



Original Article

Enhancing the Sensitivity for Rinne Test through Tuning Fork Modifications

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OBJECTIVE: The Rinne test generally detects large air-bone gaps; this approach decreases the value of tuning forks as a screening tool. The purpose of this study was to evaluate the effectiveness of simple tuning fork modifications to increase the sensitivity of the Rinne test.

MATERIALS and METHODS: Two different modifications were performed with 128 and 256 Hz tuning forks. Fifteen healthy subjects with otolaryngology specialist training backgrounds were enrolled in the measurement of tuning fork, sound-intensity output at their bone conduction threshold.

RESULTS: The reductions in the threshold gap required for the Rinne test to turn from positive to negative for 128 Hz tuning forks were not statistically significant. The threshold gap was reduced by 3.85 ± 3.88 dB when 256 Hz tuning forks were modified through metal disk attachment ($p=0.001$).

CONCLUSION: The modified 256 Hz tuning forks effectively reduced the subjective loudness gap between the two ends of the tuning fork in the Rinne test. The modification theoretically increases the sensitivity of the Rinne test, which may increase the value of tuning forks as hearing loss screening tools.

KEY WORDS: Tuning forks, Rinne test, hearing impairment, hearing loss, hearing screen

INTRODUCTION

The tuning fork was invented in 1711 by British musician John Shore and originally served as a standard pitch instrument with later developments for medical uses. Otolaryngologists are familiar with the tuning fork because several distinct examinations were developed using tuning forks to detect hearing problems^[1-3]. The Bing and Schwabach tests are seldom used because of inadequate evidence of their clinical performance. The Weber and Rinne tests are still believed to be clinically valuable and are widely used in otolaryngology.

The Rinne test was designed under the rationale that air conduction should be greater than bone conduction, and the patient should be able to hear the tuning fork next to the pinna after they can no longer hear it when held against the mastoid. Although the sound is created by the same tuning fork in the same vibrating condition, the perceived loudness from the vibrating distal end of the fork through the ear drum is subjectively compared with the loudness received from the vibration of the tuning fork handle through contact with the mastoid process. Although the two sound sources are generated by the same fork, the sounds may not necessarily be comparable for detecting conductive hearing impairments. As a result of this major fundamental flaw, the Rinne test was reported to be unreliable^[4-8]. In addition to large variance in the results, the Rinne test is generally only useful for detecting large air-bone gaps, which decreases the value of tuning forks as a screening tool.

The purpose of this study was to decrease the threshold gap required for an abnormal Rinne test by performing tuning fork modifications. The modifications included shortening the tuning fork handle and adding an attachment at the tip of the handle.

MATERIALS and METHODS

Tuning Fork Modifications

Standard tuning forks of 256 Hz and 128 Hz were used in this study revise to: (CK901 & CK902; Spirit medical, Taipei, Taiwan). The length of the nonoscillating handle shaft was 5 cm. Two modifications were performed, including shortening the shaft to 2.5 cm and attaching a metal disk at the tip of the handle. The metal disks were composed of aluminium, with a diameter of 2 cm and a thickness of 2 mm (Figure 1).

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Intensity Decay Measurements for Tuning Forks

Because the major goal of the study was to reduce the perception differences or gaps between the two ends of the tuning fork, a decay test was designed to confirm that the effect did not result from faster loudness decay during the short period of transit from bone conduction to air conduction in the Rinne test. Vibrating sound from every tuning fork was recorded using a digital sound recorder (R-05, Roland, Japan). The tuning forks were placed 1 cm in front of the recorder microphone after they were struck with the fork axis perpendicular to the axis of the microphone and the centre of the distal end metal weight disk aligned with the centre of the microphone. The recorded sounds were analysed using Praat software (Paul Boersma and David Weenink, Institute of Phonetic Sciences, University of Amsterdam) to reveal the intensity decay over time for modified and unmodified tuning forks. The starting points for the 128 and 256 Hz tuning forks were 80 and 90 dB, respectively. The intensities were subsequently measured 5 and 10 seconds from the starting point. All the recordings were performed in triplicate, and the average values were calculated and compared.

