DETERMINATION OF ACOUSTIC RADIATION USING RADIOEAR B81 BONE CONDUCTOR AMONG MALAYSIAN HEALTHY ADULTS

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UNIVERSITI SAINS MALAYSIA

2025

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by

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Thesis submitted in fulfilment of the requirements for the Bachelor of Sciences (HONOURS) Audiology

July 2025

CERTIFICATION

This is to certify that the dissertion entitled " Determination of Acoustic Radiation using Radioear B81 Bone Conductor among Malaysian Healthy Adults" is the project done by NURNADANADHIRA BINTI HASHIM from October 2024 to July 2025 under my supervision. We have read this dissertation, and ,in our opinion, it fulfils that acceptable standard of scholarly presentation and is fully adequate, in scope and quality as a dissertion to be submitted in partial fulfilment for the degree of Bachelor of Health Sciences (Honours)(Audiology). Research work and collection of the data belong to the Universiti Sains Malaysia.

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DECLARATION

I hereby declare that the work has been done by myself , all the results are of my own investigation and any ideas or quotation from other's work are fully acknowledged according to the standard referring practices of the discipline. I also declare that it has not been submitted as a whole in previous or concurrently for any other degrees in any institutions. I acknowledge that the research work and collection of data belong to Universiti Sains Malaysia.

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ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest gratitude to Allah S.W.T for granting me the strength, patience and determination to complete this thesis entitled " Determination of Acoustic Radiation using B81 Among Malaysian Healthy Adults". Without His will and grace, this research would not have been possible.

I wish to extend my heartfelt appreciations to my supervisor, Mr. Mahamad Almyzan Awang, for his continuous guidance, constructive feedback, and encouragement throughout every stage of this research. All his knowledge and support have been invaluable to the successful completion of this project. I am also grateful to Profesor Dr. Mohd Normani Zakaria for his unlimited guidance and support also input in improving this research, especially on statistical analysis. Without their expertise and support, I would not have been possible to complete this thesis.

My sincere thanks also go to all lectures, clinician, staff of Universiti Sains Malaysia, who provided assistance and facilities during the data collection and analysis process.

I would like to acknowledge the cooperation of all Malaysian healthy adult participants who generously gave their time to be part of this study. Without their participation, this research would not have been possible.

Special thanks to my family and friends for their endless love, encouragement and moral support. Their belief in me has been a source of strength and motivation.

Lastly, to everyone who has contributed to this research, whether directly or indirectly thank you for your contributions. It was such meaningful impact on the success of this thesis.

May this thesis serve as a meaningful contribution to the field of audiology and inspire future studies in the area of acoustic radiation and bone conduction assessment.

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LIST OF SYMBOLS

<	Less than
>	More than
=	Equal to
_	Minus
%	Percentage
n	Sample size

LIST OF ABBREVIATIONS

ABG	Air-bone gap
AC	Air conduction
AR	Acoustic radiation
BC	Bone conduction
CSOM	Chronic Suppurative Otitis Media
dB HL	Decibel hearing level
Hz	Hertz
EAC	External auditory canal
PTA	Pure tone audiometry
TM	Tympanic membrane
USM	Universiti Sains Malaysia

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DETERMINATION OF ACOUSTIC RADIATION USING RADIOEAR B81 BONE CONDUCTOR AMONG MALAYSIAN HEALTHY ADULTS

