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Major Article

Evaluation of the microbial contamination of the audiological diagnostic equipment and their current disinfection techniques

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Key Words:

Audiology
Hospital disinfection procedures
Microbial flora**Background:** The study aims to investigate the microbial contamination of commonly used audiological diagnostic equipment and to evaluate the effectiveness of existing disinfection methods in audiological clinics.**Methods:** Hospitals with fully equipped audiology clinics in Istanbul were included in the study. Various audiological diagnostic devices and disinfection practices in hospitals were examined. A total of 60 swab samples were collected from the stimulus button on the audiometer, patient response switch, supra-aural headphone cushion, bone conduction headphone, and disinfected probe tips used in the Tympanometer and Auditory Brainstem Response.**Results:** Bacterial growth was observed on 40% of the analyzed plates, with 11.66% showing 2 different types of bacterial growth. Staphylococcaceae family were the most common bacteria identified. Other bacteria included *Pseudomonas putida*, *Pantoea* spp., *Micrococcus luteus*, *Corynebacterium* spp., and *Bacillus* spp. The highest bacterial growth occurred on the supra-aural headphone cushion and bone vibrator.**Conclusions:** The study highlights the presence of various bacteria on audiological diagnostic equipment, emphasizing *Staphylococcus* species as predominant. Current disinfection practices, particularly for supra-aural headphones and bone vibrators, were found to be inadequate, potentially posing risks for infections. The study suggests the need for disinfection protocols, particularly for frequently touched devices, to ensure patient safety in clinics.

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BACKGROUND

Audiology is a branch of science that identifies hearing, speech, and balance disorders and provides appropriate rehabilitation for patients. Various diagnostic tests, either used independently or in combination, are employed to assess and diagnose hearing loss. These tests often include pure tone audiometry (PTA),

tympanometry, otoacoustic emissions (OAE), and auditory brainstem response (ABR) evaluation.

Supra-aural headphones and bone vibrators placed on the mastoid are commonly used during PTA. Disposable/disinfectable probe tips placed tightly in the ear canal are also used during tympanometry, OAE, and ABR evaluations. Throughout these evaluations, supra-aural headphones are positioned closely to the auricle, bone vibrators to the mastoid, and probe tips within the ear canal. In addition, the PTA test is performed in a sound-isolated booth, and patients provide feedback to the audiologist by pressing a button to indicate whether they can hear the sounds presented through the supra-aural headphones. During the test, audiologists often use the sound presentation button on the audiometer and patients use the feedback button. They inevitably touch these buttons frequently with their hands/fingers during the procedure.

There is no systematic procedure for how often and with what chemicals to disinfect these commonly used devices during the PTA

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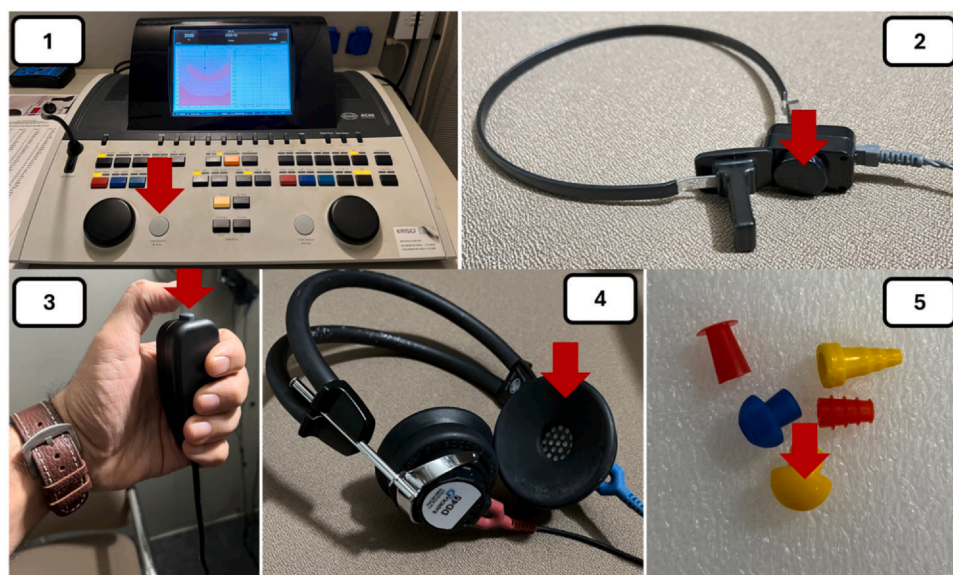
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1: Audiometer stimulus button, 2: Bone vibrator, 3: Patient response switch, 4: Headphone cushion, 5: Two types of probe tips

Fig. 1. Audiological equipment from which swab samples are collected.

assessment. In addition, it is a common problem that disposable silicone probe tips used in tympanometry, OAE, and ABR are disinfected and reused for economic reasons. This situation can create a favorable environment for the growth of microbiological pathogens.

