MAEDICA – a Journal of Clinical Medicine
2024; 19(4): 697-703
https://doi.org/10.26574/maedica.2024.19.4.697

MÆDICA - a Journal of Clinical Medicine

ORIGINAL PAPER

Measurement Accuracy of CBCT *Versus* MDCT for the Linear Distance between the Stapes and Round Window, and the Incudostapedial Joint Thickness for Cochlear Implantation Treatment Planning

Sanaz SHARIFISHOSHTARI[a], Nader SAKI[b], Zohreh ROOZBAHANI[a], Mohammad Ghasem HANAFI[c], Maryam FARASAT[c], Zahra SAADI[a]

[a]Hearing Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

[b]Department of Oral and Maxillofacial Radiology, School of Dentistry, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

[c]Department of Radiology, Imam Khomeini Hospital, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

ABSTRACT

Objectives: *This study aimed to compare the measurement accuracy of cone-beam computed tomography (CBCT) and multi-detector computed tomography (MDCT) for the linear distance between the stapes and round window, and the incudostapedial joint thickness for cochlear implantation treatment planning.*

Materials and methods: *In this in vitro study, 12 temporal bones along with their covering soft tissue underwent high-resolution (HR) and low-resolution (LR) CBCT and MDCT. The linear distance between the stapes and round window as well as the incudostapedial joint thickness were measured on images by an oral radiologist and a general radiologist. Data were analyzed by paired t-test, Wilcoxon test and Pearson's correlation test (alpha=0.05).*

Results: *Significant correlations and excellent agreement were noted between HR-CBCT and MDCT, HR-CBCT and LR-CBCT, and LR-CBCT and MDCT in both measurements (P<0.05). The mean distance between the stapes and round window on HR-CBCT was significantly higher than that on MDCT and LR-CBCT, and there were significant differences in the measurement accuracy of HR-CBCT with MDCT (P=0.014) and LR-CBCT (P=0.027). The difference between LR-CBCT and MDCT was not significant (P=0.102). The mean joint thickness on HR-CBCT was significantly higher than that on MDCT and the measurement accuracy of CBCT and MDCT was significantly different in this respect (P=0.014). The differences between LR-CBCT and MDCT, and HR-CBCT and LR-CBCT were not significant (P>0.05).*

Address for correspondence:
Zahra Saadi
Department of Oral and Maxillofacial Radiology, School of Dentistry, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
Email: Zahraasaadii1375@gmail.com

Article received on the 13th of November 2024 and accepted for publication on the 26th of November 2024

Conclusion: *The results of the present study showed an acceptable accuracy of CBCT comparable to that of MDCT for measurement of the linear distance between the stapes and round window, and the incudostapedial joint thickness for cochlear implantation treatment planning.*

Keywords: cochlear implantation, cone-beam computed tomography, multidetector computed tomography, round window, ear.

ABBREVIATIONS

CBCT: cone-beam computed tomography
MDCT: multi-detector computed tomography
HR: high-resolution
LR: low-resolution
CT: computed tomography
mAs: millampere-seconds
kVp: peak kilovoltage
ANOVA: analysis of variance
MSCT: multi-slice CT

INTRODUCTION

Hearing loss is the most common birth defect and one of the most prevalent neurosensory deficits in humans. However, due to its hidden nature, its early detection is often difficult. At present, approximately 360 million people worldwide (equal to 5% of the world's population) live with debilitating hearing loss (hearing loss > 33 dB), out of whom 32 million are children. Generally, 1-3 out of 1000 neonates are born with hearing loss. The prevalence of auditory defects is 2.6/1000 births in Asia, which is the highest in the world, and 0.7/1000 births in other continents. An estimated number of 4000 neonates with hearing loss are born in Iran every year (1).

Several etiologic factors, such as non-syndromic genetic diseases, are involved in different types of hearing loss. However, they all have the same treatment. The optimal efficacy of cochlear implants as an effective, safe and low-cost modality for treatment of severe neurosensory hearing loss has been well confirmed (2). It can profoundly improve hearing, verbal intelligence and the related aspects of the quality of life (3). Two of the most common approaches for placement of cochlear implants include the round window insertion and cochleostomy; however, controversy still exists regarding the best approach (4). Posterior tympanotomy is the main commonly adopted technique for insertion of cochlear implant, which provides a safe access to the basal turn of the cochlea through the round window. Access through the round window decreases the risk of intracochlear trauma because it does not require perforation of the cochlear bone. However, anatomical variations of the round window often complicate this approach (5).

