



Wideband Tympanometry: Key Reference Articles (v2.0)

Below is a brief overview of the findings from a selection of academic papers regarding wideband tympanometry. Section 1 focuses on wideband absorbance. Section 2 looks at the role of the middle ear resonance frequency in the diagnosis of middle ear disorders.

Section 1 Wideband Absorbance

Important note

In this section it is important to highlight that many of the studies use the term wideband REFLECTANCE in their reports. The Titan does not display reflectance instead it displays its reciprocal Absorbance. Reflectance is a power calculation and refers to the amount of sound reflected from the middle ear, whereas Absorbance refers to the amount of sound absorbed by the middle ear. The reader should be aware that reflectance can therefore describe absorbance as absorbance = 1-reflectance. The term Absorbance has been used in the Titan as it is more clinically relevant than reflectance

The following terms which are also found in the literature also describe Absorbance

Reflectance / R^2 /
WideBand Reflectance (WBR)
WideBand Energy Reflectance (WBER)
Ambient Reflectance
Power Reflectance (PR)
Energy Reflectance (ER)
Middle Ear Power Absorption (MEPA)
Wideband Acoustic Transfer Function (WATF)

Ellison, JC., Gorga M., Cohn, E., Fitzpatrick, D., Sanford, SA., Keefe DH., (2012) Wideband Acoustic Transfer functions predict middle ear effusions. Laryngoscope 122 887-894

This study looked at how accurately wideband acoustic transfer functions which included absorbance measurements at ambient pressure (as well as admittance magnitude and phase measurements) could predict middle ear effusions. These measurements we also compared to the current clinical guidelines (US) of using pneumatic otoscopy to diagnose middle ear effusions. Absorbance measurements were obtained in 53 ears prior to middle ear effusions being confirmed by myringotomy as the gold standard. These results were then compared to an age matched normative group of 59 ears. The results showed that absorbance was reduced in ears with middle ear effusions compared to normal ears. When comparing absorbance to pneumatic otoscopy, the data showed that stiff ears (thus those most likely to have middle ear effusions) had lower absorbance than non stiff ears. The most sensitive range for detecting middle ear effusions though absorbance measurements was found to be between 0.8 and 2 kHz. The authors conclude that absorbance is sensitive to middle ear stiffness and middle ear effusions, suggesting that it 's accuracy of diagnosing middle ear effusions is similar to performing pneumatic otoscopy.

Voss, SE., Merchant, GR., Horton, NJ. (2012) Effects of middle-ear disorders on power reflectance measured in cadaveric ear canals. Ear Hear. 33(2) 195-208.

The paper systematically characterises how reflectance (the reciprocal of Absorbance) is altered by five specific middle ear disorders. (1) positive and negative static pressure, (2) middle ear fluid, (3) fixation of the stapes footplate, (4) disarticulation of the incudostapedial joint, and (5) tympanic-membrane perforations. Reflectance measures were performed on 8 cadaver ears which were manipulated to be representative of conditions 1-4. Retrospective reflectance calculations were made on 11 separate cadaver ears for condition 5. These measurements were then compared to a middle ear model which was modified to represent the five middle ear disorders outlined above.

The results show that the general trends for a given condition were similar between the cadaver measurements and the model middle ear. A detailed discussion of how the measured reflectance for each modified condition differs from the normal state is provided and examples are shown (Adapted versions of these examples can however be found within the Titan software). It becomes clear that different middle ear conditions affect reflectance at different frequencies and the degree of how these frequencies are affected is determined by the extent of the disorder.

Keefe, DH., Sanford, CA., Ellison, J., Fitzpatrick, D., Gorga, M. (2012) Wideband aural acoustic absorbance predicts conductive hearing loss in children. Int J Audiol 51 880-92

