Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 18 No. 4 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijim.v18i04.45063

PAPER

Mobile Applications in Otology: A Scoping Review

Laurence Troy S. Valdez[1], Rentor Y. Cafino[2], Armando T. Isla Jr.[3], Eigen John T. Ignacio[1](✉), Patrick John Labra[4], Lemuel Clark P. Velasco[1,5]

[1]Mindanao State University-Iligan Institute of Technology, Iligan City, The Philippines

[2]Zamboanga City Medical Center, Zamboanga City, The Philippines

[3]Mercy Community Hospital, Iligan City, The Philippines

[4]Corazon Locsin Montelibano Memorial Regional Hospital, Bacolod City, The Philippines

[5]Premiere Research Institute of Science and Mathematics – Center for Computational Analytics and Modelling, Iligan City, The Philippines

eigenjohn.ignacio@g.msuiit.edu.ph

ABSTRACT

This scoping review aims to comprehensively synthesize current research on the use of mobile applications in otology, identify research gaps, and assess the feasibility of mobile-based applications in this field. The aim is to support and direct future research studies on harnessing the potential of mobile technology in otology. Following the PRISMA-ScR guidelines, a literature profiling approach was adopted using the Google Scholar search engine from September 2022 to January 2023. Only articles published in English between 2012 and 2023 were included, resulting in a final sample size of 32 papers. The results revealed an increasing focus on the remote delivery of healthcare, with the majority of the articles originating from the United States and authored by medical doctors. Two main categories were identified within the 32 selected journals: audiology and smartphone otoscopy. A total of 124 mobile applications were identified in these journals, with 48 applications for hearing tests and 27 applications for smartphone otoscopes being the most commonly utilized. Mobile applications have the potential to serve as valuable tools in the field of otology, especially in the context of smartphone hearing tests and smartphone-enabled otoscopes. However, further research is needed to assess their effectiveness, accuracy, and appropriate usage.

KEYWORDS

mobile application, medical education app, smartphone, hearing testing, otoscope

1 BACKGROUND OF THE STUDY

Otolaryngology is a medical specialty that focuses on the diagnosis and treatment of diseases of the ears, nose, and throat, specifically within the anatomic region of the head and neck. It is a diverse field that encompasses a wide range of conditions and diseases [1], [2]. Within this field, otology is a subspecialty that specifically focuses on the anatomy, physiology, and pathology of the ears. Otology utilizes a variety of medical tools to diagnose and evaluate ear conditions, with the most common ones including otoscopes, audiometers, and tympanometers. Otoscopy is a medical procedure that involves visualizing the ear using a handheld tool called an otoscope [3–6]. This tool enables the specialist to identify potential problems within the ear and detect any existing issues [7], [8]. An audiometer is a device used to measure the

Valdez, L.T.S., Cafino, R.Y., Isla Jr., A.T., Ignacio, E.J.T., Labra, P.J., Velasco, L.C.P. (2024). Mobile Applications in Otology: A Scoping Review. *International Journal of Interactive Mobile Technologies (iJIM)*, 18(4), pp. 124–144. https://doi.org/10.3991/ijim.v18i04.45063

Article submitted 2023-09-17. Revision uploaded 2023-11-23. Final acceptance 2023-12-05.

intensity of sound at different frequencies, while a tympanometer is used to assess the movement of the eardrum in response to changes in air pressure [9–11]. By utilizing these medical tools, otologists can conduct a comprehensive assessment of diseased ears to accurately diagnose and treat them [12].

Over the past few years, there have been a growing number of smartphone applications, or mobile applications, developed for the field of otology [18–20]. Examples of such applications include mobile hearing tests and smartphone-enabled otoscopes. These smartphone applications empower patients and clinicians to conduct remote consultations, follow-ups, simulation training, virtual teaching, and more [13], [14], [18–31]. Thus, access to medical care can be expanded for patients who lack access to healthcare due to geographic or logistical challenges [10], [25–27], [32–34].

The implementation of modern technology in healthcare is a complex process that involves a wide variety of factors [13], [15]. The use of mobile applications, such as OtoCare, Otoscope, hearing tests, and hearing assistants, represents just a few examples of mobile applications utilized in the field of otology [10], [18], [24], [29]. Some concerns and challenges that may arise when using mobile applications in otology include data security, privacy, interoperability, user experience, and the most effective method of integrating the mobile application into the otologist's existing workflow and processes [15–18]. The use of mobile applications for patient education, engagement, illness management, and telemedicine is an emerging trend in the field [25–27], [33], [34]. Furthermore, emerging technologies such as augmented reality, virtual reality, and artificial intelligence have the potential to revolutionize the way otologists communicate with and treat their patients [16], [35]. Furthermore, there is a lack of consistency in the research that provides a comprehensive synthesis of the extent to which mobile applications are being used in otology.

The main objective of this study is to conduct a comprehensive review of the use of mobile applications in otology. This review aims to synthesize the existing literature on mobile applications in otology, explore the potential for mobile-based applications in otology, and identify research gaps to guide future studies.

2 METHODOLOGY

2.1 Literature profiling

This review followed the 2018 Preferred Reporting Items for Systematic Reviews and Meta-Analysis—Scoping Review (PRISMA-ScR) guidelines [36–39], as illustrated in Figure 1. The authors employed a comprehensive search strategy using the Google Scholar search engine in January 2023, which yielded approximately 26,200 results. The keywords used were related to the following topics: "Mobile Applications," "Smartphone," "Otology," "Telemedicine," "Otolaryngology," "Hearing Rehabilitation," and "Smartphone Otoscope." The search was further refined by limiting the results to articles published in English within the past eleven years (2012–2023) to ensure that the most current and relevant research was included. The total number of publications was further reduced to 4,800 by focusing solely on reviewed articles. Subsequently, 132 articles were stored in a literature bank created in Google Drive after ensuring that the search phrase matched either the target article's title, abstract, or keywords. To create a comprehensive directory of qualified articles, a journal assessment matrix in the form of a spreadsheet was utilized as a tool to analyze the journals by profiling their title, year, authors, hypotheses, problem statements, objectives, methodologies, results, and the merits of the researchers for each journal [40]. The relevance of each article to the study's goals was taken into consideration when selecting the sixty papers, which were later categorized based on their themes. Furthermore, the sample size was reduced to thirty-two journal articles after confirming that each paper should be indexed in Scopus journals, Web of Science (WoS), and SCImago.

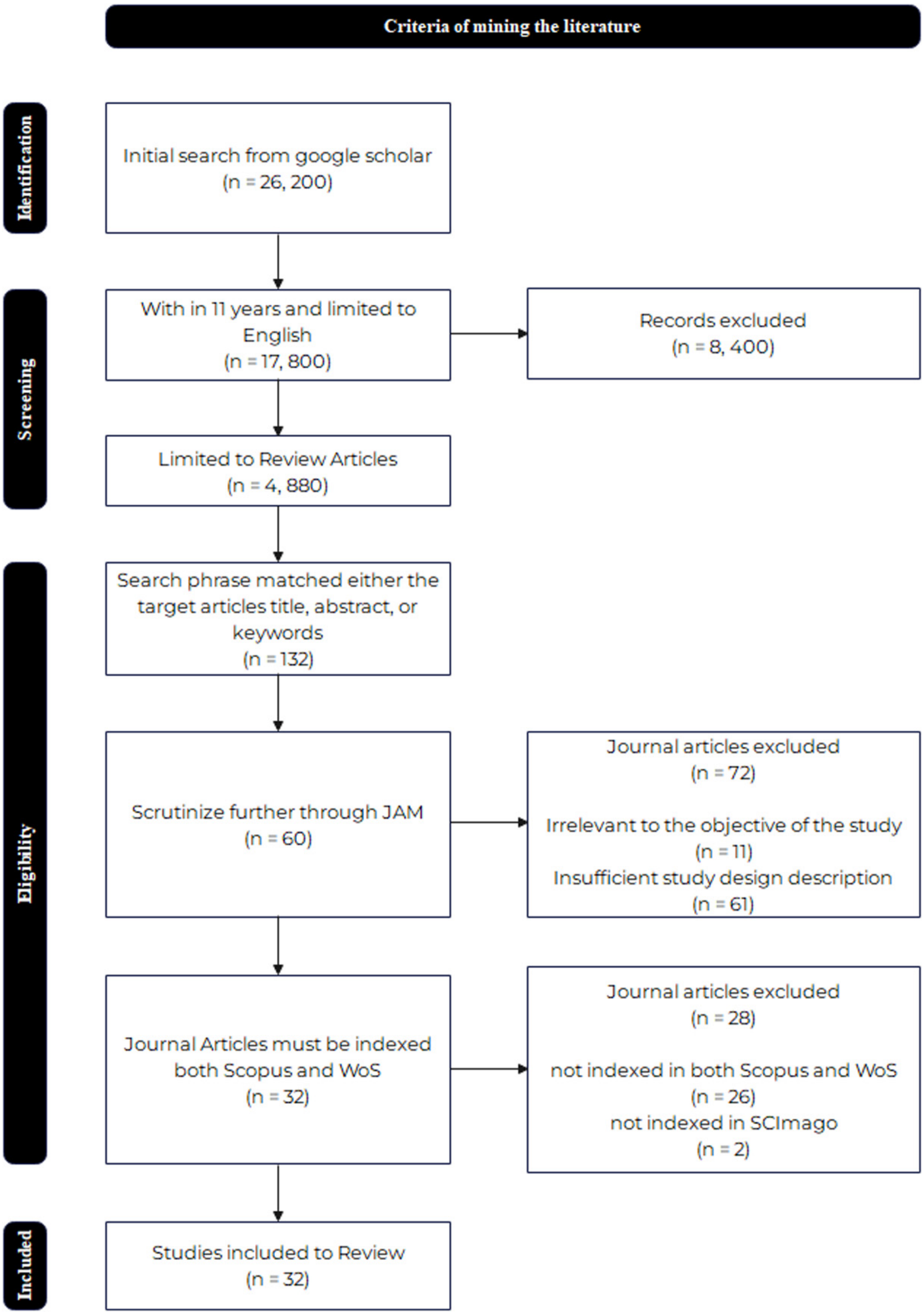

Fig. 1. PRISMA flow diagram as applied in the study

After conducting a comprehensive review and synthesis of the literature samples, the next step is to profile these studies in order to create an overview of their research background. To enhance the study's credibility, the researcher analyzed factors such as the publication year of the literature, the country where the study was conducted, the research methods used, the background of the authors, and the journal of publication. To further verify the credibility of the journals, the authors used the SCImago Journal Rank in addition to the Web of Science and Scopus databases, which provided additional information regarding the journals' subject areas and categories.