ABSTRAK

Ujian Audiometri konduksi tulang adalah prosedur yang penting untuk mengenalpasti jenis masalah pendengaran. Walaubagaimanapun, berlakunya fenomena radiasi akustik yang dihasilkan oleh penggetar tulang, terutamanya pada keseluruhan frekuensi tinggi, yang boleh mempengaruhi ketepatan keputusan ujian. Kajian ini bertujuan untuk menentukan kehadiran dan kesan radiasi akustik semasa ujian konduksi tulang dijalankan dengan menggunakan Radioear B81 di kalangan belia Malaysia yang sihat. Kajian ini melibatkan 35 orang peserta berumur antara 18 hingga 30 tahun yang mempunyai pendengaran normal dan fungsi telinga tengah yang normal. Pengukuran ambang konduksi tulang dijalankan di bawah dua keadaan: saluran telinga tidak ditutup (unoccluded) dan ditutup (occluded) pada frekuensi tinggi iaitu 2kHz, 3kHz, 4kHz, 6kHz dan 8kHz. Keputusan menunjukkan terdapat perbezaan yang signifikan secara statistik antara ambang konduksi tulang dalam keadaan tidak ditutup dan ditutup pada frekuensi 3kHz, 6kHz dan 8kHz ($p<0.05$), manakala tiada perbezaan signifikan dikesan pada 2kHz dan 4kHz. Begitu juga, nilai jurang udara-tulang (ABG) menunjukkan perbezaan ketara di frekuensi 3kHz, 6kHz dan 8kHz apabila telinga ditutup. Ini menunjukkan bahawa radiasi akustik memberi kesan terhadap ambang konduksi tulang dan boleh menyebabkan wujudnya ABG palsu dalam keadaan saluran telinga terbuka. Mengikut kajian lepas, dengan meutup saluran telinga, ia dapat mengurangkan kesan radiasi akustik dan memberikan bacaan ambang yang lebih tepat. Kajian ini juga ingin menyarankan kaedah telinga tertutup ketika ujian konduksi tulang pada frekuensi tinggi dijalankan, khususnya di kalangan individu yang mempunyai

pendengaran normal, untuk mengelakkan kesilapan dalam penentuan jenis masalah pendengaran. Keputusan melalui kajian ini dapat meningkatkan ketepatan dalam penilaian pendengaran serta memberi langkah awal mengesan dan merawat masalah pendengaran dengan lebih efektif di peringkat klinikal.

Kata kunci: Radiasi akustik, *Radioear* B81, konduksi tulang, jurang udara-tulang, audiometri

DETERMINATION OF ACOUSTIC RADIATION USING RADIOEAR B81 BONE CONDUCTOR AMONG MALAYSIAN HEALTHY ADULTS

ABSTRACT

Bone conduction (BC) audiometry is an important clinical hearing test in determining the type of hearing loss. However, the presence of acoustic radiation (AR) produced by the bone conductor, especially at high frequencies, may compromise the validity of the hearing threshold results. This study aimed to determine the presence and influence of acoustic radiation when using the Radioear B81 bone conductor among Malaysian healthy adults. 35 participants between the ages of 18 and 30 years with normal hearing and normal middle ear function were recruited. Bone conduction thresholds were recorded in two conditions: unoccluded (open ear canal) and occluded (closed ear canal) at high frequencies: 2kHz, 3kHz, 4kHz, 6kHz, and 8kHz. The results revealed differences in BC thresholds that were statistically significant between occluded and unoccluded conditions at 3kHz, 6kHz, and 8kHz ($p < 0.05$), with no significant differences at 2kHz and 4kHz. Similarly, the air-bone gap (ABG) values exhibited significant reductions at 3kHz, 6kHz, and 8kHz when the ear canal was occluded, indicating the presence of acoustic radiation on the BC measures in the unoccluded condition. These findings support the hypothesis where acoustic radiation can lead to artificial BC thresholds and false ABGs, particularly at high frequencies. This study highlights the necessity of considering acoustic radiation in BC testing using the B81 transducer and suggests that clinicians should consider occlusion procedures in high-frequency BC testing for more valid audiological tests.

Keywords: Acoustic radiation, Radioear B81, bone conduction, air-bone gap, audiometry

CHAPTER 1

INTRODUCTION

1.1 Background of study

Sound pathway

Humans used the auditory sense to perceived sound through complex process involving the ear and brain. Part of the ear in (figure 1) is the primary sensory organ for sound and it consists of 3 parts. The outer ear, middle and inner ear. The conduction of sound through the outer and middle ear is primarily via air and bone. The air conduction pathway is the primary transmission channel for reception of information regarding the acoustical sound by normal hearing people (Henry & Letowski, 2007). Air conduction (AC) pathway, the outer ear consists of an auricle, external auditory canal and tympanic membrane will collect the sound waves and transmit the sound waves through the ear canals to the middle ear. The middle and external ear mechanisms are for the direction and focus of acoustic information, to optimize its conversion into mechanical vibrations of the three small bones of the ossicular chain of the middle ear, and to send it to the mechano-neural transformer of the cochlea. It causes the vibration of the eardrum in the middle ear and tiny bones inside the inner ear which send the sound signal directly to the brain to interpret it as a sound.