This paper aimed to test whether wideband absorbance could be used as a predictor for conductive hearing loss and aimed to build on the work completed by Piskorski et al (1999). The authors compared the 226Hz tympanogram with Absorbance performed at both ambient and peak tympanic pressure in two groups of children. Group 1 consisted of 35 ears (mean age 5.2 years) with suspected middle ear effusions and an air bone gap of ≥ 20 dBHL at one or more frequencies. Group 2 was a control group of 43 ears (mean age 5.5 years) without a history of middle ear effusions within the last six months and with audiometric thresholds of ≤ 15 dBHL and air bone gaps of < 15 dBHL. The results show that ears with conductive hearing loss had reduced absorbance at frequencies between 0.7 and 8 kHz compared to ears with normal hearing. Below 0.6 kHz no significant intergroup differences were found in the absorbance domain. The accuracy of each test's ability to differentiate between normal hearing and a conductive hearing loss was measured using an area under the receiver operating characteristic curve. This analysis shows that wideband absorbance (at both ambient and peak tympanic pressure) was a better predictor of conductive hearing loss than 226Hz tympanic width and 226Hz peak-compensated static admittance magnitude. No significant differences were recorded between ambient and peak tympanometric pressure absorbance measures in predicting the presence of conductive hearing loss.

Nakajima, HH., Pisano DV., Roosli, C., Merchant., Mahfoud, GR., et al (2012) Comparison of ear-canal reflectance and umbo velocity in patients with conductive hearing loss: a preliminary study. Ear Hear. 33(1):35-43

This study compared absorbance with umbo velocity measurements (umbo velocity measurements use a laser Doppler vibrometer to measure sound induced umbo velocity, this test is still in its research stage and does not have FDA approval) in 31 adult patients with conductive hearing loss, of which 14 had surgically confirmed stapes fixation due to otosclerosis, 6 had surgically confirmed ossicular discontinuity, and 11 had computed tomography and vestibular evoked myogenic potential confirmed superior semicircular canal dehiscence (SCD). In combination with audiometry the authors could correctly categorise 28/31 into the correct pathological groups when using absorbance and 29/31 could be correctly categorised when using umbo velocity. As absorbance is a much cheaper and clinically friendly way of obtaining measurements and has similar sensitivity and specificity then this could be used as an alternative umbo velocity.

Hunter LL, Feeney MP, Lapsley Miller JA, et al (2010). Wideband Reflectance in Newborns: Normative Regions and Relationship to Hearing-Screening Results. Ear Hear. 31:599–610.

These authors obtained absorbance (studied actually measured reflectance), 1000Hz tympanometry as well as distortion product otoacoustic emissions measurements in 324 infants. These children were then separated into two groups DPOAE pass (n=352) and DPOAE refer (n=141). The results showed that the absorbance's for the group which passed the DPOAE were much higher than for those who failed the DPOAE screen especially at frequencies from 1- 6 kHz. DPOAE screening outcome was then used as the gold standard and 1000 Hz tympanometry and absorbance measurements were then compared to see how accurately they could predict a pass or fail on the DPOAE. Receiver under the operating curve data showed 1000 Hz tympanometry to score 0.72, 1000 Hz absorbance to score 0.82 and 2000 Hz reflectance scored 0.90. The authors conclude that wideband absorbance's is better than 1-kHz tympanometry at detecting those newborns who are more likely to obtain a refer result on an OAE-based hearing screen due to middle-ear dysfunction.

Beers A.N. , Shahnaz N. , Westerberg B.D. & Kozak F.K . (2010) Wideband reflectance in normal Caucasian and Chinese school-aged children and in children with otitis media with effusion . Ear Hear , 31 , 221 – 233

Absorbance data for early school-aged children was measured to determine whether absorbance differs significantly between Caucasian/Chinese children and male/female children. The results showed that gender and ear did not have any effect in the absorbance recordings but Chinese children showed higher absorbance over the mid frequency range.

The authors then compared the normative paediatric absorbance data with the measurements taken from children with abnormal middle ear conditions. 144 normal ears were compared with 30 ears with mild negative middle ear pressure, 24 ears with severe negative middle ear pressure and 42 ears with middle ear effusions. Receiver operating characteristic (ROC) curve analyses showed that absorbance measurements above 800Hz were better at identifying middle ear effusions than absorbance measurements below 800Hz. The 1250 Hz region showed the largest sensitivity and specificity to diagnosing middle ear effusions of 96% and 95% respectively.

Shahnaz N. , Bork K. , Polka L. , Longridge N. , Bell D. et al. (2009) Energy reflectance and tympanometry in normal and otosclerotic ears . Ear Hear , 30 , 219 – 233 .

