Research Article

The Correlation Between Severity Of Microtia And Abnormal CT Findings Of Ossicular Malformation And Hemifacial Microsomia

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Abstract

Background: Microtia is a congenital malformation of the pinna frequently associated with anomalies of the temporal bone and maxillofacial structures, arising from the shared embryological origin of the first and second branchial arches. In Indonesia, cases of syndromic microtia which accompanied by other congenital anomalies such as hemifacial microsomia (HFM) are more prevalent than isolated microtia. Understanding the correlation between the clinical severity of microtia and the status of the ossicles and other middle ear structures is crucial for planning complex reconstructive surgeries. **Objective**: To analyze the correlation between the severity of microtia, based on the Hunter classification, with ossicular malformations and the severity of hemifacial microsomia using the Pruzansky-Kaban classification via High-Resolution Computed Tomography (HRCT) of the temporal bone. **Methods**: This analytical observational study was conducted on 86 samples from microtia patients at Universitas Airlangga Hospital between 2020 and 2026. Microtia severity was clinically assessed using the Hunter classification, while ossicular malformations (malleus, incus, stapes) and HFM grades were evaluated using temporal HRCT by radiologists. Bivariate data analysis was performed using Spearman's correlation and Chi-square tests with a 95% confidence interval ($p<0.05$). **Results**: Sample characteristics showed a male predominance (ratio of 1.69:1) and frequent right-sided unilateral involvement. Significant strong correlations were found between microtia severity and malformations of the malleus ($r=0.748$; $p=0.000$), incus ($r=0.732$; $p=0.000$), and stapes ($r=0.722$; $p=0.000$). A moderate correlation ($r=0.410$; $p=0.000$) was observed between microtia severity and hemifacial microsomia. The correlation with external auditory canal (EAC) anomalies was strong ($r=0.733$; $p=0.000$), whereas the association with round window anomalies was weak ($r=0.381$; $p=0.006$). Approximately 32.6% of the microtia samples were associated with HFM. Despite the evident linear correlation, individual variations were noted where mild-grade microtia could still present with complex ossicular malformations. **Conclusion**: The severity of microtia is significantly and linearly correlated with the degree of ossicular malformation (particularly the malleus-incus complex) and the severity of hemifacial microsomia. However, due to internal anatomical variations that do not always mirror the external clinical appearance, temporal HRCT remains a mandatory modality for the preoperative evaluation of microtia.

Keywords: Microtia, Ossicular Malformation, Hemifacial Microsomia, Temporal HRCT, Hunter Classification.

1 Introduction

Abnormalities of the ear have been documented since prehistoric times, with the earliest surgical records found in the Edwin Smith Papyrus and Sushruta Samhita, which describe methods of reconstructing traumatically injured auricles. Contemporary ear reconstruction practice has since evolved to encompass a wide spectrum of congenital defects, including what is known as microtia, a condition characterized by a smaller and typically malformed auricle, and anotia, in which the auricle is entirely absent. The term microtia derives from two words: micro, meaning small, and otia, meaning ear. Microtia is defined as an auricle of reduced size. Microtia is a malformation of the auricle ranging from mild deformity to complete absence (anotia). Microtia is frequently associated with temporal bone anomalies. Temporal bone anomalies include ossicular abnormalities, anomalies of the relationship between the oval and round windows with the cochlea, developmental aeration anomalies of the middle ear, and anomalies of the facial nerve. Microtia may present as a spectrum of disease in isolation or may manifest as an isolated phenotype (Isolated Microtia). On the other hand, microtia may also manifest as part of various disorders and syndromes, commonly referred to as syndromic microtia [1].

Previous research on the global prevalence of microtia has demonstrated considerable geographic and ethnic variation. Although many references cite an occurrence of 3 to 5 per 10,000 live births, higher frequencies have been recorded in certain ethnic groups, such as the Navajo population at 12 per 10,000 births and the population of Chile at 8.8 per 10,000. Another study reported that in Wales, the prevalence of microtia was previously noted at 1.11 per 10,000 births, which is slightly higher than the Western European average of 0.88 per 10,000 births. Other studies indicate that Asian races and ethnicities also have a relatively high incidence of microtia, with a prevalence ratio of 2.2 to 3.2 per 10,000 births [2].

Approximately 90% of microtia cases affect only one ear (unilateral), while 10% are bilateral. The right ear is most frequently affected, with a ratio of approximately 3:2, and the condition is more common in males than females (3:2). In Indonesia, epidemiological data also demonstrates the same characteristics, namely male predominance and unilateral dominance on the right side [3]. Unlike the global epidemiological figures, which largely consist of isolated microtia, in Indonesia most patients with microtia present alongside other congenital anomalies, or syndromic microtia, with hemifacial microsomia being one of the most frequently encountered associated congenital anomalies [4].