Sound Measurements at the Bone Conduction Threshold

Fifteen healthy volunteers with otolaryngology specialist training backgrounds were enrolled in this study. Throughout the procedure, the subjects were asked to wear a headphone delivering a background noise (a narrow band noise centred around the tuning fork frequency) of 45 dB bilaterally in the testing anaechoic chamber (the background noise for the anaechoic chamber was 28-32 dB sound pressure level). Because Rinne tests are usually performed in common indoor conditions with background noise, such as examination rooms or classrooms, introducing background noise increased the relevance of the experiments. Because the background noise delivered by the sound-field speaker would be detected by the recording decibel meter, the background noise was introduced through headphones. Background noise also increased the level of the recorded sound. In an anaechoic chamber without any background noise disturbances, when the sound is no longer heard through bone conduction in the Rinne test, the level of the sound delivered by the vibrating fork end through the air is very low. In normal conditions, the level reaches the lower end of the dynamic range of the decibel meter (30-130 dB). By introducing background noise, the recorded sound would be arithmetically increased, which would cause the collected data to occur in a more accurate range of the decibel meter and increase the precision and reliability of the experiments.

The subjects were asked to self-perform the Rinne test. A vibrating tuning fork was placed initially on the mastoid process behind each ear until the sound was no longer heard. The fork was immediately placed 1 cm in front of a decibel meter (TENMARS TM-102, Taiwan), with the fork axis perpendicular to the axis of the decibel meter and the centre of the distal end metal weight disk aligned with the centre of the decibel meter receiver. The maximum measured intensities were recorded when the sound caused by the vibration was no longer heard by the tested subject. The tests were performed with every modified and unmodified tuning fork for each of the enrolled subjects, and the results were compared to determine whether the modifications reduced the subjective differences in sound perception delivered from the two ends of the tuning fork (bone and air conduction). For each condition, the tests were performed in tripli-

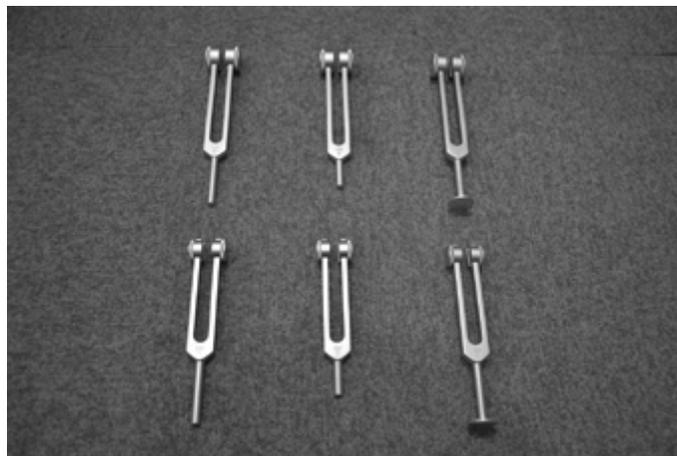


Figure 1. Tuning forks used in the study. Upper row 128 Hz; lower row 256 Hz. Left to right: original; shaft-shortening modifications; metal disk-attachment modifications

cate for each subject, and the averages of the measured values were used in the final analysis.

Statistical Analysis

Data from each group were compared using one-way analysis of variance (ANOVA). $p < 0.05$ was taken to indicate statistically significant differences.

RESULTS

Effects of Loudness Decay through Tuning Fork Modifications

The average decay values for the original, the shortening modification, and the attachment modification 128 Hz tuning forks were 2.53 ± 0.77 , 2.68 ± 0.65 , and 3.18 ± 0.28 dB at 5 seconds and 6.02 ± 0.12 , 5.82 ± 0.61 , and 6.24 ± 0.3 dB at 10 seconds, respectively. The average decay values for the original, the shortening modification, and the attachment modification 256 Hz tuning forks were 2.11 ± 0.6 , 2.57 ± 0.88 , and 2.43 ± 1.29 dB at 5 seconds and 3.99 ± 0.5 , 4.32 ± 1.4 , and 4.18 ± 1.72 dB at 10 seconds, respectively. There were no statistically significant differences between the modified and unmodified tuning forks for either frequency (Figure 2).

Decreasing the Threshold Gap Required for an Abnormal Rinne Test

The reductions in the maximum measured intensities recorded with the shortened and the metal disk-attached 128 Hz tuning forks when the sound caused by the vibration was no longer heard by the tested subject compared with the standard fork were -0.57 ± 4.16 and 1.42 ± 3.18 dB, respectively. The reductions were not statistically significant ($p = 0.87$ and 0.43 , respectively; Figure 3).