This report aimed to identify the relationship between ears with otosclerosis (confirmed by surgery) and tests of middle ear function. These included conventional 226Hz tympanometry, multi-frequency tympanometry and wideband energy reflectance. Measurements were collected from 62 adults with normal hearing and 28 patients diagnosed with otosclerosis. The results showed that ears with otosclerosis had greater energy reflectance (i.e. less sound being absorbed by the middle ear) at frequencies below 1 kHz than ears with normal hearing. Of all the measurement variables in the study, energy reflectance was identified as the most effective way of identifying ears with otosclerosis. This measure was able to identify otosclerosis in 82% of the individuals but had a false positive rate of 17.2%. The authors therefore conclude that the use of absorbance in a test battery approach including other tests of middle ear function will improve the identification of otosclerotic ears in the clinical setting.

Sanford C.A., Keefe D.H. , Liu Y., Fitzpatrick D.F., McCreery R.W. et al . (2009) . Sound conduction effects on DPOAE screening outcomes in newborn infants: Test performance of wideband acoustic transfer functions and 1-kHz tympanometry . Ear Hear , 30 , 635 – 652

This study addressed how accurately Wideband tympanometry is able to predict the status of the sound conductance pathway (outer ear and middle ear) in neonates' ears within in a universal newborn screening program. The status of each ear was determined by distortion product otoacoustic

emissions (DPOAE's) and this was used as the gold standard. Measurements from 455 ears (230 well babies) were taken and following DPOAE testing, the children were then subjected to wideband tympanometry (Absorbance was recorded at ambient and pressurised conditions) and 1 kHz tympanometry. Of the total 455 ears, 375 passed and 80 were referred on the DPOAE screen. The results showed that the majority of ears which passed the DPOAE screen showed higher absorbance than the ears which were referred on the DPOAE screen, with the largest absorbance differences between pass and refer falling in the 0.8 – 4 kHz region (Note in the Titan, the wideband averaged tympanogram tests between 0.8kHz and 2.0 kHz in children less than 6 months). The data was analysed using clinical decision theory to determine each tests ability to classify ears which passed or were referred the DPOAE. The highest area under the receiver operating characteristic curve was obtained using absorbance at ambient pressure (0.87) whereas the highest receiver operating curve for 1 kHz tympanometry (several variables were tested) was 0.75. From these results several conclusions can be drawn. Most prominent is that absorbance is more effective at classifying DPOAE outcomes than 1 KHz tympanometry. The results also showed that many of the referrals from the DPOAE are a result of sound conductance issues and therefore absorbance performed at ambient pressure many have a future role to play in newborn hearing screening.

Feeney MP, Grant IL, Mills DM (2009). Wideband energy reflectance measurements of ossicular chain discontinuity and repair in human temporal bone. Ear Hear. 30:391–400

This study used 5 human cadaver ears to see how absorbance is affected by cutting the ossicular chain and the subsequent repair of the ossicular chain. These two conditions were compared to absorbance measurements obtained before prior to the ear manipulations. Disarticulating the ossicular chain resulted in the appearance of a deep peak in absorbance in each specimen ranging in centre frequency from 561 to 841 Hz. The average increase in absorbance was 31% at a frequency of 630 Hz and this was reversible when the ossicular chain was repaired. These results suggest that absorbance has the potential for use in the diagnosis of ossicular discontinuity and to monitor the status of the repaired ossicular chain.

Liu YW., Sanford CA., Ellison JC., Fitzpatrick DF. , Gorga MP. et al. (2008) . Wideband absorbance tympanometry using pressure sweeps: System development and results on adults with normal hearing , J Acoust Soc Am , 124 , 3708 – 3719 .

Prior to this study the ability to record wideband tympanometry was both time consuming and clinically unfriendly as measurement systems were unable to automatically control the pump pressure and wideband tympanometry therefore had to be performed at fixed static pressure points. This study introduces the methodology behind how wideband tympanometry has been made clinically viable. The aim of the study was to investigate the concept of automatically sweeping the air pressure to measure the wideband tympanometry with the hope that this would reduce test time. It also aimed to see the effects of how pressure sweeps affect test result interpretation. Ambient and pressurised wideband reflectance measurements (the reciprocal of absorbance) were obtained from 92 adult ears with normal hearing. The results showed that test time reduced from around 40 s using traditional methods to 1.5 – 7 s using the modified test procedure. The ambient pressure results showed parity with normative data from previous studies. The pressurised sweep results showed that absorbance at peak tympanic pressure is not significantly affected by sweep speed but when comparing to absorbance measured at ambient levels, the peak tympanic pressure shows higher absorbance at frequency below 2000Hz. This suggests that two sets of normative data should be used to measure absorbance depending on the testing method.