The incudostapedial joint is a synovial joint in the middle ear that connects the incus to the stapes. It transfers the mechanical vibrations of the tympanic membrane to the stapes and ear cochlea and ensures the required flexibility of the bony chain in the middle ear. The width (thickness) of this joint plays a pivotal role in the cochlear implant surgical process (6).

Recent technological advances in computed tomography (CT) enable precise measurement of length and thickness of different structures of the ear. Data obtained from CT imaging minimize injuries to the nerves and cochlea (7). Preoperative assessment of the temporal region by CT prior to cochlear implantation is imperative to precisely evaluate the inner ear structures and the mastoid fossa (8). Computed tomography is the reference imaging modality for the diagnosis of ear conditions and post-surgical follow-ups (8). Knowledge about the anatomical variations of the round window and its correlation with the stapes prior to surgery can minimize the incidence of perioperative complications during cochlear implantation (9).

Cone-beam computed tomography (CBCT), which is extensively used in dentistry, has lower radiation dose than CT and much higher spatial resolution than multi-detector CT (MDCT). Also, the accuracy of linear measurements is less sensitive to patients' movement (10). Cone-beam computed tomography can be performed in high-resolution (HR) and low-resolution (LR) modes. It enables sufficient contrast between the temporal bone, air and soft tissue (10).

Some studies qualitatively compared the accuracy of CBCT and MDCT for assessment of temporal bone structures and showed that clinical application of LR-CBCT was promising for surgical planning, perioperative guide and postoperative assessments but called for further investigations in this respect (10-13).

To the best of the authors' knowledge, no previous study has compared the measurement accuracy of MDCT and CBCT for the linear distance between the stapes and round window, and also the incudostapedial joint thickness. Considering the significance of such measurements prior to cochlear implant surgery, this study aimed to compare the measurement accuracy of CBCT and MDCT for the linear distance between the stapes and round window, and the incudostapedial joint thickness for cochlear implantation treatment planning. A comparison between HR and LR-CBCT images for this purpose was made as well. Using a single CBCT and MDCT scanner model might have been a deliberate choice to reduce variability introduced by different device specifications. This ensures consistency in the imaging parameters and data quality. However, including an explanation of this decision in the present study would provide a valuable context, such as whether it was due to equipment availability, study budget, or a specific focus on evaluating the selected scanner's performance, addressing potential concerns about the scope of the study. ❑

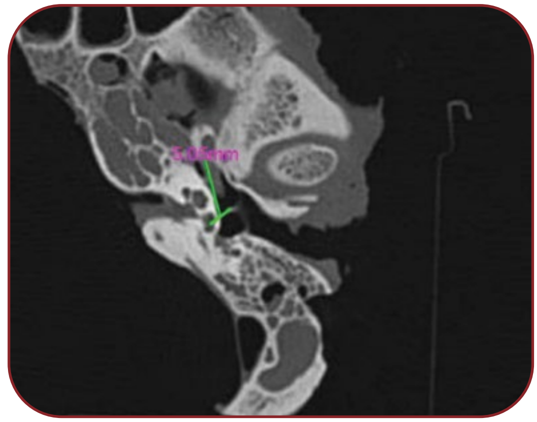

FIGURE 1. Distance between the stapes and round window on a multi-detector computed tomography (MDCT) image

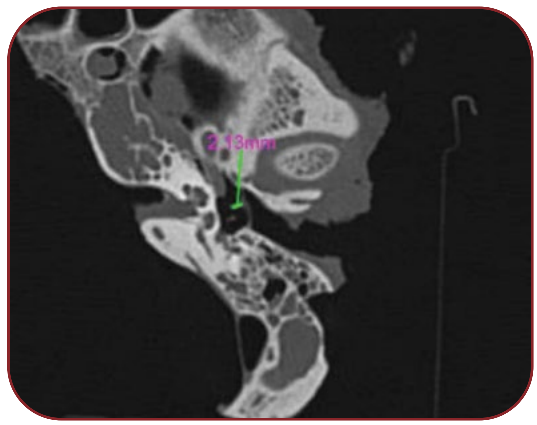

FIGURE 2. Thickness of incudostapedial joint on a multi-detector computed tomography (MDCT) image

