of stapes surgery on OAEs is not sufficiently known. Transient OAEs were detected in only a small number of patients after stapes surgery,<sup>[5]</sup> while DPOAEs were more frequently reported after successful stapedectomy.<sup>[6]</sup> In the present study, we were not able to detect DPOAEs preoperatively, which is in accordance with the fact that a reverse propagation of OAEs towards the outer ear canal is compromised by fixation of the stapedial footplate. The lack of DPOAEs continued in most of the patients postoperatively. These findings were in accordance with those reported in a previous study in which 31

patients underwent stapedectomy, and three patients underwent stapedotomy.<sup>[4]</sup>

The reasons remain somewhat unclear why DPOAEs cannot be recorded in most cases, despite a subjective hearing improvement and a sufficiently closed air-bone gap at least in middle and low frequencies. It can be speculated that, although the elastic properties of the annular ligament which are abolished by the fixation of the footplate are bypassed by the insertion of the piston prosthesis, the mobility of the reconstructed ossicular chain might have been slightly reduced by scar formation around the piston and/or by clamping the prosthesis loop around the long process of the incus. This could explain why DPOAEs were evident only in a few patients on intraoperative recordings, albeit at low amplitudes in the 1-2 kHz range, but then were found to be absent after five days postoperatively. Another possibility for the absence of DPOAEs could be insufficient

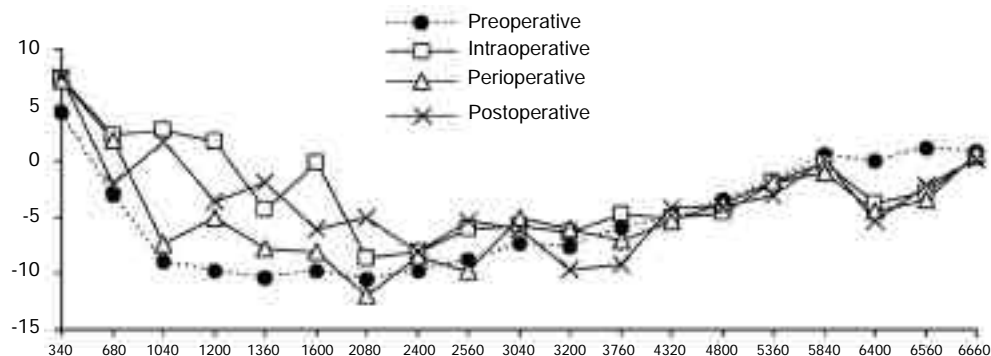


Fig. 2. The mean DP-grams recorded just before surgery, intraoperatively, five days and 30 days after stapedotomy.

sealing that may result in an incomplete coupling of the piston with the perilymph.

OAE measurements are much more sensitive to changes in inner and middle ear dynamics when compared to audiometric tests, e.g. air-bone threshold, with an intra-subject variability of about  $\pm 10$  dB. For this reason, our opinion is that OAEs cannot replace behavioral threshold tests; they may only be included in a battery of tests for a complete clinical follow-up for efficiency monitoring after stapes surgery.

#### Acknowledgements

The authors thank Giampiero Cappelli for his assistance in the audiological testing, and Dr. Marco Barbaro for his help in collecting data.

---

#### REFERENCES

---

1. Kemp DT. Stimulated acoustic emissions from within the human auditory system. *J Acoust Soc Am* 1978;64: 1386-91.
2. Balkany TJ, Telischi FF, McCoy MJ, Lonsbury-Martin BL, Martin GK. Otoacoustic emissions in otologic practice. *Am J Otol* 1994;15:29-38.
3. Osterhammel PA, Nielsen LH, Rasmussen AN. Distortion product otoacoustic emissions. The influence of the middle ear transmission. *Scand Audiol* 1993; 22:111-6.
4. Herzog M, Shehata-Dieler WE, Dieler R. Transient evoked and distortion product otoacoustic emissions following successful stapes surgery. *Eur Arch Otorhinolaryngol* 2001;258:61-6.
5. Lieberum B, Held B, Schrader M. Otoacoustic emissions (TEOAE and DPOAE) after middle ear operation. [Article in German] *Laryngorhinootologie* 1996; 75:18-22.
6. Ralli G, Cianfrone G, Fabbriatore M, Altissimi G. Analysis of otoacoustic distortion products in a group of otosclerotic patients. [Article in Italian] *Acta Otorhinolaryngol Ital* 1996;16:485-91.