Voss SE, Horton NJ, Woodbury RR, et al. (2008) Sources of variability in reflectance measurements on normal cadaver ears. Ear Hear. 29 651–655

This study looked at how absorbance measurements can be affected by the following variables 1) effect of measurement location (in ear canal), 2) effect of ear canal cross sectional area and 3) the

effect of middle ear cavity volume. 9 human cadaver ears were chosen for the experiment which did not have any history of middle ear pathology. The results showed that variations within an individual ear with respect to either measurement location or ear-canal cross-sectional area resulted in relatively small effects on absorbance. However, increasing the middle ear cavity volume was found to increase absorbance below 2000 Hz. Frequencies above 2000 Hz showed more variable results when middle ear cavity volume was increased. The authors conclude that middle ear cavity volume is likely to be the cause of inter subject variations in absorbance measurements.

Shahnaz N. & Bork K. (2006) Wideband reflectance norms for Caucasian and Chinese young adults . *Ear Hear* , 27 , 74 – 88 .

This study looked at absorbance measurements in Caucasian and Chinese young adults to see if there were any intergroup differences. 126 subjects (237 ears) between the ages of 18 and 32 years we tested with 62 subjects in the Caucasian group and 64 subjects in the Chinese group. The results showed that the Caucasian group had significantly lower absorbance than the Chinese group particularly in the high frequencies (3891 to 6000 Hz) but significantly higher absorbance's the Chinese group in the frequency range 469 to 1500 Hz. The authors assumed that these differences were down to body size but body size indices were not measured in this study. It does however make the clinician aware that interracial differences in absorbance may exist.

Feeney M.P. & Sanford C.A. (2004) Age effects in the human middle-ear: Wideband acoustical measures . *J Acoust Soc Am* , 116 , 3546 – 58 .

This study compared 226 Hz tympanometry and absorbance at ambient pressure in a group of 40 young adults and a group of 30 adults over 60 years. The authors found that admittance measures of the middle ear at 226 Hz did not differ between the groups. However, significant age effects were found in wideband absorbance. Older adults show increased in absorbance from 800 to 2000 Hz then a decrease near 4000 Hz. The authors suggest that these results as present because the middle-ear stiffness decreases with age.

Keefe, D., and Simmons, J. (2003) Energy transmittance predicts conductive hearing loss in older children and adults. *J. Acoust. Soc. Am.* 114 (6) 3217 – 3238.

This paper has two key messages. Firstly it introduces theory behind the calibration of wideband acoustic transfer functions (ATF): absorbance. Secondly it uses this improved calibration method to predict the presence of conductive hearing loss in older children and adults. Section II of this paper describes the calibration method in detail.

Keith and Simmons recruited 42 normal ears from children and adults over 10 years of age and compared these to 18 ears with conductive hearing loss. The underlying aetiologies of conductive hearing loss were unknown. This is the first study where both ambient and pressurised wideband acoustic transfer functions were recorded and compared to traditional 226Hz tympanometry. When comparing tests at a fixed specificity of 0.90, the sensitivities for peak-compensated static acoustic admittance at 226 Hz was 0.28, ambient-pressure ATF showed a specificity of 0.72, and pressurized ATF showed the largest sensitivity of 0.94. Furthermore, pressurized ATF was accurate at predicting conductive hearing loss with an area under the receiver operating characteristic curve of 0.95. The paper concludes with the proposals that Ambient-pressure reflectance may have sufficient accuracy to be used in some hearing-screening applications, whereas pressurized reflectance has additional accuracy that may be appropriate for hearing-diagnostic applications.

Keefe, D. H., Zhao, F., Neely, S. T., et al. (2003). Ear-canal acoustic admittance and reflectance effects in human neonates. I. Predictions of otoacoustic emission and auditory brainstem responses. *J Acoust Soc Am*, 113, 389–406.