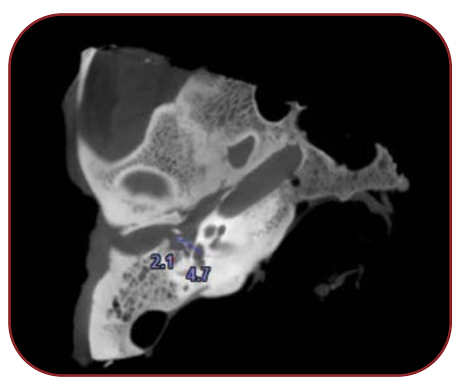

FIGURE 3. Distance between the stapes and round window and incudostapedial joint thickness on a low-resolution cone-beam computed tomography (LR-CBCT) image

MATERIALS AND METHODS

This *in vitro* study was conducted on 12 temporal bones with the covering soft tissue containing the cochlear structure that were obtained from the archives of the Ear, Nose and Throat Department of Imam Khomeini Hospital in Ahwaz, Iran. The study was approved by the ethics committee of Ahwaz Jundishapour University of Medical Sciences.

For imaging, the temporal bones were fixed in a plastic container containing alginate impression material and underwent MDCT (Helical Emotion 16-slice; Siemens, CT, USA) with the exposure settings of 70 mAs, 120 kVp, 0.6 slice thickness and 1.4 pitch. To obtain CBCT scans, the containers containing temporal bones were fixed in the scanner with adhesive tape and CBCT images were obtained with 8 x 12 cm field of view, 110 kVp, and 3.6 seconds time in LR mode, and 5.4 seconds time in HR mode. A total of 24 CBCT scans were obtained. Both MDCT and CBCT images were transferred to NNT viewer software and after coding, they were saved on a DVD. The images were viewed by an oral radiologist and a general radiologist on a LED flat-screen 14-inch monitor (Asus) with 1080 x 1920-pixel resolution in a semi-dark room. The observers evaluated the images in the axial, coronal, and sagittal planes and were allowed to change the contrast and brightness of the images. On each image, the distance between the round window and the stapes and also the thickness of the incudostapedial joint were measured by the digital ruler of CT and CBCT software programs (Figures 1 to 5).

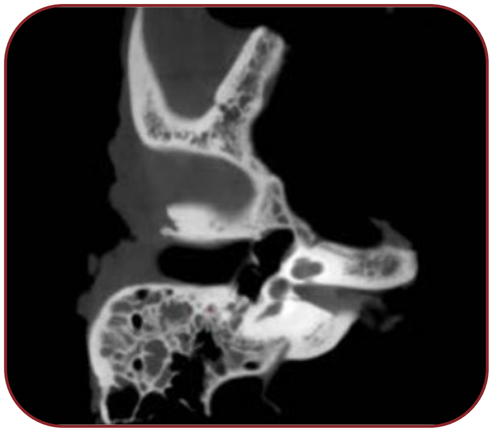

FIGURE 4. High-resolution cone-beam computed tomography (HR-CBCT) of the temporal bone

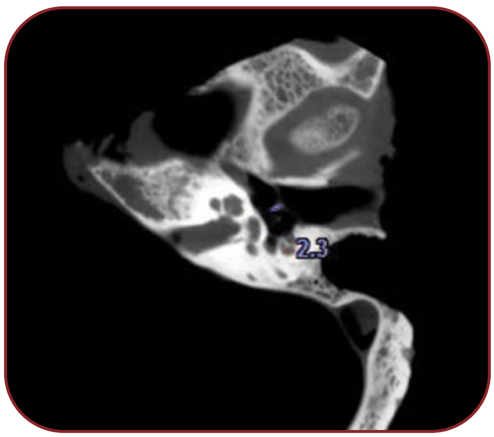

FIGURE 5. Thickness of incudostapedial joint on a high-resolution cone-beam computed tomography (HR-CBCT) image