The shortened and metal disk-attached 256 Hz tuning forks exhibited reductions of the intensities of the sound (air conduction sound when the bone conduction sound was no longer heard), by 1.58 ± 1.95 and 3.85 ± 3.88 dB, respectively. The differences between the standard and the metal disk-attached forks were statistically significant ($p = 0.001$; Figure 4).

DISCUSSION

We have found that it is possible to reduce the sound output gap between the two ends of the tuning fork using simple modifications.

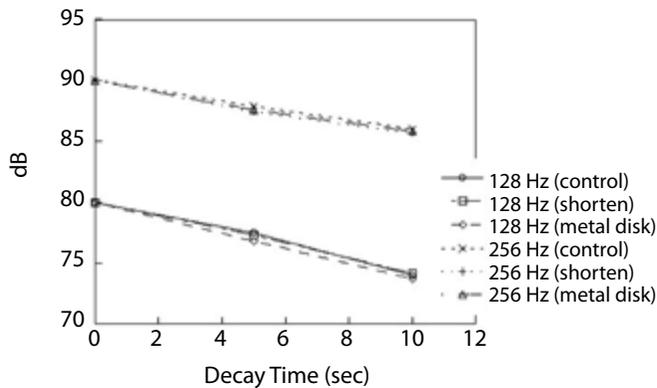


Figure 2. Effects of loudness decay through tuning fork modifications. There were no statistically significant differences between modified and unmodified tuning forks for either frequency

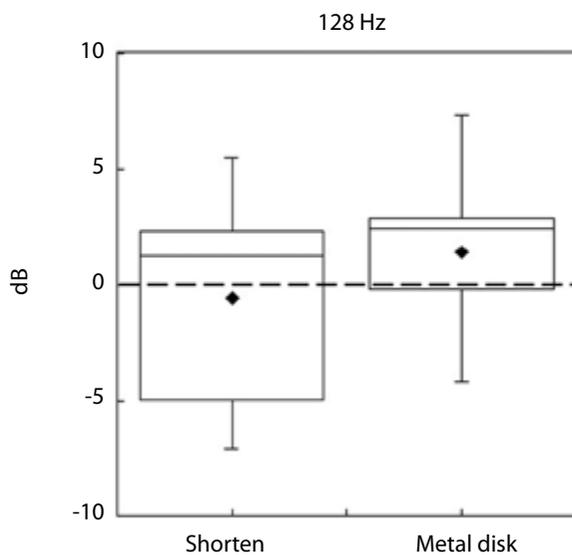


Figure 3. The reduction of the threshold gap required for an abnormal Rinne test through tuning fork modifications was not statistically significant for 128 Hz tuning forks ($p=0.87$ and 0.43)

The reduction of the sound output gap could theoretically increase the sensitivity of the Rinne test.

The Weber and the Rinne tests are typically performed together, and the results are combined to determine the location and nature of any hearing loss detected. There are not many technical problems with performing the Weber test because the tuning fork is placed in contact steadily throughout the entire examination. The tuning fork may be located in the middle of the forehead, above the upper lip and under the nose, or on top of the head equidistant from the ears. However, major technical flaws may be encountered when performing the Rinne test. The Rinne test is commonly performed by placing a vibrating tuning fork against the patient's mastoid bone and asking the patient to indicate when the sound is no longer heard. Immediately after the patient expresses that the sound can no longer be heard, the vibrating tuning fork is positioned 1-2 cm from the auditory canal, and the patient is asked to indicate whether the sound can be heard. In normal hearing individuals, air conduction should be greater than bone conduction. If

an individual is not able to hear the tuning fork after the mastoid test, the passage of sound waves from the ear canal through the middle ear apparatus and into the cochlea is likely inhibited, which is known as conductive hearing loss [5].

The Rinne test is limited by low sensitivity in detecting conductive hearing loss, a concern that has been addressed for decades with similar conclusions [5, 9-12]. Several studies have reported that the minimal air-bone threshold gap required for the Rinne test may vary from the normal to abnormal range, from 17 dB to 40 dB [4-8]. In a review article published by Bagai et al. [13] in 2006, the authors found that a normal Rinne test result may be less useful in dismissing hearing impairment. The authors concluded that the large variance in the results precluded using the Rinne test as an accurate screening tool.

The tuning fork does not appear to be an ideal hearing loss screening tool. Tuning forks may be more useful if improvements could be made specifically for the Rinne test, which would allow the remarkable advantages of tuning forks, such as low cost, low maintenance, and no tuning or calibration requirements to be utilised. The small size allows tuning forks to be carried and handled by primary care physicians or health workers in daily practices.