Certain bacteria are known to be present in the healthy external ear canal. Some of these bacteria are *Staphylococcus*, *Alloioococcus*, *Turicella*, *Propionibacterium*, and *Coryneform*-derived bacteria.¹ Many other bacteria colonize the healthy ear canal and the normal flora is unique to each individual.² They can be transferred to other patients during hearing assessment via inadequately disinfected ear probe tips.³ On the other hand, a polymicrobial profile has been observed in 95% of earmolds placed in the ear canal. In addition, *coagulase-negative Staphylococci* and *diphtheria* were found to be the most common microbial isolates, but pathogenic bacteria and fungi were also detected on earmolds both before and after disinfection process.⁴ Moreover, it was found that wearing the occlusive device in the healthy external ear canal resulted in a 36.8% increase in organisms.⁵

The polymicrobial flora colonizing inadequately disinfected diagnostic tools, such as supra-aural headphones or probe tips, may lead to chronic otitis externa of the pinna and ear canal. These pathogens can cause various diseases, such as upper respiratory tract infections, through contact with the mouth or nose.⁶⁻⁸

The purpose of this study was to determine the presence and nature of the microbial contamination of audiological diagnostic equipment and the effectiveness of current disinfection methods.

METHODS

Hospitals and inclusion/exclusion criteria

The study group consists of 10 hospitals located on the Anatolian and European sides of Istanbul that have a fully equipped audiology clinic. Istanbul was selected as the study area due to its large population, exceeding 15 million, making it larger than many countries in the world. To ensure homogeneity, 4 university hospitals, 3 training and research hospitals, 2 private hospitals, and 1 state hospital were included in the study. In addition, it was also considered whether the socioeconomic status of the districts where the

hospitals are located was homogeneous. In addition to hospital type and location, hospitals that had Pure Tone Audiometer, Tympanometer, and ABR devices and performed these tests regularly every day were included in the study. Hospitals that did not have one of the mentioned diagnostic devices or did not use them regularly were not included in the study.

Sampling and transport

Audiology clinics on the Anatolian and European sides of Istanbul were visited by a researcher assigned to each region to save time and preserve microbiological samples. Samples were collected by the same person. A dry, sterile, and cotton-tipped swab was used for sample collection. Dry swabs were slightly moistened with a sterile saline solution (0.5% NaCl) before the swabbing. The area to be sampled for each material was determined visually. The entire area was swabbed in a zigzag pattern, rolling the swab over to ensure the entire swab is used. The samples were obtained from the “stimulus button” on the audiometer, the “patient response switch” in the sound booth, the supra-aural headphone cushion, the bone conduction headphone (bone vibrator), and the disinfected probe tips used in the Tympanometer and ABR tests (see Fig. 1). After swabbing, each swab was immediately placed in a transport swab-sterilized culture tube (True Line transport swab) and each specimen was labeled carefully. Thus, 6 different swabs were obtained from each audiology clinic and a total of 60 samples were collected from 10 hospitals. Specimen collection was completed, and the samples were delivered to Istanbul Medeniyet University Medical Faculty Microbiology Laboratory where the microbiological examination was performed within a 2-hour time frame.

Culturing technique

Samples were received and culturing began within 2 hours of the specimen being taken in the laboratory. Samples were inoculated to 5% sheep blood agar (bioMérieux), Eosin Methylene-blue Agar (bioMérieux), chocolate agar, and Sabouraud Dextrose Agar (bioMérieux). All agar plates were incubated at 35 °C in 5% CO₂ for 24 to 36 hours. The Petri dishes that showed no bacterial growth were

incubated under the same conditions for another 24 hours. After Gram staining of the bacteria was detected to grow in culture, their identification was performed using fully automated systems (VITEK2 and VITEK MS Compact, bioMérieux).

After incubation for 24 to 48 hours, the number of quadrants with bacterial growth were assessed. A result of “there is no growth” was recorded if no growth was observed on the plate; “light” was reported if growth was only observed in the first quadrant; “moderate” was reported if growth was observed on the first and second quadrants; and “heavy” was reported if growth was observed in the first, second, and third quadrants or all quadrants. All culture evaluations were performed by a microbiologist.