The search strategy did not include a search for gray literature on the subject. This search was also limited to Google Scholar electronic search only.

2.2 Scoping synthesis

To gain a deeper understanding of the role of mobile applications in otology, the authors conducted a scoping review analysis of 32 journal articles. The researcher utilized the content, context, and process (CCP) framework, as depicted in Figure 2, to analyze the literature, providing a comprehensive approach to understanding the scope of mobile applications in otology [41–43]. This framework was originally utilized in organizational strategy to assess internal and external environmental factors in IS research, and it was modified to specifically consider the scope of mobile applications in otology [43]. By extracting key concepts from the literature and putting them into practice, the researcher was able to identify the specific techniques and materials used in this area and comprehend the factors that lead to change. The utilization of the CCP framework enabled a comprehensive and systematic analysis of the literature, providing valuable insights for future research.

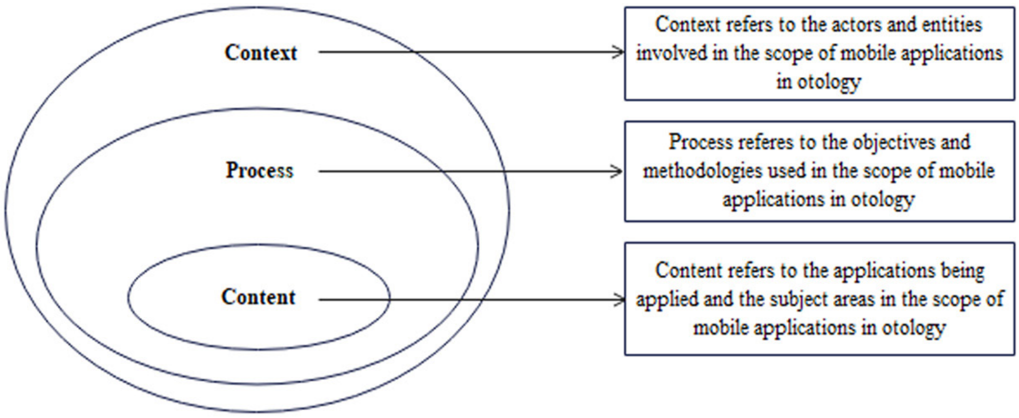

Fig. 2. Context-content-process [41–43]

This study conducted a comprehensive evaluation of 32 journal articles on mobile applications in the field of otology using a qualitative coding process. The analysis focused on the context (involving who and why) of these applications, which pertains to the individuals and entities involved in the workflow of using these mobile applications. Key variables in this study were identified from relevant journal articles and sources. The process of using mobile applications in otology, including the goals and methodologies outlined in the journal articles, was also evaluated. The content of the applications was analyzed, referring to the scope of study where these applications are being applied and the relevant subject areas [41–43]. A thematic analysis procedure was utilized during the qualitative coding process to reveal key variables and subject areas in the content of these mobile applications.

The key variable identified using the context-content-process framework of analysis, along with other variables identified through thematic analysis, and were tabulated in an electronic spreadsheet.

2.3 Research gap analysis

In this section, we present the method for conducting a comprehensive research gap analysis of mobile applications in otology. The purpose of this analysis is to present the most common findings from existing studies and to provide recommendations for future researchers. To accomplish this, the researcher initially conducted a scoping review to outline the context-content-process framework in the field of mobile applications in otology [41–43]. Subsequently, the conclusion and recommendation sections of all thirty-two journal articles were analyzed to identify common findings and suggestions. To record and synthesize the information, a tally sheet was used. To overcome the limitations and deficiencies in the existing literature, an inductive coding approach was utilized to identify common recommendations for future research topics. Additionally, a mind mapping technique was utilized to categorize the common limitations and recommendations from the 32 journal articles and to illustrate common conclusions. Through a comprehensive review of existing studies, the researchers synthesized the most common recommendations for future research, which were organized using mind mapping.

3 RESULTS AND DISCUSSION

3.1 Literature profiling results

The sample articles were analyzed to demonstrate the annual publication trends, the country of the research setting, authorship, and journal of publication background [40]. Figure 3 illustrates a significant increase in published articles between 2020 and 2021, which may reflect the growing importance of implementing healthcare from a distance, especially for high-risk patient groups, due to the COVID-19 pandemic. This further emphasizes the importance of mobile applications in otology for addressing the healthcare challenges brought about by the pandemic.

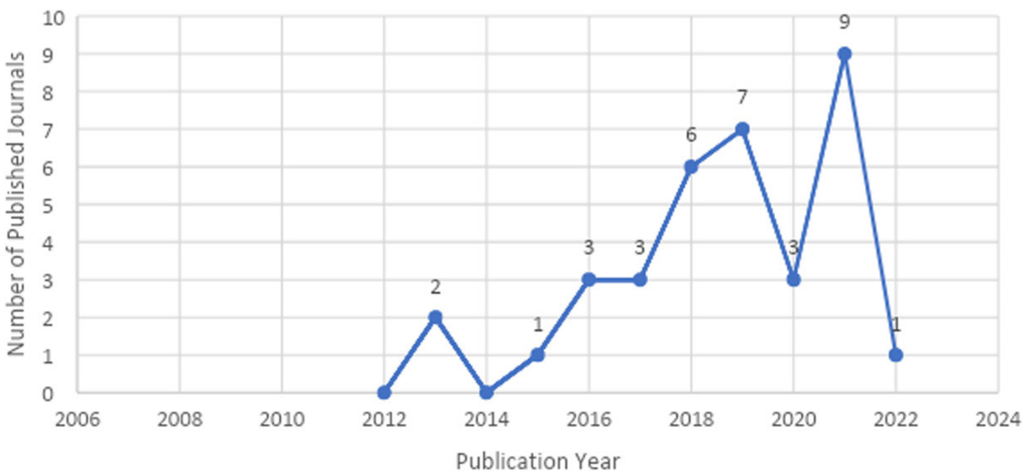

Fig. 3. Studies published year

In Figure 4, the distribution of articles per country is shown. The United States has the highest frequency among the thirty-two studies, with eighteen studies (56.3%) [2], [19–24], [26], [28], [31], [33], [44–50]. Following that, the United Kingdom has three studies (9.4%) [34], [51], [52], and both India and Denmark have two studies each (6.3%) [11], [40], [53], [54]. Other countries collectively have seven studies, making up 21.9% [10], [18], [55–59]. The "other countries" category includes only one publication from each of the following countries: Italy, Israel, Turkey, Finland, Switzerland, Canada, and South Africa.

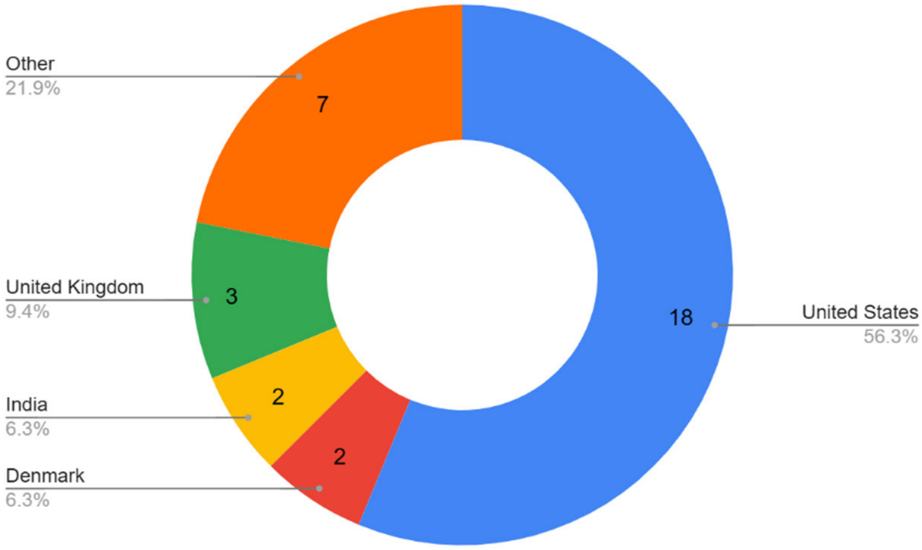

Fig. 4. Overview of the sample literature per country

Note: Other countries only have one publication. They are Italy, Israel, Turkey, Finland, Switzerland, Canada, and South Africa.

Figure 5 shows the sample size of the literature contributed by 163 authors from 15 different countries. Among these authors, 93 were from the United States [2], [19–24], [26], [28], [31], [33], [44–50], 13 were from the United Kingdom [34], [51], [52], [54], 10 were from India [11], [53], eight were from Israel [55], and seven were from Denmark [40], [54], while the remaining authors originated from other countries [10], [18], [26], [48], [54], [56–59].

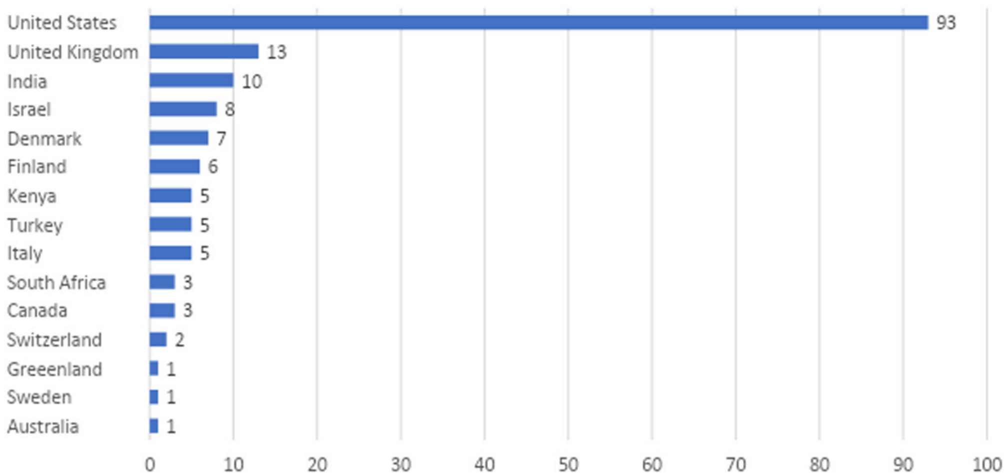

Fig. 5. Authors' geographic location

Most of the authors in the field are Medical Doctors (MDs) [18], [20–22], [24], [31], [33], [40], [44–46], [55], [58], followed by Doctor of Philosophy (PhDs) [19], [20], [31], [46], [59], Doctor of Medicine and of Philosophy (MD, PhD) [20], [24], [40], [56], [59], and those with Bachelor of Science (BSs) degrees [21], [28], [33] (see Figure 6). Authors from the United States have the highest number of degrees, while authors from other countries have fewer degrees.