This report uses the same data set of ears which was used in (Keefe et al 2000) but this time describes the extent to which ear-canal acoustic admittance and energy reflectance can classify OAE and ABR responses as present or absent. The results showed that reflectance factors classified OAEs with an area under the relative operating characteristic (ROC curve) as high as 0.79, this is suggestive that that middle-ear dysfunction is partly responsible for the inability to record OAEs in many ears. The reflectance factors classified ABR responses less well, with ROC areas of 0.64 for predicting wave-V latency and 0.56.

Feeney, M. P., Grant, I. L., and Marryott, L. P. (2003) Wideband energy reflectance measurements in adults with middle-ear disorders. *J. Speech Lang. Hear. Res.* 4, 901–911.

This paper aimed to measure wide band energy reflectance (the reciprocal of Absorbance) in 9 patients with conductive hearing loss (two ears with negative middle ear pressure, two ears with hypermobile tympanic membranes, two ears with otosclerosis, two ears with perforations of the tympanic membrane, one ear with ossicular discontinuity and four ears with middle ear effusions). Wideband energy reflectance was measured and then compared to a group of 40 adults with normal middle ear function determined by otoscopy, pure tone audiometry, 226Hz tympanometry and medical history. 9 of the 13 ears with middle ear pathology showed that the energy reflectance fell outside of the 5th -95th percentile for some portions of the frequency range. Detailed examples are provided on how different middle ear conditions affect energy reflectance (see Voss 2012 for an updated review). Although small in sample size this research does suggest that energy reflectance and thus absorbance can play a role in middle ear diagnostics.

Keefe, D. H., Folsom, R. C., Gorga, M. P., et al. (2000). Identification of neonatal hearing impairment: Ear canal measurements of acoustic admittance and reflectance in neonates. *Ear Hear*, 21, 443–461.

The author's of this study looked to described admittance and reflectance measures in 2081 ears and to see how these measurements relate to age, gender, left and right ears and selected risk factors. They found that the reflectance (reciprocal of absorbance varied with neonatal age range and is sensitive to the presence or absence of risk factor and gender differences. As absorbance did vary with selected risk factors they conclude that this measure (in this specific case reflectance) could be useful in neonatal screening. It should be noted however, that in 13% of these recordings evidence of improper probe seal in the ear canal was found and suggests that a real-time acoustic test of probe fit is proposed to better address the probe seal problem (addressed in the titan).

Piskorski, P., Keefe, D. H., Simmons, J. L., et al. (1999). Prediction of conductive hearing loss based on acoustic ear-canal response using a multivariate clinical decision theory. *J Acoust Soc Am*, 105, 1749–1764.

In this paper, Piskorski et al proposed that a wideband tympanometry test, based on an acoustic transfer function, such as absorbance may be desirable for diagnostic applications. The study provides evidence that wideband ambient absorbance can detect a conductive hearing loss with a suggestion of increased detection accuracy when including tympanometry data at 0.226 kHz. These conclusions are derived from performing wideband reflectance (reciprocal of absorbance) at ambient pressure on 194 ears (age range between 2 – 10 years). Early work on obtaining normative paediatric wide band reflectance data is also presented.

Margolis, R. H., Saly, G. L., Keefe, D. H. (1999). Wideband reflectance tympanometry in normal adults. *J Acoust Soc Am*, 106, 265–280.

This study aimed to identify the characteristics of wideband reflectance in normal adult ears. A research device was used to measure both standard tympanograms and reflectance (the reciprocal of absorbance) in 20 adults (mean age 34 years). When converting their reflectance measurements to absorbance the authors describe a normative absorbance range as a function of frequency which has two distinct maxima at 1.2 and 3.5 kHz with absorbance decreasing thereafter until 8 KHz. The authors also note that pressurising the ear canal decreases absorbance at low frequencies, increases absorbance in the region of the maximum, and decreases absorbance slightly at high frequencies

Section 2: Resonant Frequency / Multi Frequency Tympanometry

Shahnaz N, Davies D (2006) Standard and Multifrequency tympanometric norms for Caucasian and Chinese young adults. Ear Hear 27(1):75–90

This study examined differences of a number of tympanic parameters including resonant frequency between a group of normal-hearing Caucasian (n=76) and Chinese adult (n=83). The results show that in the Caucasian group the mean resonant frequency was found to be significantly lower than the Chinese group which is thought to be a result of differences in body size. The recommendation from this study is that homogenous norms should be used when testing the resonant frequencies of these two ethnic groups.