Meanwhile, as can be seen in figure 1, the inner er is quite deep inside the head and surrounded by the bone, when the bone vibrates, the cochlear can be directly stimulated and that produce same sensation of hearing achieved through air conduction(Lundgren, n.d.). This type of sound pathway is bone conduction (BC). Bone conduction is a signal transmission through vibration of the mastoid bones of the skull to the cochlea and then directly through the auditory pathways of the brain (Carl et al., 2024). The bone conduction pathway bypasses the middle and the external ear mechanisms and results in transmission of sound to the cochlea. This type of testing bypasses the outer and middle ear. The bone vibrator vibrates the mastoid bones of the skull, then directly stimulates both cochlear. The oscillator may produce a vibration that is perceived by the patient, thus eliciting a vibrotactile response instead of a response to the auditory stimulus (Joe Walter Kutz, 2023).

In either event, the limits to which human hearing can be protected from external noise by hearing protective devices are set by bone conduction transmission. Earmuffing or plugging the ears reduces the amount of sound energy reaching the auditory system via the ear canal but not that reaching the auditory system via bone conduction. In other words, if there is a sufficient intensity of sound, the ears may still be excited by bone conduction even when the air conduction occluded. Furthermore, all humans are heard by air conduction and bone conduction when speaking since the vibrations from the vocal folds stimulate the bones of the skull.

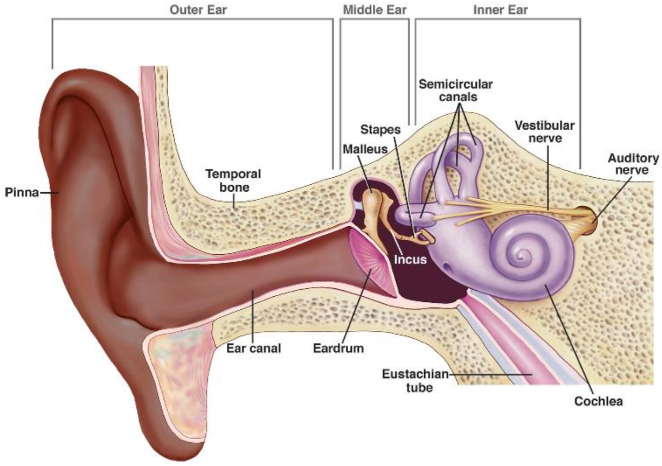

Figure 1 part of the ear (NIDCD National Institutes of Health (NIH), 2022)

For the purpose of measuring hearing ability of an individual, audiologist commonly using pure tone audiometry (PTA) to test each of healthy individual hearing including individual with hearing problem. According to (Kung & Willcox, 2007) pure tone signals will be delivered via these 2 pathways one by one in various of frequencies, normally from 250Hz to 8khz (AC) and 250Hz to 4kHz (BC). These two pathways need to be completed in order to enable audiologist to interpret the degree and type of hearing loss.