In this study, we have demonstrated that certain modifications reduce the minimal air-bone threshold gap required for the Rinne test to change from normal to abnormal, which potentially increases the sensitivity of the test during hearing screening. The threshold gap may also be reduced to increase the sensitivity of the Rinne test by using an ear plug or similar devices during the test. When an ear plug is used during the Rinne test, it increases the sound perception at the bone conduction phase because it attenuates the outside noise interference. In the air conduction phase, after the individual can no longer hear the sound, the ear plug increases the threshold required for the sound to be heard through the ear canal. The alternative protocol theoretically reduces the gap and could also potentially increase the sensitivity of the Rinne test. However, specially designed ear plugs or noise-reducing devices are needed because most of the commercially available ear plugs, including disposable foam ear-plugs, possess a noise attenuation of more than 20 dB [14-17]. An ideal noise attenuation for ear plugs for the Rinne test would be approximately 15 dB or less.

The most important limitation of this study is the inconsistent nature of the Rinne test, which originates from the various factors affecting sound conduction, from the tuning fork to the mastoid. Johnston et al. [12] performed a study determining the optimum force used in the Rinne test to achieve higher accuracy and reproducibility and found that the results varied with the force of applying the tuning fork to the mastoid process. During our examinations, the tested subjects needed to practise the test a few times to achieve consistent results, which reflects the variable nature of the Rinne test. The pressure with which the tuning fork was pressed against the skull was neither standardised nor measured because the data in this study were obtained by comparing different tuning forks used by the same individual. After several practice tests, the individuals became familiar with the procedure and subsequently adopted a maximum affordable pressure on the skull to perceive the weakest sound at the end point of the bone conduction phase of the Rinne test.

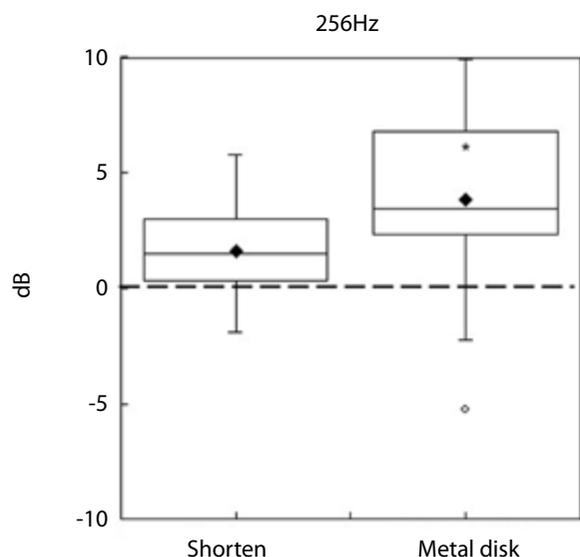


Figure 4. The threshold gap required for an abnormal Rinne test was significantly reduced by 3.85 ± 3.88 dB for metal disk-attached 256 Hz tuning forks (* $p=0.001$)

Another limitation of the test involves the headphones used to deliver the background noise. Background noise was administered because human hearing is sensitive, and the sound delivered from the distal end of the fork would be too weak to be recognised by the tested subject without background noise after the subject could no longer detect the vibrational sounds caused by the fork handle, even in the anaechoic chamber. Applying the background noise effectively increased this value. Because it was not possible to deliver a precisely consistent and uniform loud background sound through the speakers, headphones were used to deliver the sound. However, by putting on the headphones to test the tuning fork, the experimenters inevitably introduced the occlusion effect. The effect significantly increased the loudness of bone conduction and increased the length of time in which the tuning fork was heard on the mastoid. Nevertheless, we believe that this may not have changed the results, because in the study we were comparing various modifications of the tuning fork with each other.

More studies are needed because our tuning fork modifications only reduced the desired gap by several decibels. Nevertheless, we believe that tuning forks may still be useful tools for the detection of hearing loss.

In conclusion, the modified 256 Hz tuning forks effectively reduced the subjective loudness gap between the two ends of the tuning fork in the Rinne test. The modifications may theoretically increase the

sensitivity of the Rinne test, which may further increase the value of tuning forks as a hearing loss screening tool.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Taipei Medical University.

Peer-review: Externally peer-reviewed.

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Conflict of Interest: No conflict of interest was declared by the authors.

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