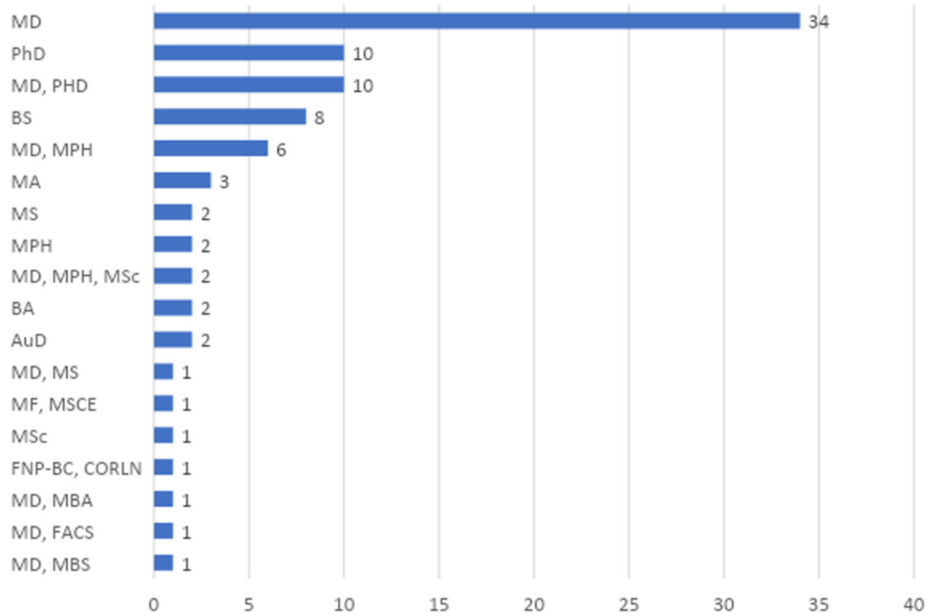

Fig. 6. Authors' medical background

In addition to author profiling, the sample literature was also categorized based on the journal of publication. The results of this activity showed that six out of the 32 articles were published in the *Annals of Otology, Rhinology, and Laryngology* [18], [22], [24], [31], [40], [55], and the *International Journal of Pediatric Otorhinolaryngology* [2], [26], [47], [48], [54], [59]. The primary subject area covered in these journals is medicine [2], [10], [11], [18–24], [26], [28], [31], [33], [34], [40], [44–56], [58], [59], and the main category is otorhinolaryngology [2], [10], [11], [18], [22–24], [26], [28], [31], [33], [34], [40], [45–55], [59], as depicted in Figure 7.

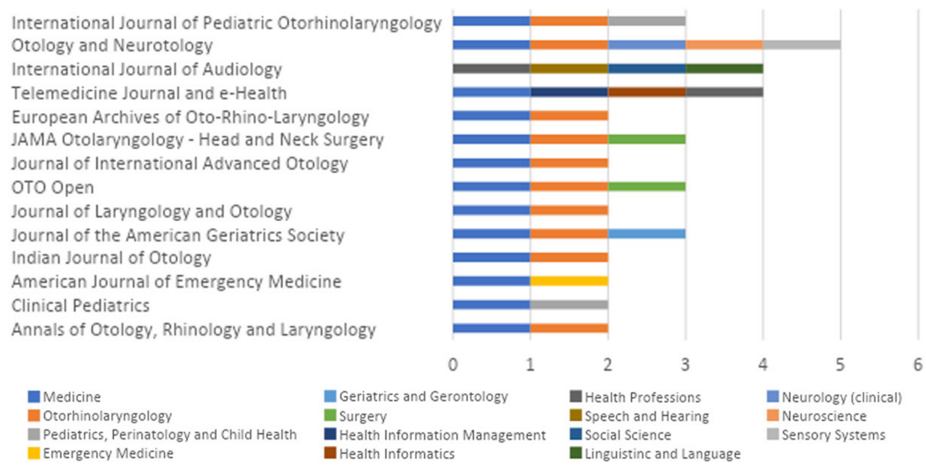

Fig. 7. Subject areas of the journals

3.2 Scoping synthesis results

To gain a comprehensive understanding of the context, content, and process of mobile applications in otology, the researcher conducted a systematic literature review to extract key concepts from 32 journal articles. These concepts will be analyzed using qualitative coding techniques, including inductive coding and thematic analysis. The aim of this analysis is to develop a more profound understanding of the nature of these applications and their role within the field of otology, which will guide future research and implementation efforts in the domain.

The sample size for this study consisted of 32 journal articles related to mobile applications in otology. Out of these articles, 18 specifically focused on smartphone otoscopes [2], [19–21], [26], [31], [33], [40], [44], [45], [47], [48], [50–53], [56], [58]. 14 studies were found within the field of audiology [10], [11], [18], [23], [24], [26], [28], [45], [46], [48], [49], [52], [55], [57], as shown in Figure 8.

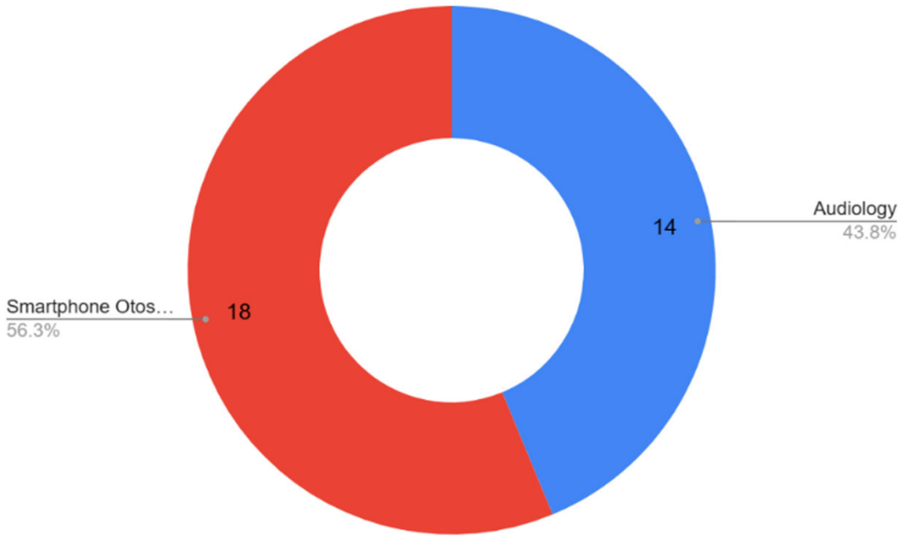

Fig. 8. Mobile applications used in the sample size

In this study, a total of 124 mobile applications were identified from 32 literature articles within the field of otology, as depicted in Figure 9. The most widely used applications were hearing tests, with 48 applications found in seven literature articles [10], [11], [18], [23], [28], [49], and [52]. Smartphone otoscopes with 27 applications have been discussed in 18 literature articles [2], [19–21], [26], [31], [33], [40], [44], [45], [47], [48], [50–52], [54], [56], [58]. Followed by hearing checks, 11 applications were found in three literature articles [23], [28], [52]. Followed by hearing aid and tinnitus applications, seven applications were found in three literature articles [18], [28], [57], and two articles [18], [57]. Followed by a hearing screening using six assessment tools identified in a single literature article [28]. Five audiometer tests were conducted, as described in a single literature article [28]. Followed by reviewing four applications mentioned in two literature articles [18], [28]. After learning applications, a single literature article [28], [49] presented three applications. Similarly, one literature article [22] featured three applications related to audiograms. Followed by the development of applications, as described in two articles [24] and [46] in the literature. Followed by hearing therapy, with one application found in a single literature article [28]. These findings demonstrate the wide range of available applications in the field of otology, with the majority of usage concentrated on hearing tests and smartphone otoscopes. This information sheds light on the current landscape of mobile applications in otology and provides valuable insights for future researchers and implementation efforts in this field.

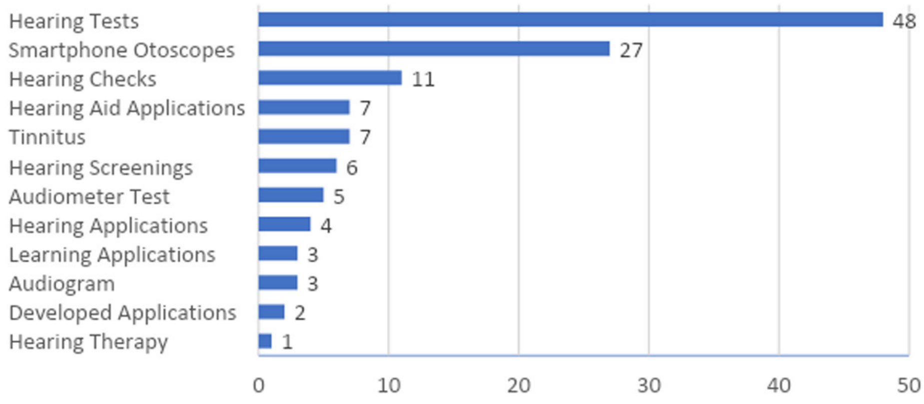

Fig. 9. Breakdown of the mobile applications used in the sample size

Mobile applications in context of otology. This section of the CCP framework focuses on examining the context of mobile applications in otology, their user audience, and their usage. As illustrated in Figure 10, the analysis of 32 journal articles in the study indicates that the primary users of these applications are healthcare professionals, with twenty-eight articles identifying this audience [2], [10], [19–22], [26], [44], [45], [48], [50], [51], [53], [54], [58]. Figure 11 provides a breakdown of the representation of the target audience in the sample literature. The next largest group consists of researchers, with 12 studies including this audience in their literature articles. The authors noted that if the literature does not specify the user of the mobile application, it will automatically be counted as a researcher [11], [18], [20], [23], [28], [33], [40], [46], [49], [52], [55], [57]. Followed by the parents of the patient, five references were found in five literature articles [2], [20], [31], [47], [56]. Four literature articles [24], [28], [46], and [57] identified four distinct audience segments for developers to target. Finally, a patient with a specific condition was found in a single literature article [24]. These findings imply that healthcare professionals, particularly those within healthcare facilities, predominantly use the majority of mobile applications in otology. This emphasizes the significance of comprehending the context in which these applications are utilized and their influence on the target audience.