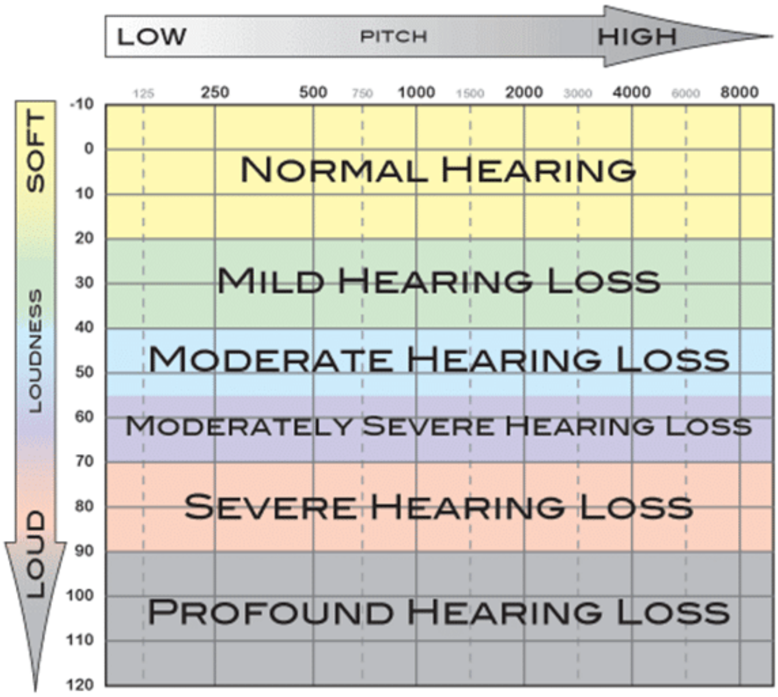

Figure 2 Type and degree of hearing impairment (hearing doctors, 2021)

Air-bone gap

The most importance feature of audiometric testing is an air-bone gap (ABG) between AC and BC. It will help to distinguish individuals with conductive hearing loss, mixed hearing loss and sensory neural hearing loss (type of loss). Air-bone gap commonly found in people with conductive and mixed hearing loss. It is essential to know that an air-bone gap may give a hint of outer or middle ear disease such as otitis externa, tympanic membrane and chronic suppurative otitis media (CSOM). In healthy individuals without any hearing issues, we did not expect the air-bone gap to exhibit more than 10dB HL gaps with degree of hearing is 20dB HL above (Oosterloo et al., 2020).

Since air-bone gap is one of the most important features of audiometry testing, tester should be aware of false air-bone gap during bone conduction threshold. False air bone gap is one of the factors that could influence the size of air bone gap including the test result. Study from (Margolis et al., 2013a) stated that in normal hearing and SNHL participants both have larger air bone gap at 4kHz might be due to the presence of false air bone gap at high frequencies. Not only that, false air bone gap at 250Hz and above 2kHz were found by (Margolis et al., 2024).

Phenomenon of acoustic radiation

In any type of bone conductor, bone conduction thresholds will be measured from 250Hz to 4kHz (Rhebergen, 2023). According to (Matos et al., 2010a), bone conduction threshold will not be measured above 4kHz due to limitations in BC vibrator including higher effect of acoustic radiation.

BC threshold have not been measured above 6kHz because of the limitations in BC transducer output for both standard clinical BC used such as Radioear B71 and B81. According to the (Remenschneider et al., 2023) both bone conductor has excellent output level, low distortion and limited acoustic radiation between 250Hz and 4kHz. However, above 4kHz there is rapid increased in acoustic radiation that limit clinically the useful range of bone conduction testing. Mainly, one of the concerns regarding bone conduction thresholds is rapid increasing of the effect of acoustic radiation from the bone conductor at higher frequencies region.

Acoustic radiation is an unintended airborne sound energy produced by a bone conduction transducer including Radioear B81 and B71 bone conductor during audiological testing specifically at higher frequencies region. Although bone conduction was design to transmit the sounds vibrations to the skulls directly to the inner ear, but the bone conductor is also capable of radiating sound waves into the air. These sound waves can be detected by the outer ear and converted through air conduction pathway. This acoustic radiation produced by the bone conductor is a clinical concern when measuring bone-conduction thresholds. This emitted acoustic energy can travel through the air conduction medium and enter the external auditory canal (EAC), potentially creating a misleading response presented via the bone vibrator. As a result, the bone-conduction thresholds might appear artificially elevated, leading to false air-bone gaps, particularly at higher frequencies region. This can compromise the accuracy of the diagnosis associated with these audiometric findings. (Matos et al., 2010a)

In individuals with normal hearing, the acoustic radiation from a bone conductor is often perceived as more intense than the energy produced by the conductor itself. This can lead the thresholds that appear to better than expected, resulting in a false air-bone gap. The size of this air bone gap depends on the amount of acoustic radiation recorded. Particularly at high frequencies, acoustic radiation from the bone vibrator can stimulate air conduction by transmitting energy into the external auditory canal (EAC), a phenomenon extensively discussed by various researchers.