Statistical analysis

Data were analyzed using SPSS version 23 (SPSS Inc., IL, USA). The Shapiro-Wilk test was applied to analyze the normality of data distribution. Considering the normal distribution of data ($P>0.05$), comparisons were made with paired t-test and Analysis of variance (ANOVA) and correlations were analyzed by the Pearson's correlation test. Level of statistical significance was set at 0.05. ❑

RESULTS

Distance between the stapes and round window

Table 1 presents the mean distance between the stapes and round window on MDCT and LR and HR-CBCT images. Significant correlations were found between the linear distance from the stapes to the round window measured on MDCT and HR-CBCT ($r=0.953$, $P<0.001$), MDCT and LR-CBCT ($r=0.948$, $P<0.001$), and HR-CBCT and LR-CBCT ($r=0.985$, $P<0.001$). Also, the inter-examiner agreement was found to be excellent.

Table 2 compares the measurement accuracy of HR and LR-CBCT and MDCT in measuring the distance between the stapes and round window by paired t-test. The mean distance between the stapes and round window on HR-CBCT was greater than that on MDCT. Paired-test showed a significant difference in the measurement accuracy of HR-CBCT and MDCT in measuring this distance ($P=0.014$). The difference in this regard was not significant between LR-CBCT and MDCT ($P=0.102$). The measurement accuracy of HR-CBCT was also significantly different from that of LR-CBCT in this respect ($P=0.027$).

Thickness of the incudostapedial joint

Table 3 presents the mean thickness of the incudostapedial joint measured on MDCT and HR and LR-CBCT images. Significant correlations were found between the measured incudostapedial joint thickness on MDCT and HR-CBCT ($r=0.908$, $P<0.001$), MDCT and LR-CBCT ($r=0.924$, $P<0.001$), and HR-CBCT and LR-CBCT ($r=0.985$, $P<0.001$). Also, the inter-examiner agreement was found to be excellent.

Variable	MDCT		HR-CBCT		LR-CBCT	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Distance between the stapes and round window	4.84	0.57	5.00	0.46	4.95	0.45

TABLE 1. Mean distance between the stapes and round window (in millimeters) on MDCT and LR and HR-CBCT images

Imaging modality	Mean	Standard deviation	Standard error	95% confidence interval		t	Degree of freedom	P-value
				Lower bound	Upper bound			
HR CBCT *vs.* MDCT	0.162	0.191	0.055	0.283	0.040	2.928	11	0.014
LR CBCT *vs.* MDCT	0.103	0.200	0.058	0.231	0.024	1.786	11	0.102
HR CBCT *vs.* LR CBCT	0.058	0.079	0.023	0.008	0.109	2.548	11	0.027

TABLE 2. Comparison of measurement accuracy of HR and LR-CBCT and MDCT in measuring the distance between the stapes and round window

Variable	MDCT		HR-CBCT		LR-CBCT	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Joint thickness	2.05	0.35	2.17	0.38	2.13	0.38

TABLE 3. Mean thickness of incudostapedial joint (in millimeters) measured on MDCT and HR and LR-CBCT images

Comparisons	Mean	Standard deviation	Standard error	95% confidence interval		t	Degree of freedom	P-value
				Lower bound	Lower bound			
HR CBCT *vs.* MDCT	0.117	0.159	0.046	0.015	0.218	2.537	11	0.028
LR CBCT *vs.* MDCT	0.083	0.144	0.042	-0.008	0.175	2	11	0.071
HR CBCT *vs.* LR CBCT	0.033	0.065	0.019	-0.008	0.075	1.773	11	0.104

TABLE 4. Comparison of measurement accuracy of HR and LR-CBCT and MDCT in measuring the incudostapedial joint thickness

Table 4 compares the measurement accuracy of HR and LR-CBCT and MDCT in measuring the incudostapedial joint thickness by paired t-test. The mean joint thickness measured on HR-CBCT was higher than that on MDCT and the paired t-test showed a significant difference in measurement accuracy of HR-CBCT and MDCT in this respect (P=0.014). Paired t-test showed no significant difference in measurement accuracy of LR-CBCT and MDCT (P=0.071), and HR-CBCT and LR-CBCT in this regard (P=0.104). ❑