Frade C, Martin C (1998) Diagnostic value of the Multifrequency tympanometry in active rheumatoid arthritis. Auris Nasus Larynx (25)131–136

This paper investigates the relationship between rheumatoid arthritis (RA) and resonant frequency determined by Multifrequency tympanometry. It notes that significant group differences between normal ears and those with rheumatoid arthritis (n=37) exist, with those with the disease displaying increased resonant frequencies. This is important to the clinician to be aware of patients with RA as it may confound the results obtained from middle ear assessment using resonant frequency.

Shahnaz, N., & Polka, L. (1997). Standard and multi-frequency tympanometry in normal and otosclerotic ears. Ear & Hearing, (18) 268-280.

Nine tympanometric measures were examined in 68 normal ears and 14 ears surgically confirmed as having otosclerosis. The goal of the study was to evaluate whether alternative tympanometric parameters could be used to distinguish normal middle ears from ears with otosclerosis. The authors found that resonant frequency was superior at identifying otosclerotic ears than all other tympanometric measurement methods. They also found that otosclerosis can be more accurately identified when resonant frequency is estimated using positive (rather than negative) tail compensation. The study concludes with the suggestion that performing resonant frequency tympanometry with other tympanometric measures could improve the overall identification of otosclerosis.

Valvik B, Johnsen M, Laukli E (1994) Multifrequency tympanometry. Audiology 33:245–253

This study compared the distribution of resonant middle ear frequencies with ears with middle ear disorders. 100 normal ears were compared with 28 pathological middle ears which were subdivided into 3 groups. 1) Tympanic membrane pathology, 2) otosclerosis pre-operative 3) otosclerosis post operative. The results showed that the resonant frequency of the normal ears fell between 350 Hz and 1750Hz (mean resonant frequency 1049Hz). Despite this large intragroup variability, significant group differences were seen when comparing the normative group to the otosclerosis groups. Pre operative otosclerotic ears showed higher resonant frequencies (mean 1238Hz SD 209) and post operative otosclerotic ears showed lower resonant frequencies (mean 692Hz SD 127Hz). The authors therefore suggest that resonant frequency can be used to assist in the diagnosis of otosclerosis.

Margolis, R., & Goycoolea, H. (1993). Multifrequency tympanometry in normal adults. Ear & Hearing, 14, 408-413.

This normative data study looked at identifying normative data for Multifrequency tympanometry and to establish boundaries of normal and abnormal test results. Static admittance, tympanometric width,

and tympanometric peak pressure at 226 Hz were analyzed along with eight different methods of identifying resonant frequency of the middle ear. The results showed that resonant frequency falls within range from 800 and 2000Hz, but depending on the method used the exact frequency where the resonant frequency is identified at can fluctuate. They conclude by suggesting that the preferred clinical method for determining resonant frequency is dependent on whether abnormally high or abnormally low resonant frequency is suspected. For high resonant frequencies a sweep pressure method, compensated at +200 daPa is preferred. However for detecting low resonant frequencies they suggest a sweep frequency method, compensated at +200 daPa, is recommended

Shanks, J. E. (1984). Tympanometry. Ear & Hearing, 5, 268-280.

This study performs an overview of interpreting tympanograms collected using a variety of methods. The final section however, provides resonant frequency data from those with confirmed middle ear disorders. The author's demonstrate that certain pathologies such as middle ear effusions, otosclerosis, ossicular adhesion and tympanic membrane retraction cause the resonant frequency to increase. On the other hand, otitis externa, serous otitis media, tympanic membrane pathology, and ossicular discontinuity cause the resonant frequency to reduce.

Liden G, Harford E, & Hallen O. (1974). Tympanometry for the diagnosis of ossicular disruption. Archive of Otolaryngology, 99 (1):23

These authors identified that the use different probe tones produces varying tympanograms in patients with ossicular discontinuity . They obtained three tympanogram son ten patients with disruption of the ossicular chain using the following probe frequencies: 220, 625, and 800 Hz. Their results showed that when using an 800 Hz probe tone a clear undulating tympanographic pattern was present for each case. This characteristic was also present in the majority of cases when using the 625Hz tone but was not present at all when using the 200Hz tone. The authors therefore recommend that in order to obtain a tympanogram from a patient with ossicular discontinuity that can be easily distinguished from a version of a type A (Jerger classification) then a 800-Hz probe tone should be used