The purpose of this study is to investigate further the presence of the acoustic radiation produce by the bone conductor Radioear B81 at high frequencies specifically at 2kHz, 3kHz, 4kHz, 6kHz and 8kHz in which bone conduction threshold will be obtain through unoccluded and occluded ear canal among Malaysian young healthy adults.

1.2 Problem statement and Study rationale

BC testing is one of the most important clinical procedures used to determine types of hearing loss. However, it is quite challenging for audiologists to deal with acoustic radiation especially when testing BC in high frequencies area. A normal-hearing individual perceives the sound through the acoustic radiation of a bone vibrator as being subjectively louder than the actual energy emitted by the vibrator. When this phenomenon happens, the bone conduction measure will seem better than expected and artificial ABG will be recorded. According to the (Harkrider & Martin, 1998a), the ABG caused by the acoustic radiation is greater than 10dB at high frequencies in unoccluded ear canal situations.

The impact of acoustic radiation emitted by transducers used in bone conduction audiometry has been recognized for many years. A new bone conduction transducer, the Radioear B-81, has been designed to be an improvement over the commonly used transducer, which is the Radioear B-71 (Rao et al., 2020) . Radioear B81 is a universal component used during hearing testing in order to know the type of hearing loss. It has been reported that Radioear B81 vibrator has higher maximum output levels and lower distortion to be used in pure-tone audiometry (Zhang et al., 2022) and modification of Radioear B81 most likely improve the effect of acoustic radiation across all frequencies tested. Unfortunately, there is no recently published study done using BC Radioear B81 in estimating the effect of acoustic radiation using bone vibrator Radioear B81.

There are still arising questions on the ability of Radioear B81 functionality in detecting the acoustic radiation at high frequencies and additional research needs to be done to validate the improvement of Radioear B81 as well as to identify possible challenges and limitations of bone vibrator B81.

1.3 Research questions

I. Is there a difference of the bone conduction thresholds when testing using Radioear B81 bone conductor between unoccluded canal and occluded canal condition?

II. Is there a difference in the size of air-bone gap during the bone conduction testing using Radioear B81 bone conductor when the ear canal is unoccluded and occluded?

1.4 Research objectives

1.4.1 General objective

To determine the effect of acoustic radiation using Radioear B81 bone conductor in Pure Tone Audiometry (PTA)

1.4.2 Specific objectives

I. To determine the bone conduction threshold in unoccluded and occluded ear canal at high frequencies specifically at 2kHz, 3kHz, 4kHz, 6kHz and 8kHz in Pure Tone Audiometry.

II. To compare between bone conduction thresholds when testing using Radioear B81 bone conductor in two testing condition unoccluded and occluded ear canal at high frequencies specifically at 2kHz, 3kHz, 4kHz, 6kHz and 8kHz in Pure Tone Audiometry.

III. To compare the difference of air bone gap between unoccluded and occluded ear canal at high frequencies specifically at 2kHz, 3kHz, 4kHz, 6kHz and 8kHz in Pure Tone Audiometry.

1.5 Research Hypothesis

1.5.1 Hypothesis 1

Null hypothesis, H_0

There is no significant difference of bone conduction thresholds when testing using Radioear B81 bone conductor in unoccluded and occluded ear canal conditions.

Alternative hypothesis, H_1

There is a significant difference of bone conduction thresholds when testing using Radioear B81 bone conductor in unoccluded and occluded ear canal conditions.

1.5.2 Hypothesis 2

Null hypothesis, H_0

There is no significant difference in size of air bone gap between unoccluded and occluded ear canal at high frequencies specifically at 2kHz, 3kHz, 4kHz, 6kHz and 8kHz in Pure Tone Audiometry (PTA).