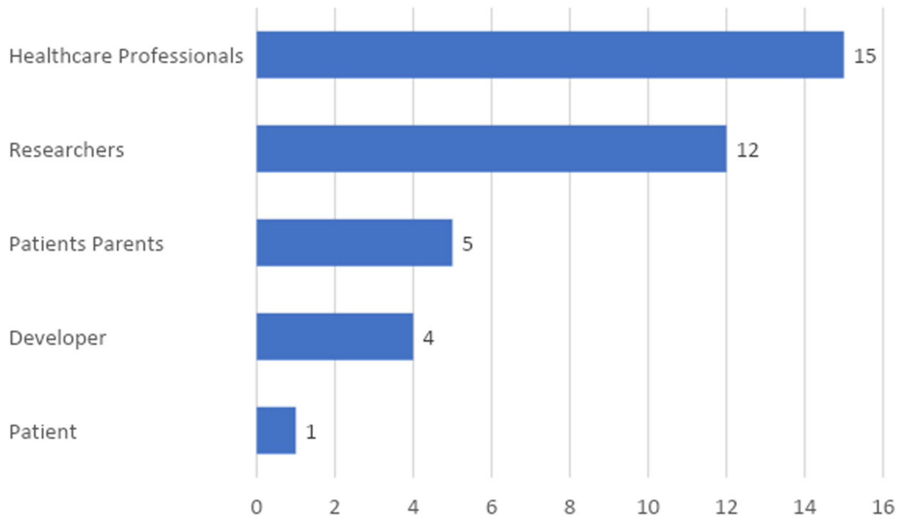

Fig. 10. Context graph

Figure 11 illustrates the distribution of healthcare professionals depicted in Figure 10. Most users of mobile applications in otology are medical students or residents, as referenced in eleven studies [2], [20–22], [26], [44], [50], [51], [53], [54], [58], followed by nurses, as referenced in three studies [44], [48], [54]. This was then followed by otologists, as cited in three studies [20], [26], and followed by community health workers, as referenced in two studies [26], [45].

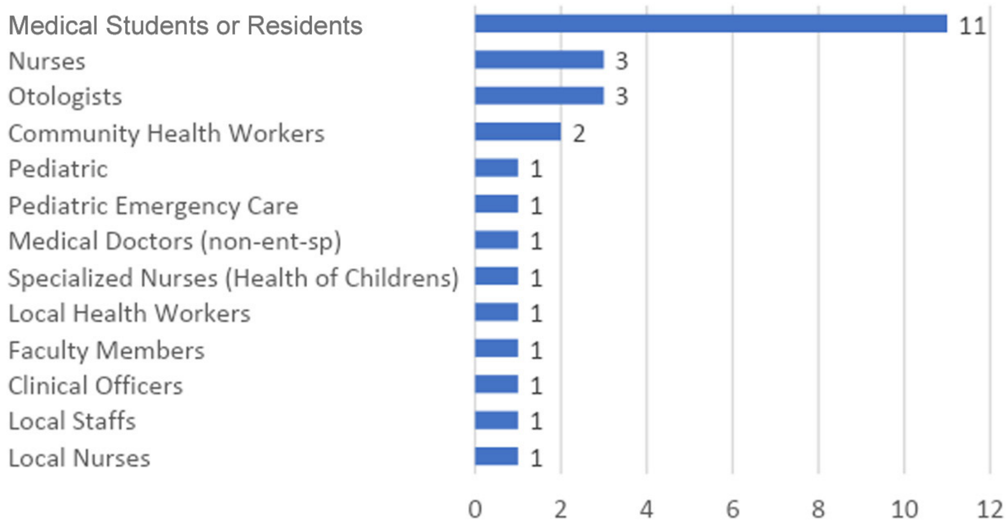

Fig. 11. Healthcare professionals' breakdown

Figure 12 illustrates the target audiences for which the applications were used. Actual patients were referenced in twelve studies [10], [21], [23], [26], [33], [44–46], [53–55], [58], while children were present in five studies [31], [47], [56], [58], [59]. Students were the subsequent users, as identified in three studies [2], [45], and [50], followed by medical students, as highlighted in one study [51]. And someone with typical hearing was mentioned in one study [10].

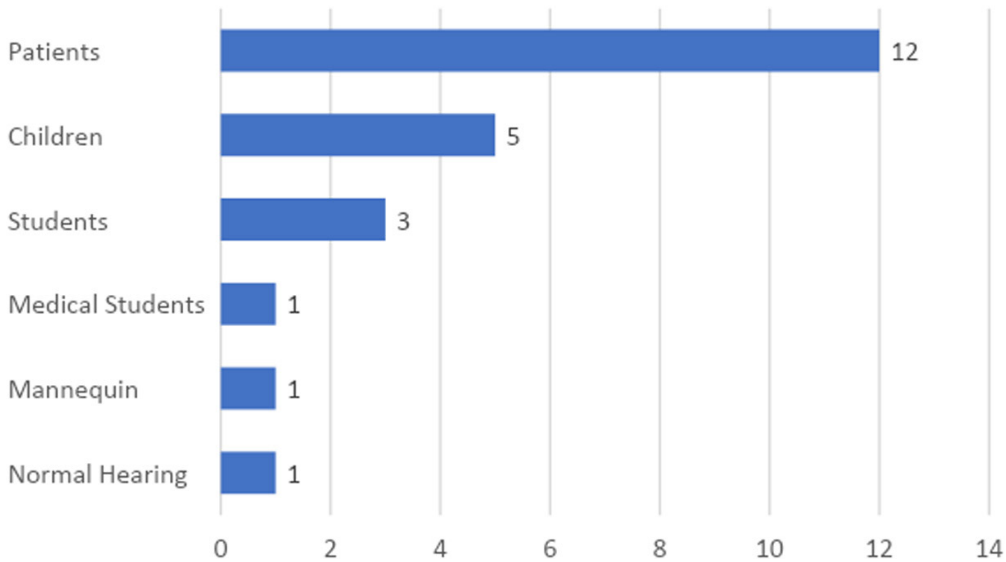

Fig. 12. Used on audience

Mobile applications in process of otology. This section of the CCP framework focuses on examining the process of mobile applications in otology and exploring the areas in which they are applied. As depicted in Figure 13, there are three main clusters: trial and study types, healthcare and medical settings, and app store platforms. The trial and study type cluster includes three type, the healthcare and medical settings cluster includes two medical settings; and the app store platforms cluster consists of two platforms. Additionally, the analysis reveals two unclassified categories labeled as 'others' and 'development'.

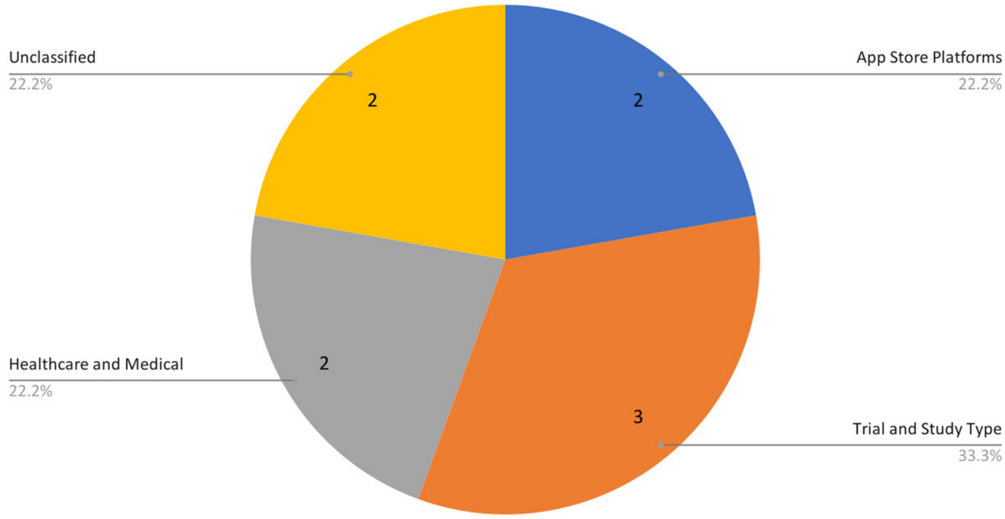

Fig. 13. Clusters

In Figure 14, we further explore the breakdown of trial and study types. This cluster includes three types of studies: clinical trials, with seven studies found in 32 journal articles [10], [33], [44], [45], [50], [53], [55]; randomized controlled trials, with five studies found in thirty-two journal articles [19], [24], [44], [51], [58]; and randomized trials, with four studies found in 32 journal articles [11], [49], [55].