RESULTS

A total of 60 samples were collected, 6 samples from each of the audiology clinics at 10 different hospitals. Bacteria grew on 24 of the plates analyzed (40%). In addition, 2 different types of bacterial growth were observed on the same plate in 7 of 60 samples (11.66%). A total of 31 bacteria of 9 different species were identified in 24 cultures. No fungal growth was observed on any of the plates.

Among the 31 (83.8%) bacterial growths detected in audiological diagnostic instrument specimens, 26 (83.8%) were identified as belonging to the Staphylococcaceae family. Of these, 11 were identified as *Staphylococcus hominis* (42.3%), 9 as *S epidermidis* (34.6%), 3 as *S capitis* (11.5%), and 3 as *S auricularis* (11.5%). In addition to the Staphylococcaceae family, *Pseudomonas putida*, *Pantoea* spp, *Micrococcus luteus*, *Corynebacterium* spp, and *Bacillus* spp were also identified in 1 sample (3.84%). Only 1 bacterium (*Corynebacterium* spp) with a value greater than 100.000 cfu/mL was found in the study. This bacterium was found growing in a sample taken from the tip of a tympanometer probe. The types and amounts of bacteria detected are shown in Table 1.

When the distribution of bacteria was examined according to audiological diagnostic instruments, the highest bacterial growth was observed in cultures taken from the supra-aural headphone cushion (n = 11) and the bone vibrator used as a bone conduction headphone (n = 8). Three bacterial growths were observed in the audiometer stimulus button, patient response switch, tympanometer, and ABR probe tips. The numbers, types, and amounts of bacteria detected on audiological diagnostic instruments are shown in Table 1.

Table 1
The number, types, and quantities of bacteria detected on the audiological diagnostic tools

Number of swabs	Swabbed audiological tools	The number, types, and quantities of detected bacteria
10	Audiometer stimulus button	1 <i>Staphylococcus hominis</i> (light) 1 <i>Pantoea</i> spp (light)
10	Patient response switch	1 <i>Micrococcus luteus</i> (light) 2 <i>S hominis</i> (light) 1 <i>S epidermidis</i> (light)
10	Supra-aural headphone cushion	1 <i>S hominis</i> (heavy) + 1 <i>S epidermidis</i> (heavy) 1 <i>S hominis</i> (moderate) + 1 <i>S epidermidis</i> (moderate) 3 <i>S hominis</i> (light) 1 <i>S auricularis</i> (moderate) + 1 <i>S epidermidis</i> (moderate) 1 <i>S capitis</i> (moderate) + 1 <i>Bacillus</i> spp (light)
10	Bone conduction headphone/bone vibrator	1 <i>S hominis</i> (heavy) 1 <i>S hominis</i> (light) 1 <i>S epidermidis</i> (moderate) 4 <i>S epidermidis</i> (light) + 1 <i>S capitis</i> (light)
10	Tympanometer probe tips	1 <i>S hominis</i> (light) + 1 <i>S auricularis</i> (light) 1 <i>Corynebacterium</i> spp (heavy)
10	ABR probe tips	1 <i>S auricularis</i> (heavy) + 1 <i>S capitis</i> (moderate) 1 <i>Pseudomonas putida</i> (light)

ABR, auditory brainstem response.

The study also examined the disinfectants used by the hospitals, whether there was a staff member dedicated to disinfection, and whether the hospital had a routine disinfection procedure. While 7 out of 10 hospitals (70%) reported using liquid disinfectants at the manufacturer-recommended use-dilution, 2 hospitals (20%) reported using the foam form and 1 hospital (10%) reported using the powder form diluted at the manufacturer-recommended use-dilution. All hospitals reported disinfecting the probe tips used for tympanometry and ABR on a daily basis. However, no specific routine procedure was reported for the supra-aural headphones, bone vibrator, patient response switch, and audiometer stimulus button. Four hospitals (40%) reported disinfection on every working day of the week. One hospital (10%) reported disinfection on 3 days of the week, 2 hospitals (20%) reported disinfection on 2 days of the week, and 1 hospital (10%) reported disinfection on 1 day of the week. Regrettably, 2 hospitals (20%) reported that they only disinfect probe tips and do not regularly disinfect other equipment, such as headphone cushions. Furthermore, 3 out of 10 clinics (30%) have a cleaning staff assigned by the hospital to disinfect audiological equipment and probe tips, while 3 clinics have audiologists assigned by the clinic manager to perform these tasks. Four clinics (40%) lacked any assigned personnel for the disinfection process (see Table 2).