Radiology plays a very important role in the diagnosis and management of microtia, particularly in evaluating the middle ear structures. Although the diagnosis of microtia itself can be made through physical examination alone, radiological imaging is necessary for planning reconstructive procedures. High-Resolution Computed Tomography (HRCT) of the temporal bone is the gold standard modality for evaluating the ossicular structures, the middle ear, the External Auditory Canal (EAC), and mastoid pneumatization. Temporal bone HRCT using a multidetector CT scanner (64 slices or more) provides excellent anatomical detail for evaluation of the middle and outer ear. In the context of microtia, scoring systems for surgical reconstruction candidacy also use temporal HRCT findings as a data basis. Temporal HRCT is currently used extensively to evaluate the middle ear not only in microtia and other congenital cases, but also in cases of infection and malignancy of the middle ear [5].

Embryologically, the outer ear, including the auricle, is closely related to the middle ear and the mandibular bone, as they share the same embryological origin. The middle ear and outer ear develop from the first and second branchial arches of the mesoderm and the first pharyngeal pouch of the endoderm between the fourth and 30th weeks of gestation. Anomalous development of the first pharyngeal pouch leads to disturbances of the Eustachian tube and tympanic and mastoid pneumatization. Failure of differentiation of the first branchial arch results in malformation of the incudomalleal joint, the tensor tympani muscle, and the mandible. Failure of differentiation of the second branchial arch affects the facial nerve canal, the stapedius muscle, the inferior portion of the ossicular chain, and the styloid process. Disturbances of the first and second branchial arches also result in auricular cartilage dysplasia. This explains why ossicular malformation and hemifacial microsomia, characterized by mandibular malformation, frequently accompany microtia [6].

Reconstructive surgery (correction surgery) is the primary treatment for microtia, encompassing auricular reconstruction, reconstruction of the outer and middle ear (canaloplasty and tympanoplasty), and maxillofacial reconstruction when associated congenital anomalies of the maxillofacial bony structures are present. Several scoring systems have been developed to assist clinicians in selecting ideal surgical candidates for correction surgery, including the Jahrsdoerfer Grading System, the Modified Jahrsdoerfer Grading System, and the Active Middle Ear Implant Score (AMEI Score). Ossicular malformation carries a considerable scoring weight within these systems. Ossicular malformation makes reconstruction more complex and requires prostheses, with inconsistent postoperative outcomes. These facts give rise to the hypothesis that the degree of microtia severity is related to the degree of severity of middle ear anomalies, particularly ossicular malformation [7].

The greater prevalence of syndromic microtia compared to isolated microtia has heightened attention toward hemifacial microsomia in microtia cases in Indonesia. As with microtia, the treatment of hemifacial microsomia is correction surgery, including distraction osteogenesis, fibular free flap, and other orthopedic management, depending on the severity of hemifacial microsomia. Scoring systems commonly used for the classification of hemifacial microsomia include the Pruzansky classification, the Pruzansky-Kaban classification, and the OMENS classification. These classifications are partly based on malformation of the mandibular bone and the temporomandibular joint. Like the outer and middle ear, the mandibular bone and temporomandibular joint originate from the branchial arch. This shared embryological developmental origin raises the hypothesis that the degree of microtia severity is closely related to the degree of hemifacial microsomia severity [8]. On the other hand, studies examining the relationship between the severity of microtia and the severity of ossicular malformation and hemifacial microsomia in syndromic microtia have not been widely conducted. Research assessing the accuracy and relationship of the Jahrsdoerfer Grading System, the Modified Jahrsdoerfer Grading System, and the Active Middle Ear Implant Score (AMEI Score) with the degree of microtia severity has been conducted extensively. However, a detailed discussion of the relationship between ossicular malformation and other middle ear structures as components of assessment and the degree of microtia severity is not commonly found. Similarly, the degree of hemifacial microsomia severity has not been specifically addressed. Many previous studies state that hemifacial microsomia is a congenital anomaly that frequently accompanies microtia. However, there is no literature that specifically examines the relationship between the degree of microtia severity and the degree of severity of ossicular malformation, other middle ear structures, and hemifacial microsomia.