DISCUSSION

This study compared the measurement accuracy of CBCT and MDCT for the linear distance between the stapes and round window, and the incudostapedial joint thickness for cochlear implantation treatment planning. A comparison between HR and LR-CBCT images for this purpose was made as well. The results showed a significant difference in the measured distance between the stapes and round window on MDCT and HR-CBCT, and also HR-CBCT and LR-CBCT, but the difference between MDCT and LR-CBCT was not significant. Also, a significant difference was found in incudostapedial joint thickness measured on MDCT and HR-CBCT, but the difference between HR-CBCT and LR-CBCT, and also LR-CBCT and MDCT was not significant. Significant differences between HR-CBCT and MDCT measurements have important clinical implications. So, HR-CBCT may provide superior detail for smaller anatomical structures, potentially improving diagnostic precision in complex cases, such as identifying fine fractures or variations in bone morphology. Conversely, MDCT might excel in broader diagnostic applications where high accuracy in larger regions is needed. These differences emphasize the importance of selecting the appropriate imaging modality based on the clinical question, balancing resolution requirements with radiation exposure and accessibility to optimize patient outcomes.

Burck *et al* (14) compared the accuracy of CBCT (95 kV, 120 kV) and MDCT by histological analysis of 20 temporal bone samples after placement of cochlear implant electrode. They showed significantly higher radiographic assessment of the otic capsule bony structures, cochlear wall (except for the outer part), osseous spiral lamina, electrode position, visualization of single electrode contacts on the array, and metal artifacts on CBCT, and its significantly higher overall image quality, compared with MDCT. They found no significant difference between 96 kV and 120 kV CBCT scanners. They concluded that CBCT had higher diagnostic accuracy than MDCT for temporal bone imaging for cochlear implant placement. Despite different methodology, their results were in agreement with the present findings. Debeaupte *et al* (15) compared CBCT with MDCT for detection of hearing loss in 10 adults who required temporal bone reconstruction. They reported a satisfactory agreement between MDCT and CBCT (kappa value=0.69) and concluded that CBCT is a reliable low-dose modality for evaluation of hearing loss in adults with sound tympanic membrane. They added that its superiority to MDCT for detection of middle ear pathologies such as otosclerosis has not yet been confirmed. However, the preliminary data are promising in this respect (15). Kemp *et al* (16) compared CBCT and multi-slice CT (MSCT) for diagnosis of hearing loss. They evaluated 16 landmarks in the inner ear and middle ear and showed higher image quality of HR-CBCT than MSCT. Also, the effective dosage of HR-CBCT was 69.5% lower than that of MSCT. They concluded that CBCT is a promising imaging modality for temporal bone scanning in patients with hearing loss. They also revealed comparable efficacy of CBCT and MSCT for evaluation of important clinical anatomical structures. Their results were in agreement with the present findings despite different methodologies.

Erovic *et al* (11) compared CBCT and MSCT for temporal bone imaging and concluded that the CBCT image quality was comparable to that of MSCT for evaluation of anatomical areas of the temporal bone. Although they assessed the results qualitatively, their findings were in accordance with the present results. Saeed *et al* (17) used CBCT for identification of cochlear implant electrode position in human temporal bone by evaluation of fresh frozen temporal bones with cochlear implants that were histologically sectioned. The results revealed that CBCT images optimally visualized the position of implant electrodes, and had a shorter scanning time and lower radiation those than the conventional CT. Their results were in line with the present findings.