DISCUSSION

In this study, *S hominis* was the most frequently recovered bacterium. Typically, parts of skin flora, this bacterium can cause infections, particularly in immunocompromised or postsurgery patients.⁹ Infections such as skin and urinary tract infections are common, and while treatable, caution is advised, especially for hospitalized patients.^{10–12} Similarly, *S epidermidis*, another significant bacterium found in our study, is part of normal skin flora but can cause skin infections, sepsis, and implant-related infections.^{13–16}

Additional Staphylococcal species, *S capitis* and *S auricularis*, are also opportunistic pathogens that can cause skin and bloodstream infections, particularly in individuals with conditions like diabetes or a weakened immune system.^{10,17,18} Notably, infections from these bacteria are more resistant in hospital settings, especially in intensive care units. Recognition of their potential risks is essential in such contexts.¹⁸

Another key bacterium, *Corynebacterium* spp, part of the normal skin and respiratory flora, can become pathogenic in immunocompromised

Table 2
General information about disinfectants used in hospitals, disinfection staff, and routine disinfection procedure

Hospital	Disinfectant	Chemical content	Disinfectant form	Assigned personnel	Routine procedure for probe tips	Routine procedure for audiologic equipment*
University hospital	Derm	60% Ethyl alcohol, 10% isopropyl alcohol	Liquid	Yes, a cleaning staff	5 days a week	3 days in a week
University hospital	Derhand Plus	70% Ethyl alcohol, 5% isopropyl alcohol, 0.1% benzalkonium chloride, glycerin, and deionized water	Liquid	No	5 days a week	No
University hospital	Detro Activ	Peracetic acid, enzymes (amylase, lipase, and protease) formed as a result of the reaction of disodium carbonate and TAED (tetraacetylenediamine) with water	Powder	Yes, a cleaning staff	5 days a week	1 day in a week
University hospital	Konix	12.5% Ethanol, 65% propan-2-ol	Liquid	Yes, a cleaning staff	5 days a week	5 days a week
TRH	Incidin OxyFoam S	Hydrogen peroxide, glycolic acid	Liquid, foam	Yes, an audiologist	5 days a week	5 days a week
TRH	Aniosyme x3	Quaternary ammonium propionate, chlorhexidine digluconate, nonionic surfactant, enzyme complex (protease, lipase and amylase), and excipients	Liquid	No	5 days a week	5 days a week
TRH	Derm	60% Ethyl alcohol, 10% isopropyl alcohol	Liquid	No	5 days a week	2 days a week
Private hospital	Incidin OxyFoam S	Hydrogen peroxide, glycolic acid	Liquid, foam	Yes, an audiologist	5 days a week	2 days a week
Private hospital	Hydrogen peroxide	Hydrogen peroxide	Liquid	Yes, only for probe tips	5 days a week	No
State hospital	Detro Enzym	Enzymes (amylase, protease, lipase, and cellulase), glycol, nonionic surfactants, quaternary ammonium compounds, and anticorrosive substances	Liquid	Yes, 2 audiologists	5 days a week	5 days a week

TRH, training and research hospital.

* Audiologic equipment: supra-aural headphone, bone vibrator, patient response switch, and audiometer stimulus button.

individuals.¹⁹ Detected in significant numbers on tympanometry probe tips in this study (a count of 100 000 cfu/mL), *Corynebacterium* spp poses a particular risk in audiology settings. Given its opportunistic characteristics, we recommend single-use or disinfection of probe tips with hydrogen peroxide instead of powder disinfectant for effective prevention.

M luteus and *Pantoea* spp, found in each sample, pose low risk due to minimal presence and are typically nonpathogenic except in immunocompromised individuals. Additionally, *P putida*, common in soil and water environments, was detected at low levels. It rarely causes infections but should be monitored, especially in settings where patients have weakened immune systems. Similarly, *Bacillus* spp was only identified in a single sample and thus not considered a significant threat in this context.