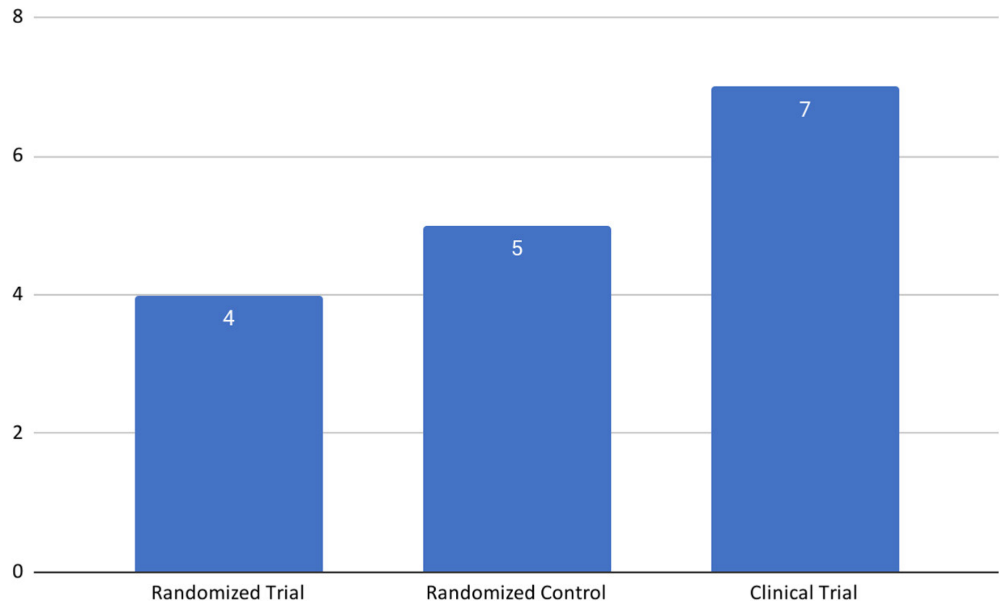

Fig. 14. Trial and study type

Figure 15 illustrates the breakdown of healthcare and medical settings within the CCP framework. This cluster primarily consists of two medical settings: the emergency department, with five studies found in 32 journal articles [21], [23], [44], [49], [58]; and home-based, with four studies found in 32 journal articles [2], [20], [31], [47].

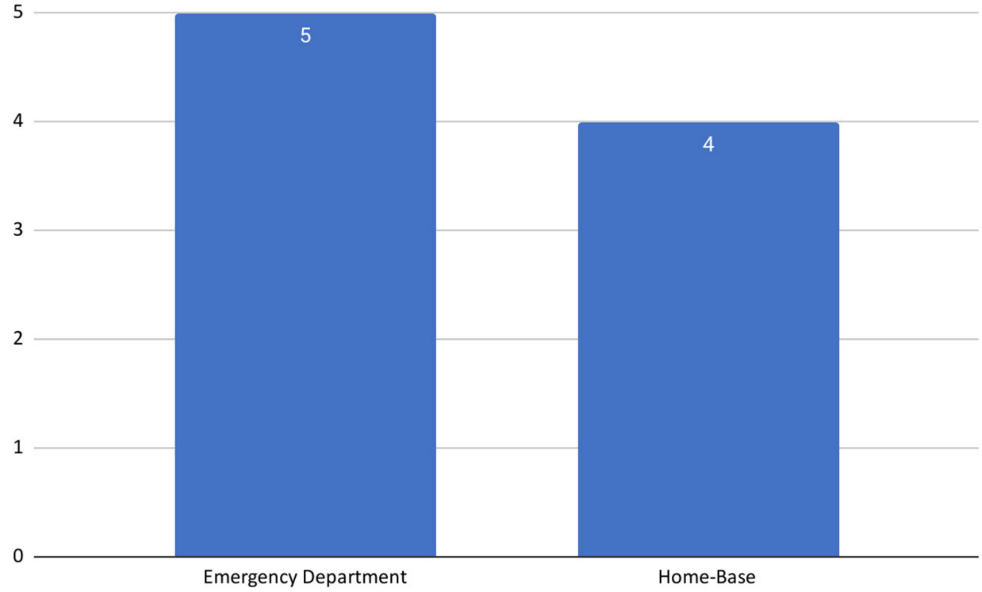

Fig. 15. Healthcare and medical settings

Figure 16 illustrates the breakdown of the app store platform. This cluster mainly comprises two application publishing platforms: the iOS App Store and the Google Play Store. Three studies related to these platforms were found in 32 journal articles [18], [28], [52].

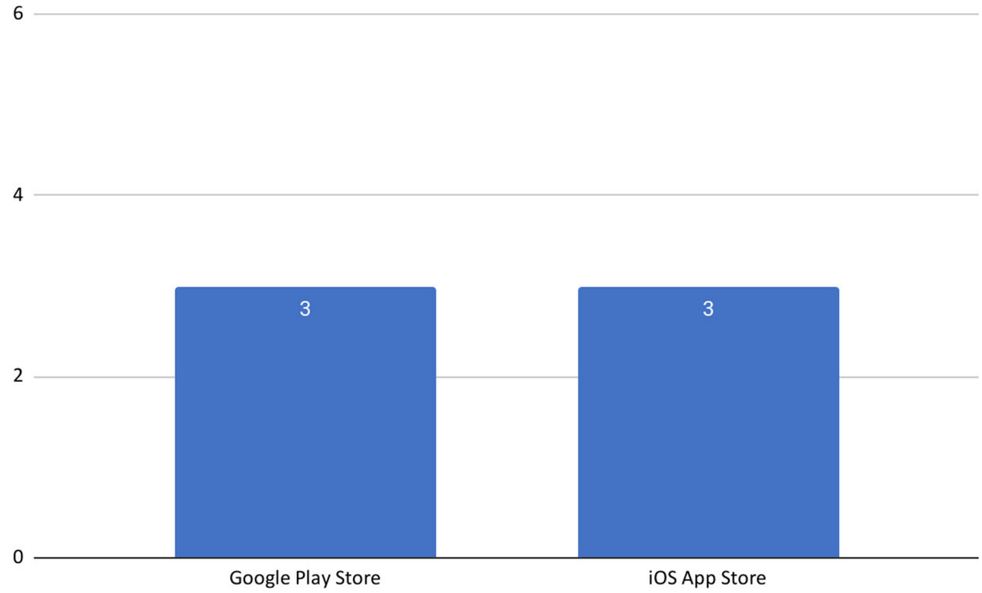

Fig. 16. App store platforms

Finally, Figure 17 presents the breakdown of the unclassified categories. The development category includes four studies identified in 32 journal articles [24], [28], [46], [57]. The "others" category comprises 17 studies identified in 32 journal articles, which explore various aspects that do not fit directly into the predefined clusters but still contribute to the overall subject.

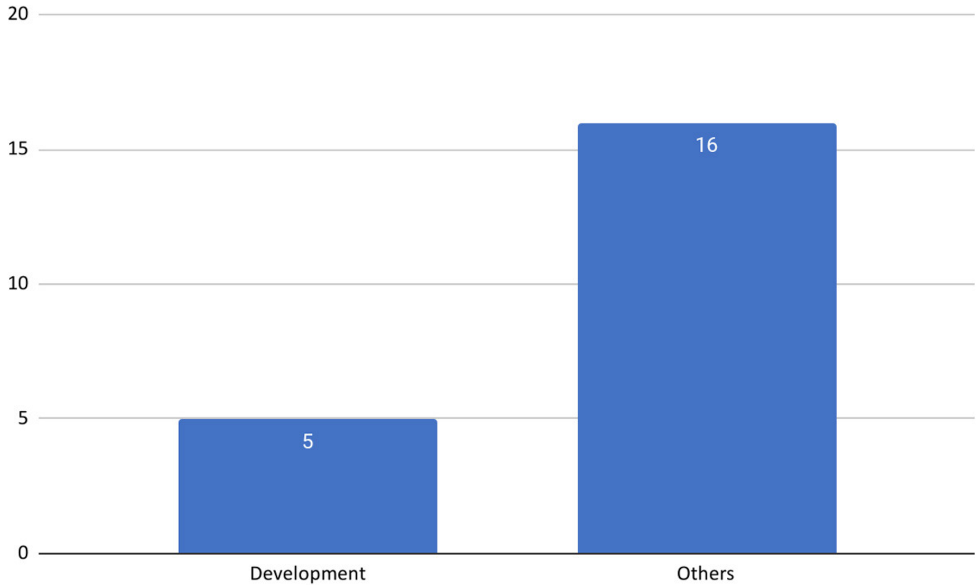

Fig. 17. App store platforms

By visually representing these clusters and breakdowns, we can gain a comprehensive understanding of the various dimensions and areas of focus within the field of mobile applications in otology.

Mobile applications in content of otology. This section of the CCP framework examines the content of mobile applications in otology, including their areas of application. Figure 18 illustrates that the majority of the 32 journal articles analyzed in the study found that the most common subject area for these applications is screenings, with 17 studies cited in 17 journal articles [2], [10], [11], [24], [26], [28], [40], [44–50], [52], [55], [57]. The next largest subject area is diagnosis, with seven studies found in six journal articles [19], [23], [33], [53], [55], [56], [58]. Followed by learning tools, six studies were found in six journal articles [22], [40], [44], [50], [51], [58]. These results indicate that mobile applications in otology are extensively utilized for screening purposes and are a subject of ongoing exploration and research. The examination of the content provides valuable insights into the use of these technologies in otology and will contribute to the advancement of the field.

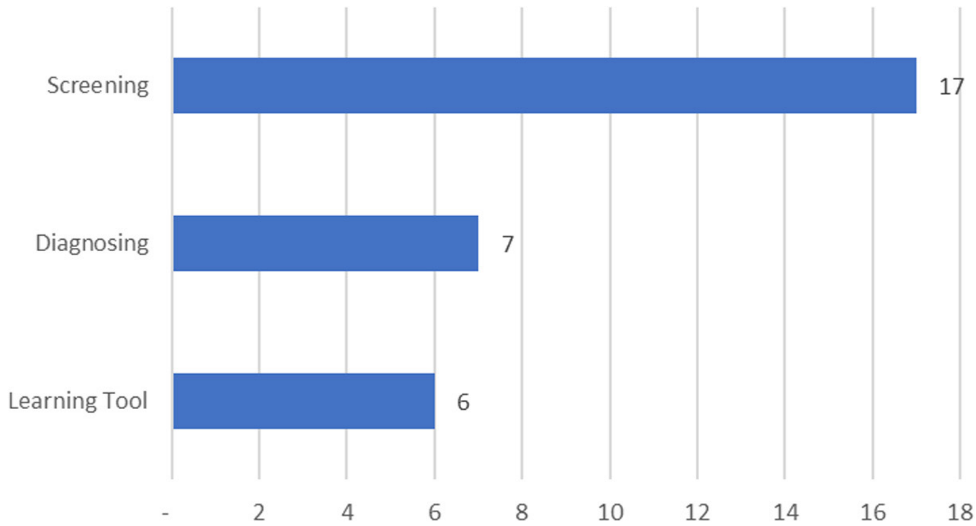

Fig. 18. Content graph

The researcher also presented twelve comparative studies in the thirty-two journal articles that examined the use of mobile applications in otology [2], [10], [11], [21], [24], [26], [33], [44], [45], [52], [58], [59]. These studies specifically compared the use of smartphone otoscopes to traditional otoscopes and also examined the accuracy and effectiveness of the mobile application compared to traditional methods. These findings provide valuable insights into the usefulness of smartphone otoscopes and their applications in the field of otology.