In a prospective study, Redfors *et al* (18) assessed the anatomy and pathologies of temporal bone by MSCT and CBCT in patients with otosclerosis. They evaluated patients who had undergone stapedectomy 30 years earlier and showed that CBCT reliably revealed anatomical structures of the middle and inner ear with lower artifacts and lower radiation dose than MSCT. They concluded that CBCT may be suitable for assessment of otosclerosis patients with small otosclerotic areas and middle ear prosthesis. Their results were in accordance with the present findings. Pein *et al* (19) compared CBCT and MDCT for precise imaging of temporal bone, and middle ear structures, and reported that both modalities would yield comparably excellent results given that optimal imaging protocols are applied. They reported that CBCT with optimal protocol better revealed the stapes and incudostapedial joint, while CT with optimized protocol more clearly visualized the inner ear structures such as the modulus and osseous spiral lamina. Their results were in agreement with the present findings since in the present study, the incudostapedial joint thickness and the distance between the stapes and round window were measured on CBCT scans with acceptable accuracy. Komori *et al* (12) compared the quality of CBCT and MSCT for temporal bone assessment. They reported significantly higher image quality of CBCT compared with MSCT. They concluded that CBCT can provide images of temporal bone with higher quality and lower radiation dose than MSCT. Although they performed qualitative assessment (unlike the present study), they stated that CBCT is qualitatively valuable for evaluation of the stapes and malleus. Dahmani-Causse *et al* (12) morphologically evaluated the temporal bone by CBCT and MSCT. They concluded that, due to the higher spatial resolution of CBCT compared with MSCT, CBCT enabled a reliable morphological assessment of the temporal bone with lower radiation dose. Their methodology and type of CBCT scanner were similar to those in the present study and reported results similar to the present findings.

All the above-mentioned studies, irrespective of their *in vitro* or *in vivo* design and qualitative or quantitative nature, confirmed the comparable or even higher accuracy of CBCT than MDCT for measurements related to external, middle, or inner ear. In the present study, LR-CBCT had no significant difference with MDCT in two important measurements. However, higher values were shown by HR-CBCT compared with MDCT. Considering the higher resolution of HR-CBCT, the obtained values may be closer to the actual values; however, further studies are required to verify the accuracy of this statement.

Only one CBCT scanner and one MDCT scanner were evaluated in the present study. Also, the sample size was limited and an assessment of measurement accuracy in comparison with the actual peri-operative values was not possible. Future studies on different types and brands of CBCT and MDCT scanners with a larger sample size are required. Also, the measurements made on CBCT scans should be compared with the actual perioperative values. The accuracy of CBCT for other important measurements related to ear bones should be evaluated as well.

Furthermore, Gheorghe *et al* (20) discusses a rare congenital malformation of the middle ear. The case involves the coexistence of three anomalies: a persistent stapedial artery, oval window atresia and congenital stapes agenesis. These conditions lead to conductive hearing loss. Their report emphasizes the significance of detailed imaging and clinical examination in diagnosing such anomalies. Computed tomography scans revealed the absence of the stapes, closure of the oval window and presence of a stapedial artery. Surgical intervention was not performed due to the anatomical complexities, and alternative treatment options were considered. Moreover, the importance of anatomic variability of the inner ear region should also be subject to future comparison between CBCT and HRCT (20). Using Micro-CT imaging, a 3D model of the stapes and nearby anatomical structures was developed to assess their detailed dimensions. Measurements obtained from this model emphasized the need for precision in stapedotomy procedures, recommending an implanted piston diameter of approximately 0.6 mm and a length near 4.6 mm. During surgery, extra care should be taken to avoid damage to the facial nerve canal, ensuring patient safety and optimal outcomes (21).

This research has some limitations. The study's small sample size restricts the statistical power and robustness of the findings, making it challenging to draw definitive conclusions. Additionally, the limited sample may not fully represent the broader population, reducing the generalizability of the results. Future research should involve larger and more diverse samples to validate the findings and improve their applicability across different clinical settings (22). ❑

CONCLUSION

The results of the present study showed an acceptable accuracy of CBCT comparable to that of MDCT for measurement of the linear distance between the stapes and round window, and the incudostapedial joint thickness for cochlear implantation treatment planning. ❑

Conflicts of interest: none declared.
Financial support: none declared.