In the 1984 study by Brook and Coolbaugh, participants wore rubber hoods for 25 to 30 minutes and then a sample was taken from the ear canal, which remained occluded during that time. Even with this brief occlusion, the researchers observed an increase in bacterial flora in 37% of the participants. The predominant bacteria in the study were *S epidermidis*, which was found in 70% of the samples. In addition, *Propionibacterium acnes* (24%) and *alpha hemolytic Streptococci* (18%) are other commonly observed bacterial species. In our study, the PTA test performed with the supra-aural headphone takes approximately 20 to 30 minutes and is occluded by ear cushions during this time. In our study, *S epidermidis* (29%) followed by *S hominis* (35%) was the most common bacterial species found on the headphone cushions, similar to the study by Brook and Coolbaugh. Nevertheless, during tympanometry and ABR testing, the ear is blocked by the probe tips for a much shorter time than during PTA. Therefore, *S epidermidis* may not have been among the bacteria recovered from ABR and tympanometry probe tips in our study. Surprisingly, *S epidermidis* was found at low levels.⁵

Cerumen microbiology studies have identified *S epidermidis* and *Corynebacterium* spp as prevalent species.³ In this study, *S epidermidis* was frequently detected on bone vibrators and headphone cushions, rather than on probe tips that are routinely disinfected. This discrepancy likely results from inconsistent disinfection practices across different devices. Equipment like headphones and bone vibrators often lack a standardized cleaning protocol, leading to higher bacterial loads.

In a study conducted by Sjövall and colleagues, the most prevalent bacterial species identified in the external ear canal of individuals with no apparent ear pathology were *S auricularis*, *Alloicoccus otitis*, *P acnes*, and *Turicella otitidis*. In our study, we identified *S auricularis* as a common bacterial species, consistent with the findings of Sjövall et al.² On the other hand, the bacterial species *S hominis*, *Corynebacterium* spp, *S capitis*, and *P putida* were found in addition to *S auricularis* in disinfected probe tips placed tightly in the ear canal. This difference may be due to individual ear cleaning habits or hospital disinfection methods.² Another comprehensive study published in 2001 found that *S hominis* and *Corynebacterium* spp species can be detected at low densities in the healthy external ear canal and cerumen.¹

A study by Ahmad et al (2006) on hearing aid users found microbial presence in 95% of earmolds, likely due to prolonged ear canal contact.⁴ Our study showed a lower bacterial growth rate (40%) on audiological devices, perhaps due to shorter contact times and consistent cleaning practices. Furthermore, fungal species, including *Candida*, were identified in earmolds. However, the specific fungal species present in the audiological equipment were not the focus of our investigation, and therefore, a direct comparison cannot be made.

Our study also examined the type of disinfectant, form of disinfectant, and disinfection procedures preferred by clinics. For instance, while no bacterial growth was observed in clinics utilizing hydrogen peroxide for the disinfection of tympanometry and ABR

probe tips, it was noted that the disinfectant, prepared by the dilution of a powder mixture comprising peracetic acid and enzymes, exhibited limited efficacy in the disinfection of the probe tip. However, this may be due to the way the cleaning staff dilute and use the product rather than the type of disinfectant. Disinfecting of the headphone cushion, patient response switch, and audiometer stimulus button was related to the frequency of disinfection rather than the disinfectant used. While clinics that disinfected these devices 5 working days per week had minimal bacterial rates, the highest bacterial rate (on all devices) was found in a clinic that disinfected only 1 day per week. In addition, it was observed that these clinics also had staff, consisting of an audiologist or cleaning staff, involved in the disinfection process. Although clinics generally emphasize the importance of frequent disinfection of probe tips, it was noted that a standard disinfection protocol for equipment such as bone vibrators, patient response switches, and headphones was lacking. As a result, the highest bacterial growth was found in swab samples taken from the headphone cushion and bone vibrator. Disposable pillow covers designed for the headphone cushions can be used. In addition, the audiometer buttons, patient response switch, headphones, and bone vibrator should be disinfected daily with liquid disinfectants, and designated personnel should be responsible for the daily disinfection procedure.

The study's inclusion of hospitals across regions with diverse socioeconomic backgrounds contributes to its representativeness. However, limitations include the small sample size and lack of vestibular and voice assessment tools in the analysis. Additionally, since fungi were not part of our study, incubation times were shorter. It would be beneficial for future studies to aim for larger samples across more hospitals to strengthen findings and enhance the comprehensiveness of the results.

CONCLUSIONS

Swab samples were collected from devices commonly used in audiology clinics and tested for microbial growth. Bacterial growth was observed in all sampled devices, but supra-aural headphone cushions and bone vibrators showed the most intense growth. Nine species of bacteria were found in the sampled devices. The most common bacterial genus was *Staphylococcus*, with *S. hominis* as the predominant bacterium. Audiology clinics typically use liquid disinfectants to treat probe tips used for tympanometry and ABR

testing on a daily basis, but they have not yet established a regular disinfection protocol for headphones, bone vibrators, audiometer buttons, and patient response switches.

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