3.3 Research gap analysis results

Common conclusions. The sample size of this study primarily consisted of thirty-two journal articles related to mobile applications in otology. The results revealed several common findings among the studies, as depicted in Figure 19, which emphasize the utilization of mobile applications, especially in smartphone-based hearing tests or smartphone-enabled otoscopes within the field of otology. Mobile applications have the potential to become valuable tools in the field of otology. The use of these tests may reduce the need for traditional hearing tests in underserved areas and offer a cost-effective alternative, [10], [23], [33], [45], [48]. The accessibility and user-friendly nature of smartphone hearing tests make them a valuable tool for patients and healthcare professionals [20], [22–24], [28], [33], [40], [44], [47–51], [53], [55–58]. However, additional research is required to ascertain their effectiveness and accuracy [2], [18], [19], [28], [40], [46], [52], [55]. Additionally, it is important to provide adequate training for users and to exercise caution when interpreting the data to ensure the correct use of this technology [23], [52]. Despite these limitations, the smartphone-enabled otoscope has been found to be preferred over traditional otoscopy by patients and emergency physicians [10], [20], [21], [26], [31], [57–59]. The ease of use, portability, and excellent image quality produced by this technology make it a viable option for home-based testing and learning [20], [22–24], [28], [33], [40], [44], [47–51], [53], [55–58]. The use of these tests in remote settings may also facilitate the effective use of telehealth and remote consultations [10], [23], [33], [45], [48]. However, accurate instructions and guidance are essential for the effective utilization of the technology [33], [34], [47], [49], [52], [54], [55].

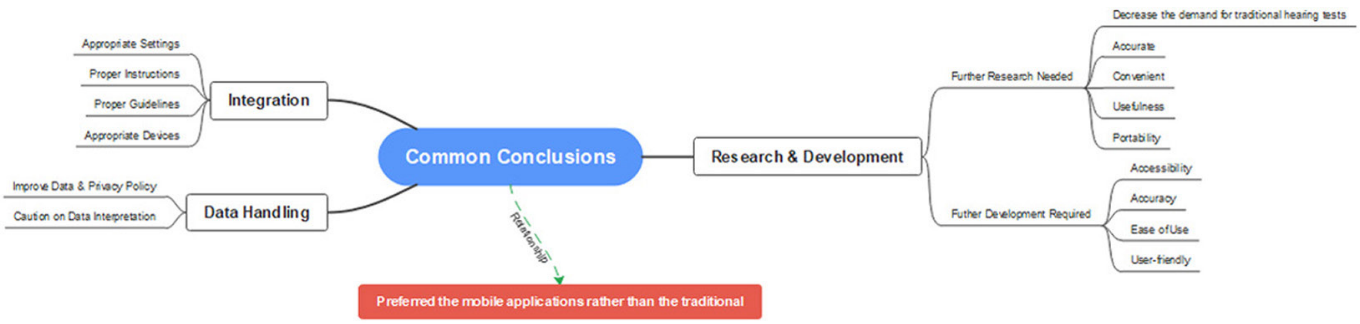

Fig. 19. Common conclusions

Common limitations. The results revealed several common limitations, particularly the need for a quiet room to prevent ambient noise during a hearing test [10], [45], as well as the absence of a standardized calibration procedure [10], [23], [28], [50], [54–56]. The studies also encountered selection bias, small patient cohorts, limited evaluation of outcomes, and a predominance of patients with normal or mild hearing loss [11], [20], [24], [33], [47–49], [59]. The training for using the smartphone otoscope was limited to written instructions, and there was a lack of reference to diagnostic sources [20], [21], [40], [50]. Additionally, the study population was restricted to English-speaking patients, and most of the study was non-randomized, making it nearly impossible to blind the physician, parent, and child to the instrument being used [33], [55].

Common recommendations. Figure 20 displays the recommendations that were most shared by the analyzed journal articles. These common recommendations emphasize the use of mobile applications, especially in the development of an optimal platform that gathers audiograms, otoscopy, otoacoustic emissions, and automated auditory brainstem recordings on the same interface [45]. It is recommended to conduct future randomized controlled trials with larger sample sizes and a wider range of populations to validate the effectiveness of mobile applications [11], [24], [26], [34]. Furthermore, additional research is necessary to assess the clinical utility of these applications and to compare their accuracy with traditional diagnostic methods in otology [21], [26], [31], [44], [50], [52], [56], [57], [59], [60]. The proficiency of students, non-otolaryngology providers, and parents in using the smartphone-enabled otoscope should also be explored [50]. Additionally, the impact of smartphone-enabled otoscopy on clinical decision-making and its benefits for educators and learners [50], [51]. To ensure the validity of the results, it is important to compare the assessments with established "gold-standard" studies [34]. The issue of data protection also requires further research. It is recommended that application developers, healthcare professionals, and scientific associations collaborate to make these applications more accessible [18], [52]. Finally, integrating deep learning algorithms to support real-time automated diagnosis could enhance the capabilities of these mobile applications [48], [61].

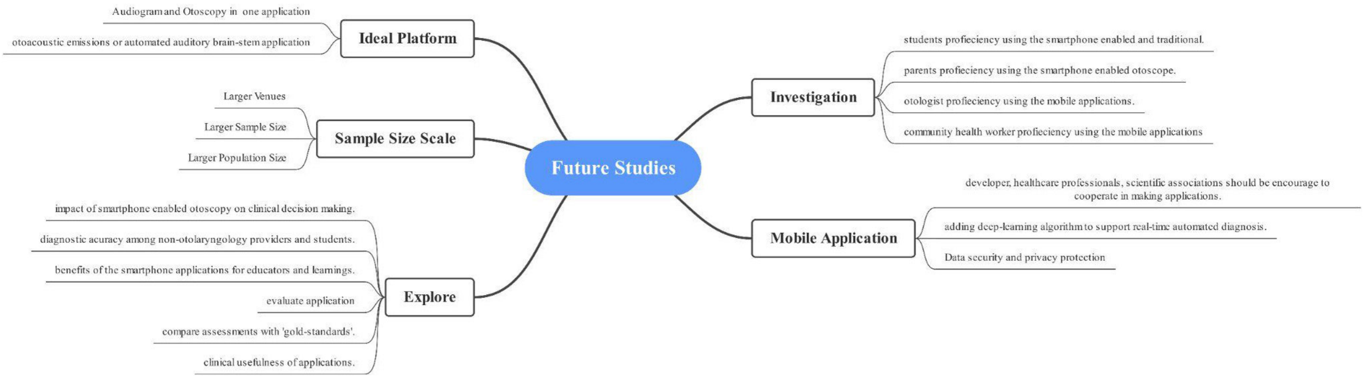

Fig. 20. Future studies

4 CONCLUSIONS AND RECOMMENDATIONS

This study aimed to conduct a scoping review of mobile applications in otology, an underexplored area due to the lack of comprehensive synthesis on how mobile applications are being used in the field of otology and the limited research in this area. To fill this gap, the researcher utilized the context-content-process framework and inductive coding to integrate the existing literature. The study analyzed 32 relevant journal articles from the Scopus and Web of Science databases published between 2012 and 2023. It employed a qualitative coding process to identify key themes and factors that influence the use of mobile applications in otology. The analysis revealed that smartphone otoscopes were the most frequently studied mobile applications, primarily used for screening purposes in clinical trials. Based on the findings, the study emphasizes the necessity for additional research in this field and the potential advantages of mobile applications in otology for enhancing healthcare delivery, especially in the realms of telemedicine and remote examination.

The researcher suggests the following recommendations for future studies: Firstly, it is recommended that the development of mobile applications in this field be based on the content-context-processes framework identified within the scope. Secondly, the applications should comply with relevant laws and regulations, such as the FDA and the Health Insurance Portability and Accountability Act (HIPAA), to ensure the safety and privacy of the users. Thirdly, there must be a collaboration between app developers and healthcare professionals to ensure the accuracy and validity of the results produced by these applications. Lastly, it is important to encourage the integration of electronic medical records (EMR) into these mobile applications to enhance the data privacy of the users.

5 ACKNOWLEDGMENTS

The authors express their gratitude for the support of the Mindanao State University-Iligan Institute of Technology (MSU-IIT) Office of the Vice Chancellor for Research and Enterprise and the Office of the Vice Chancellor for Public Affairs for their assistance in this study. This work is supported by MSU-IIT as an internally funded research and extension project of the Information Systems program under the Office of Research Management, WE CARE Office, and the College of Computer Studies-Department of Information Technology. The authors would also like to thank the ILIGANiCE (Innovation thru Leveraging Industry, Government, Academe Networks and inclusive Community Engagements) Program for their assistance in this study.

6 REFERENCES

[1] L. E. Miller *et al.*, "Reliability and accuracy of remote fiberoptic Nasopharyngolaryngoscopy in the pediatric population," *Ear Nose Throat J.*, vol. 100, no. 8, pp. 604–609, 2021. https://doi.org/10.1177/0145561320919109

[2] A. Schafer, S. Hudson, and C. A. Elmaraghy, "Telemedicine in pediatric otolaryngology: Ready for prime time?" *Int. J. Pediatr. Otorhinolaryngol.*, vol. 138, p. 110399, 2020. https://doi.org/10.1016/j.ijporl.2020.110399

[3] F. D. B. Kravchychyn *et al.*, "Smartphone-enabled otoscopy: Method evaluation in clinical practice," *Braz. J. Otorhinolaryngol.*, vol. 89, no. 1, pp. 122–127, 2023. https://doi.org/10.1016/j.bjorl.2021.08.012

[4] A. Mudry, "References in the history of Otology," *Otology & Neurotology*, vol. 28, no. 1, pp. 135–140, 2007. https://doi.org/10.1097/01.mao.0000231595.10714.f4

[5] O. Moshtaghi *et al.*, "Smartphone-enabled otoscopy in Neurotology/Otology," *Otolaryngology–Head and Neck Surgery*, vol. 156, no. 3, pp. 554–558, 2017. https://doi.org/10.1177/0194599816687740

[6] A. C. Moberly *et al.*, "Digital otoscopy versus microscopy: How correct and confident are ear experts in their diagnoses?" *J. Telemed. Telecare*, vol. 24, no. 7, pp. 453–459, 2018. https://doi.org/10.1177/1357633X17708531

[7] M. E. Quick, C. G. Brennan-Jones, and J. Kuthubutheen, "Remote paediatric ear examination comparing video-otoscopy and still otoscopy clinician rated outcomes," *International Journal of Pediatric Otorhinolaryngology*, vol. 177, p. 111871, 2024. https://doi.org/10.1016/j.ijporl.2024.111871

[8] "Otoscopy," PubMed. https://pubmed.ncbi.nlm.nih.gov/32310550/ [Accessed: November 9, 2022].