REFERENCES

1. **Saki N, Abshirini H, Bayat A, et al.** Factors affecting age of diagnosis and rehabilitation intervention in children receiving cochlear implant. *Int Tinnitus J* 2018;22:123-127.
2. **Petersen NK, Jørgensen AW, Ovesen T.** Prevalence of various etiologies of hearing loss among cochlear implant recipients: Systematic review and meta-analysis. *Int J Audiol* 2015;54:924-932.
3. **Shearer AE, Eppsteiner RW, Frees K, et al.** Genetic variants in the peripheral auditory system significantly affect adult cochlear implant performance. *Hear Res* 2017;348:138-142.
4. **Fan X, Xia M, Wang Z, et al.** Comparison of electrode position between round window and cochleostomy inserting approaches among young children: a cone-beam computed tomography study. *Acta Otolaryngol* 2018;138:815-821.
5. **Leong AC, Jiang D, Agger A, Fitzgerald-O'Connor A.** Evaluation of round window accessibility to cochlear implant insertion. *Eur Arch Otorhinolaryngol* 2013;270:1237-1242.
6. **Jiang S, Gan RZ.** Dynamic properties of human incudostapedial joint – Experimental measurement and finite element modeling. *Med Eng Phys* 2018;54:14-21.
7. **Jiang Y Jr, Liu X, Yao J, et al.** Measurement of cochlea to facial nerve canal with thin-section computed tomographic image. *J Craniofac Surg* 2013;24:614-616.
8. **Hiremath SB, Biswas A, Mndebele G, et al.** Cochlear Implantation: Systematic Approach to Preoperative Radiologic Evaluation. *RadioGraphics* 2023;43:e220102.
9. **Jain S, Gaurkar S, Deshmukh PT, et al.** Applied anatomy of round window and adjacent structures of tympanum related to cochlear implantation. *Braz J Otorhinolaryngol* 2019;85:435-436.
10. **Mahmoudinezhad SS, AryanKia A, Shooshtari SS, Moradi K.** The Effect of Mandibular Angulation on Preoperative Assessment of Dental Implant Insertion at Premolar Region: CBCT Study. *Biomed Res Int* 2022;2022:7879239. doi: 10.1155/2022/7879239.
11. **Erovic BM, Chan HH, Daly MJ, et al.** Intraoperative cone-beam computed tomography and multi-slice computed tomography in temporal bone imaging for surgical treatment. *Otolaryngol Head Neck Surg* 2014;150:107-114.
12. **Dahmani-Causse M, Marx M, Deguine O, et al.** Morphologic examination of the temporal bone by cone beam computed tomography: comparison with multislice helical computed tomography. *Eur Ann Otorhinolaryngol Head Neck Dis* 2011;128:230-235.
13. **Peltonen LI, Aarnisalo AA, Käser Y, et al.** Cone-beam computed tomography: A new method for imaging of the temporal bone. *Acta Radiol* 2009;50:543-548.
14. **Burck I, Schneider SV, Balster S, et al.** Radiohistologic Comparison Study of Temporal Bone Specimens After Cochlear Implant Electrode Array Insertion: Is Cone-Beam CT Superior to MDCT? *AJR Am J Roentgenol* 2021;216:752-758.
15. **Debeaupte M, Hermann R, Pialat JB, et al.** Cone beam *versus* multi-detector computed tomography for detecting hearing loss. *Eur Arch Otorhinolaryngol* 2019;276:315-321.
16. **Kemp P, Stralen J van, de Graaf P, et al.** Cone-Beam CT Compared to Multi-Slice CT for the Diagnostic Analysis of Conductive Hearing Loss: A Feasibility Study. *J Int Adv Otol* 2020;16:222-226.
17. **Saeed SR, Selvadurai D, Beale T, et al.** The use of cone-beam computed tomography to determine cochlear implant electrode position in human temporal bones. *Otol Neurotol* 2014;35:1338-1344.
18. **Redfors YD, Gröndahl HG, Hellgren J, et al.** Otosclerosis: anatomy and pathology in the temporal bone assessed by multi-slice and cone-beam CT. *Otol Neurotol* 2012;33:922-927.
19. **Pein MK, Brandt S, Plontke SK, Kösling S.** Darstellung subtiler Schläfenbeinstrukturen. *In-vivo*-Vergleich digitale Volumentomographie *vs.* Multidetektor-CT (Visualization of subtle temporal bone structures. Comparison of cone beam CT and MDCT). *Radiologe* 2014;54:271-278.
20. **Gheorghe DC, Epure V, Oprea D, et al.** Persistent Stapedial Artery, Oval Window Atresia and Congenital Stapes Agenesis-Case Report. *Medicina* (Kaunas) 2023;59:461.
21. **Gong L, Feng Y, Tang X, et al.** Variation of the stapes and its surrounding anatomical structures based on micro-computed tomography. *Folia Morphologica* 2024;83:401-411.