Alternative hypothesis, H_1

There is a significant difference in size of air bone gap between unoccluded and occluded ear canal at high frequencies specifically at 2kHz, 3kHz, 4kHz, 6kHz and 8kHz in Pure Tone Audiometry (PTA).

CHAPTER 2

LITERATURE REVIEW

2.1 Mechanism of bone conduction

This chapter focuses on previous study and review the relevant literature including bone conduction testing and assessing the effect of acoustic radiation.

The mechanism of bone conduction by which an individual is able to perceive sound by bone conduction (BC) have been studied for many decades and it involved three mechanism that are thought to be main contributor to the bone conduction hearing (Archer et al., 1952). Bone conduction mechanisms is including the process by which sound vibration are transmitted to the cochlea through the bones of the skull, without utilization of the outer and middle ear. There are three main mechanisms that contribute to bone conduction hearing: distortional, inertial, and osseotympanic mechanisms (Flood, 2016).

The compressional or distortional mechanism occurs when sound causes the skull to vibrate, the transducer placed on the mastoid area can induce vibration of soft tissues and these vibrations allow sound to be perceived even when the air conduction pathway is affected. The pressure waves are generated in the cochlear fluid by this vibration, exciting the basilar membrane and the auditory nerve endings. This is considered to be the primary mechanism of bone conduction, especially at higher frequencies.(Dauman, 2013)

The inertial mechanism involves motion of the ossicular chain (malleus, incus, and stapes). When the skull vibrates, the small bones momentarily lag due to inertia, so the stapes moves in and out of the oval window. This motion creates fluid waves in the cochlea identical to those created by air-conducted sound. The inertial response is more prevalent in lower frequency hearing and may get altered in cases of ossicular fixation, such as in otosclerosis. (Stenfelt & Goode, 2005)

The third contributor, the osseotympanic mechanism, is vibration of the external auditory canal. The ear canal walls also vibrate when the skull is vibrating. The vibration generates sound waves within the canal, which go on to the tympanic membrane and excite the middle ear in the same way as in air conduction. The mechanism is more pronounced when the ear canal is open and is reduced or eliminated when occluded (Geal-Dor et al., 2024) .

Together, these mechanisms enable bone-conducted sounds to still reach the inner ear and be perceived, which is why bone conduction testing is vital in differentiating between conductive and sensorineural hearing loss. Bone conduction is also why people perceive their own voice more intensely when the ears are blocked or why vibrations from a tuning fork placed on the skull can be heard in the absence of external sound waves.

2.2 Types of bone conductor

Bone conduction (BC) is a part of audiometric testing while doing hearing assessment. Instead of using AC only, BC also has mainly used in this field to complete the PTA testing. Conventional bone conduction is usually obtained with a BC transducer placed on the surface of the skin on the mastoid area. BC will be testing by presenting pure tone signal through bone vibrator (Ben Lutkevich, 2024). The sound will be transmitted through the mastoid bone of the skull instead of travelling in ear canal. The vibration of the mastoid bone of the skull excites the inner ear and cochlear directly bypass the outer and middle ear. Bone conduction transmission is much more effective contributor to auditory perception since the signal is transmitted directly to the inner ear through vibrations of the human skulls.

Radioear B81 had an improved electroacoustic performance compared to Radioear B71 (Jansson et al., 2015). The Radioear B81 is the new audiometric bone conductor that design with higher output level at low and high frequencies (RadioEar B-81 Bone Transducer, n.d.). Study from (Eichenauer et al., 2014) describes that Radioear 81 when compared to Radioear B71 has less distortion and capable of higher output level from 500Hz to 2000Hz but at more than 2kHz the Radioear B81 and B71 bone conductor produce same tactile thresholds at which the distortion compenonts become audible. Author mentioned that future researcher is needed to continue research on effect of bone conduction harmonic distrotion at higher frequencies. Figure 3 shows the physical comparison between Radioear B81 and B71.

Figure 3 Radioear B81 and B71 bone conductor