[9] L. V. Yesantharao, M. Donahue, A. Smith, H. Yan, and Y. Agrawal, "Virtual audiometric testing using smartphone mobile applications to detect hearing loss," *Laryngoscope Investig. Otolaryngol.*, vol. 7, no. 6, pp. 2002–2010, 2022. https://doi.org/10.1002/lio2.928

[10] L. Renda, O. T. Selcuk, H. Eyigor, U. Osma, and M. D. Yilmaz, "Smartphone based audiometric test for confirming the level of hearing; Is it useable in underserved areas?" *J. Int. Adv. Otol.*, vol. 12, no. 1, pp. 61–66, 2016. https://doi.org/10.5152/iao.2016.1421

[11] T. Prithivi *et al.*, "Comparison of hearing thresholds using audiometric versus android-based application," *Indian Journal of Otology*, vol. 25, no. 4, p. 206, 2019. https://doi.org/10.4103/indianjotol.INDIANJOTOL_70_19

[12] F. Ross, A. Wohllebe, and E. Diez, "The role of personal assistance in the uptake of smartphone-based tele-audiology—An extension of the technology acceptance model," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 12, pp. 18–31, 2022. https://doi.org/10.3991/ijim.v16i12.30133

[13] T. Lee *et al.*, "Assessment of central auditory processing in children using a novel tablet-based platform: Application for low- and middle-income countries," *Otology & Neurotology*, vol. 45, no. 2, p. 176, 2024. https://doi.org/10.1097/MAO.0000000000004085

[14] R. Ravi, D. R. Gunjawate, K. Yerraguntla, and C. Driscoll, "Knowledge and perceptions of teleaudiology among audiologists: A systematic review," *J. Audiol. Otol.*, vol. 22, no. 3, pp. 120–127, 2018. https://doi.org/10.7874/jao.2017.00353

[15] H. Patel and R. Connolly, "Factors influencing technology adoption: A review," in *8th International Business Information Management Conference*, Dublin, Ireland, 2007. [Online]. Available: https://www.researchgate.net/publication/273140050

[16] E. You, V. Lin, T. Mijovic, A. Eskander, and M. G. Crowson, "Artificial intelligence applications in Otology: A state of the art review," *Otolaryngology–Head and Neck Surgery*, vol. 163, no. 6, pp. 1123–1133, 2020. https://doi.org/10.1177/0194599820931804

[17] D. A. Gârdan, "The mobile media communication and the doctor-patient relationship in the case of children ENT disorders," *Annales Universitatis Apulensis Series Oeconomica*, vol. 22, no. 1, pp. 31–39, 2019. https://doi.org/10.29302/oeconomica.2019.22.1.3

[18] E. M. C. Trecca, A. Lonigro, M. Gelardi, B. Kim, and M. Cassano, "Mobile applications in Otolaryngology: A systematic review of the literature, Apple App Store and the Google Play Store," *Annals of Otology, Rhinology & Laryngology*, vol. 130, no. 1, pp. 78–91, 2021. https://doi.org/10.1177/0003489420940350

[19] K. N. Chan, A. Silverstein, L. N. Bryan, C. E. McCracken, W. K. Little, and A. L. Shane, "Comparison of a smartphone otoscope and conventional otoscope in the diagnosis and management of acute otitis media," *Clin. Pediatr. (Phila)*, vol. 58, no. 3, pp. 302–306, 2019. https://doi.org/10.1177/0009922818812480

[20] K. M. Rappaport *et al.*, "Assessment of a smartphone otoscope device for the diagnosis and management of otitis media," *Clin. Pediatr. (Phila)*, vol. 55, no. 9, pp. 800–810, 2016. https://doi.org/10.1177/0009922815593909

[21] J. R. Richards, K. A. Gaylor, and A. J. Pilgrim, "Comparison of traditional otoscope to iPhone otoscope in the pediatric ED," *Am. J. Emerg. Med.*, vol. 33, no. 8, pp. 1089–1092, 2015. https://doi.org/10.1016/j.ajem.2015.04.063

[22] S. Samra, A. Wu, and M. Redleaf, "Interactive iPhone/iPad app for increased tympanic membrane familiarity," *Annals of Otology, Rhinology & Laryngology*, vol. 125, no. 12, pp. 997–1000, 2016. https://doi.org/10.1177/0003489416669952

[23] R. K. V. Sethi, I. Ghanad, V. Kanumuri, B. Herrmann, E. D. Kozin, and A. K. Remenschneider, "Mobile hearing testing applications and the diagnosis of sudden sensorineural hearing loss: A cautionary tale," *Otology & Neurotology*, vol. 39, no. 1, pp. e1–e4, 2018. https://doi.org/10.1097/MAO.0000000000001621

[24] M. Abouzari *et al.*, "Adapting personal therapies using a mobile application for tinnitus rehabilitation: A preliminary study," *Annals of Otology, Rhinology & Laryngology*, vol. 130, no. 6, pp. 571–577, 2021. https://doi.org/10.1177/0003489420962818

[25] N. Gupta, N. Chawla, D. Gupta, N. Dhawan, and V. R. Janaki, "Community triage of otology patients using a store-and-forward telemedicine device: A feasibility study," *Ear Nose Throat J.*, vol. 96, no. 7, pp. 246–249, 2017. [Online]. Available: www.entjournal.com.

[26] J. R. Shinn, M. G. Zuniga, I. Macharia, J. Reppart, J. L. Netterville, and A. D. L. Jayawardena, "Community health workers obtain similar results using cell-phone based hearing screening tools compared to otolaryngologists in low resourced settings," *Int. J. Pediatr. Otorhinolaryngol.*, vol. 127, p. 109670, 2019. https://doi.org/10.1016/j.ijporl.2019.109670

[27] A. Salisu, "Extending otology services to the rural community: Use of smartphone for hearing screening," *Nigerian Journal of Basic and Clinical Sciences*, vol. 13, no. 2, p. 72, 2016. https://doi.org/10.4103/0331-8540.187359

[28] A. L. Irace, R. K. Sharma, N. S. Reed, and J. S. Golub, "Smartphone-based applications to detect hearing loss: A review of current technology," *J. Am. Geriatr. Soc.*, vol. 69, no. 2, pp. 307–316, 2021. https://doi.org/10.1111/jgs.16985

[29] T. C. Cavalcanti, H. M. Lew, K. Lee, S. Y. Lee, M. K. Park, and J. Y. Hwang, "Intelligent smartphone-based multimode imaging otoscope for the mobile diagnosis of otitis media," *Biomed. Opt. Express*, vol. 12, no. 12, p. 7765–7779, 2021. https://doi.org/10.1364/BOE.441590

[30] D. W. Swanepoel, "Smartphone-based national hearing test launched in South Africa," *The Hearing Journal*, vol. 70, no. 1, pp. 14–16, 2017. https://doi.org/10.1097/01.HJ.0000511726.41335.83

[31] D. M. Don, J. A. Koempel, L. M. Fisher, C. P. Wee, and B. Osterbauer, "Prospective evaluation of a smartphone otoscope for home Tympanostomy tube surveillance: A pilot study," *Annals of Otology, Rhinology & Laryngology*, vol. 130, no. 2, pp. 125–132, 2021. https://doi.org/10.1177/0003489420938820

[32] R. Sahyouni *et al.*, "Evaluation of an iPhone otoscope in a neurotrauma clinic and as an adjunct to neurosurgical education," *Insights Neurosurg.*, vol. 1, no. 1, p. 4, 2016.

[33] Y. Cai *et al.*, "Patient use of low-cost digital videoscopes and smartphones for remote ear and Oropharyngeal examinations," *JAMA Otolaryngology–Head & Neck Surgery*, vol. 147, no. 4, p. 336, 2021. https://doi.org/10.1001/jamaoto.2020.5223

[34] C. Metcalfe, J. Muzaffar, L. Orr, and C. Coulson, "A systematic review of remote otological assessment using video-otoscopy over the past 10 years: Reliability and applications," *European Archives of Oto-Rhino-Laryngology*, vol. 278, no. 12, pp. 4733–4741, 2021. https://doi.org/10.1007/s00405-020-06596-2

[35] T. Miwa *et al.*, "Application of artificial intelligence using a convolutional neural network for detecting cholesteatoma in endoscopic enhanced images," *Auris. Nasus. Larynx*, vol. 49, no. 1, pp. 11–17, 2022. https://doi.org/10.1016/j.anl.2021.03.018

[36] N. Leventi, A. Vodenitcharova, K. Popova, A. Yanakieva, and K. Ivanova, "P10-07 m-Health apps and health-promoting behavior: Medical students' opinion," *Eur. J. Public Health*, vol. 32, no. 2, 2022. https://doi.org/10.1093/eurpub/ckac095.146

[37] F. Monteiro-Guerra, O. Rivera-Romero, L. Fernandez-Luque, and B. Caulfield, "Personalization in real-time physical activity coaching using mobile applications: A scoping review," *IEEE J. Biomed. Health Inform.*, vol. 24, no. 6, pp. 1738–1751, 2020. https://doi.org/10.1109/JBHI.2019.2947243

[38] A. P. Sinha, A. Joshi, M. Singhal, and M. Gupta, "Scoping review using PRISMA-SCR on m-health interventions on self-care management of type 2 diabetes at home," *Research Square*, 2022. https://doi.org/10.21203/rs.3.rs-1680004/v2

[39] A. Yang, D. Kim, P. H. Hwang, and M. Lechner, "Telemedicine and telementoring in Rhinology, Otology, and Laryngology: A scoping review," *OTO Open*, vol. 6, no. 1, p. 2473974X2110727, 2022. https://doi.org/10.1177/2473974X211072791

[40] A. Frithioff, M. J. Guldager, and S. A. W. Andersen, "Current status of handheld otoscopy training: A systematic review," *Annals of Otology, Rhinology & Laryngology*, vol. 130, no. 10, pp. 1190–1197, 2021. https://doi.org/10.1177/0003489421997289

[41] A. Eslami Andargoli, H. Scheepers, D. Rajendran, and A. Sohal, "Health information systems evaluation frameworks: A systematic review," *Int. J. Med. Inform.*, vol. 97, pp. 195–209, 2017. https://doi.org/10.1016/j.ijmedinf.2016.10.008

[42] R. Cuthbertson and W. Piotrowicz, "Performance measurement systems in supply chains," *International Journal of Productivity and Performance Management*, vol. 60, no. 6, pp. 583–602, 2011. https://doi.org/10.1108/17410401111150760

[43] R. Stockdale and C. Standing, "An interpretive approach to evaluating information systems: A content, context, process framework," *Eur. J. Oper. Res.*, vol. 173, no. 3, pp. 1090–1102, 2006. https://doi.org/10.1016/j.ejor.2005.07.006

[44] K. Kleinman, K. J. Psoter, A. Nyhan, B. S. Solomon, J. M. Kim, and T. Canares, "Evaluation of digital otoscopy in pediatric patients: A prospective randomized controlled clinical trial," *Am. J. Emerg. Med.*, vol. 46, pp. 150–155, 2021. https://doi.org/10.1016/j.ajem.2021.04.030

[45] A. D. L. Jayawardena, C. N. Kahue, S. M. Cummins, and J. L. Netterville, "Expanding the capacity of Otolaryngologists in Kenya through mobile technology," *OTO Open*, vol. 2, no. 1, p. 2473974X1876682, 2018. https://doi.org/10.1177/2473974X18766824

[46] D. Jethanamest, M. Azadpour, A. M. Zeman, E. Sagi, and M. A. Svirsky, "A smartphone application for customized frequency table selection in cochlear implants," *Otology & Neurotology*, vol. 38, no. 8, pp. e253–e261, 2017. https://doi.org/10.1097/MAO.0000000000001409

[47] M. U. Shah, M. Sohal, T. A. Valdez, and C. R. Grindle, "iPhone otoscopes: Currently available, but reliable for tele-otoscopy in the hands of parents?" *Int. J. Pediatr. Otorhinolaryngol.*, vol. 106, pp. 59–63, 2018. https://doi.org/10.1016/j.ijporl.2018.01.003

[48] K. L. Yancey, L. J. Cheromei, J. Muhando, J. Reppart, J. L. Netterville, and A. D. L. Jayawardena, "Pediatric hearing screening in low-resource settings: Incorporation of video-otoscopy and an electronic medical record," *Int. J. Pediatr. Otorhinolaryngol.*, vol. 126, p. 109633, 2019. https://doi.org/10.1016/j.ijporl.2019.109633

[49] E. A. Kelly, M. E. Stadler, S. Nelson, C. L. Runge, and D. R. Friedland, "Tablet-based screening for hearing loss: Feasibility of testing in nonspecialty locations," *Otology & Neurotology*, vol. 39, no. 4, pp. 410–416, 2018. https://doi.org/10.1097/MAO.0000000000001752

[50] A. A. Hakimi, A. S. Lalehzarian, S. P. Lalehzarian, A. M. Azhdam, S. Nedjat-Haiem, and B. D. Boodaie, "Utility of a smartphone-enabled otoscope in the instruction of otoscopy and middle ear anatomy," *European Archives of Oto-Rhino-Laryngology*, vol. 276, no. 10, pp. 2953–2956, 2019. https://doi.org/10.1007/s00405-019-05559-6

[51] J. R. Schuster-Bruce, A. Ali, M. Van, J. Rogel-Salazar, E. Ofo, and E. Shamil, "A randomised trial to assess the educational benefit of a smartphone otoscope in undergraduate medical training," *European Archives of Oto-Rhino-Laryngology*, vol. 278, no. 6, pp. 1799–1804, 2021. https://doi.org/10.1007/s00405-020-06373-1

[52] J. Wallace and R. Kanegaonkar, "The role of smartphone applications in clinical practice: A review," *J. Laryngol. Otol.*, vol. 134, no. 2, pp. 96–103, 2020. https://doi.org/10.1017/S0022215119002652

[53] K. Bhavana, M. Ahmad, and P. Sharma, "Smartphone otoscopy sans attachment: A paradigm shift in diagnosing ear pathologies," *OTO Open*, vol. 2, no. 3, p. 2473974X1878649, 2018. https://doi.org/10.1177/2473974X18786496

[54] M. N. Demant, R. G. Jensen, M. F. Bhutta, G. H. Laier, J. Lous, and P. Homøe, "Smartphone otoscopy by non-specialist health workers in rural Greenland: A cross-sectional study," *Int. J. Pediatr. Otorhinolaryngol.*, vol. 126, p. 109628, 2019. https://doi.org/10.1016/j.ijporl.2019.109628

[55] L. Livshitz *et al.*, "Application-based hearing screening in the elderly population," *Annals of Otology, Rhinology & Laryngology*, vol. 126, no. 1, pp. 36–41, 2017. https://doi.org/10.1177/0003489416672873

[56] N. Erkkola-Anttinen, H. Irjala, M. K. Laine, P. A. Tähtinen, E. Löyttyniemi, and A. Ruohola, "Smartphone otoscopy performed by parents," *Telemedicine and e-Health*, vol. 25, no. 6, pp. 477–484, 2019. https://doi.org/10.1089/tmj.2018.0062

[57] B. H. B. Timmer, S. Launer, and L. Hickson, "Using smartphone technology to support the adult audiologic rehabilitation journey," *Int. J. Audiol.*, vol. 60, no. 1, pp. S61–S67, 2021. https://doi.org/10.1080/14992027.2020.1854483

[58] S. Mousseau, A. Lapointe, and J. Gravel, "Diagnosing acute otitis media using a smartphone otoscope; A randomized controlled trial," *Am. J. Emerg. Med.*, vol. 36, no. 10, pp. 1796–1801, 2018. https://doi.org/10.1016/j.ajem.2018.01.093

[59] T. Lundberg, L. Biagio de Jager, D. W. Swanepoel, and C. Laurent, "Diagnostic accuracy of a general practitioner with video-otoscopy collected by a health care facilitator compared to traditional otoscopy," *Int. J. Pediatr. Otorhinolaryngol.*, vol. 99, pp. 49–53, 2017. https://doi.org/10.1016/j.ijporl.2017.04.045

[60] M. Masalski, M. Turski and T. Zatoński, "Self-assessment of bone conduction hearing threshold using mobile audiometry: Comparison with pure tone audiometry," *International Journal of Audiology*, 2023. https://doi.org/10.1080/14992027.2023.2208287

[61] T. Dhar, N. Dey, S. Borra and R. S. Sherratt, "Challenges of deep learning in medical image analysis—Improving explainability and trust," *IEEE Transactions on Technology and Society*, vol. 4, no. 1, pp. 68–75, 2023. https://doi.org/10.1109/TTS.2023.3234203

7 AUTHORS

Laurence Troy S. Valdez is a student, pursuing Bachelor of Science in Information Systems at the College of Computer Studies, Mindanao State University-Iligan Institute of Technology. He specializes in research engagements focused on the role of innovative technologies in healthcare. As a software engineer, he develops desktop, mobile, and web applications with expertise in JavaScript, Flutter, Kotlin, and Java programming languages (E-mail: laurencetroy.valdez@g.msuiit.edu.ph).

Rentor Y. Cafino, MD, DPBO-HNS is a diplomate of the society of Otorhinolaryngology – Head and Neck Surgery training program and is among the pioneers of medical 3D printing in the Philippines. He is the unit head and founder of the Zamboanga City Medical Center Medical Makerspace and Prosthesis Laboratory (E-mail: rcafino@gmail.com).

Armando T. Isla Jr., MD, FPSO-HNS earned his medical degree from the University of the Philippines. He completed his residency training in Otolaryngology-Head and Neck Surgery at the Philippine General Hospital, where he honed his surgical skills and gained valuable clinical experience. Dr. Isla has served as a leader in the Philippine Society of Otolaryngology - Head and Neck Surgery. His contributions to these organizations have been instrumental in fostering collaboration among healthcare professionals and driving advancements in the field. One of Dr. Isla's most notable areas of interest lies in influencing the future of medical practices in the community setting. He envisions a healthcare landscape where quality medical care is accessible to all, and he actively works towards making this vision a reality (E-mail: donisla.md@gmail.com).

Eigen John T. Ignacio, PhD is a faculty member at MSU-IIT's laboratory school for high school students. His professional interests include mathematics and computer applications and how they intersect with education (E-mail: eigenjohn.ignacio@g.msuiit.edu.ph).

Patrick John Labra, MD, FPSO-HNS is a practicing Otorhinolaryngologist and Head and Neck Surgeon practicing in the Western Visayas Region of the Philippines. He had obtained his medical degree from the University of the Philippines - Manila Campus and underwent training for ORL-HNS as the Philippine General Hospital. He has had further subspecialty training in Otology and Neurotology under the Philippine National Ear Institute based in University of the Philippines - Manila. His research focus is on newborn hearing screening program development, cochlear implantation program development, and health information systems (E-mail: pplabra@alum.up.edu.ph).

Lemuel Clark P. Velasco is an Associate Professor of information systems from the Department of Information Technology at the Mindanao State University-Iligan Institute of Technology. He was the pioneering Director of FAB LAB Mindanao- Center of Innovation and Invention, co-founder of FAB LABs Philippines-the Philippine FAB LAB Network, and co-founder of Webforest Digital Solutions. He is a predictive analytics researcher at the Premiere Research Institute of Science and Mathematics – Center for Computational Analytics and Modelling (E-mail: lemuelclark.velasco@g.msuiit.edu.ph).