Based on these issues, this study focuses on evaluating the relationship between the degree of microtia severity and ossicular malformation, as well as the relationship between the degree of microtia severity and the severity of hemifacial microsomia. Specifically, this study aims to analyze the association between the degree of microtia severity and the degree of ossicular malformation, and to determine the relationship between the degree of microtia severity and the severity of hemifacial microsomia.

2 Methods

2.1 Type and Research Design

This study is an analytical observational study with a retrospective research design.

2.2 Population and Study Sample

The population consists of temporal HRCT results of microtia patients from 2020 to 2026 at Universitas Airlangga Hospital. The study sample consists of temporal HRCT results of microtia patients from 2020 to 2026 at Universitas Airlangga Hospital that met the inclusion and exclusion criteria, with total sampling as the sampling method. Sampling was conducted using consecutive sampling. This is a non-probability sampling technique in which every patient meeting the inclusion and exclusion criteria is included in the study within the designated time period.

2.3 Research Variables and Operational Definitions

The degree of severity of microtia, ossicular malformation, and hemifacial microsomia, anatomical anomalies of the External Auditory Canal, middle ear aeration, anatomical anomalies of the oval and round windows, and mastoid pneumatization were assessed through temporal HRCT. The degree of microtia severity serves as the independent variable, while the other variables serve as dependent variables.

2.4 Research Criteria

The inclusion criteria for this study consist of temporal HRCT results meeting the study criteria and complete, accessible patient medical records. The exclusion criteria include a history of ear trauma and the presence of degenerative conditions such as otosclerosis. The instrument used in this study was a Siemens 128-slice CT scanner with serial number 14587. The study was conducted at the Radiology Installation of Universitas Airlangga Hospital, Surabaya, with microtia patients during the period 2020 to 2026 as the study subjects.

2.5 Data Analysis

Data analysis was performed using SPSS software version 27 to obtain the characteristics of the study sample, presented in the form of mean values and percentages (%).Descriptive analysis was conducted by grouping the examination results based on age, gender, and radiological findings obtained.

Quantitative analysis consisted of univariate and bivariate analyses. Univariate analysis was used to describe the severity profile of microtia, ossicular malformation severity, hemifacial microsomia severity, anatomical anomalies of the External Auditory Canal (EAC), middle ear aeration, anatomical anomalies of the oval and round windows, and mastoid pneumatization. Subsequently, bivariate analysis was conducted to examine the relationship between the degree of microtia severity as the independent variable and the various dependent variables. The relationships between the degree of microtia severity and ossicular malformation, degree of hemifacial microsomia severity, EAC anatomical anomalies, and mastoid pneumatization were analyzed using the Spearman rank correlation test. Meanwhile, the relationships between the degree of microtia severity with middle ear aeration and the anatomical anomalies of the oval and round windows were analyzed using the Chi-square test.

2.6 Research Ethics

The study was conducted following approval from the Medical Research Ethics Committee of UNAIR / Universitas Airlangga Hospital, submitted prior to the commencement of the study. The study utilized secondary data in the form of raw results from HRCT examinations, retrospectively obtained from medical records in accordance with applicable regulations and permissions. All data used were ensured confidentiality by removing subject identifiers (de-identification), thereby ensuring that patient privacy and confidentiality remained protected throughout the research process.

3 Results

3.1 Descriptive Characteristics of the Sample

3.1.1. Sample Availability. This study assessed the relationship between the degree of microtia severity and ossicular malformation and hemifacial microsomia. From a review of medical records from January 2020 to February 2026, a total of 45 patients with a diagnosis of microtia were identified at Universitas Airlangga Hospital. All samples had no history of trauma or degenerative abnormalities. Due to the unavailability of raw Computed Tomography (CT) data in the form of temporal HRCT, 2 samples were excluded because they could not be adequately used to evaluate the ossicles and mandibular bone, making classification according to the Pruzansky-Kaban criteria for hemifacial microsomia unfeasible. Only 43 patient samples remained available for further analysis.

3.1.2. Microtia Profile. The microtia profile was further analyzed based on gender, age distribution at the time of temporal HRCT examination, and the side of the ear affected by microtia. Of the 43 samples, 27 were male (62.8%) and 16 were female (37.2%). Of the total 43 samples, 13 (30.2%) were patients with bilateral microtia, and 30 (69.8%) were patients with unilateral microtia, consisting of 18 patients (41.9%) with right unilateral microtia and 12 patients (27.9%) with left unilateral microtia.

Of the 43 samples, the youngest patient was 4 months old and the oldest was 38 years old. The mean age was 14 years. The age range with the highest number of patients undergoing temporal HRCT examination was the first decade of life, with 17 patients (39.5%), three of whom were under one year of age.

Each right and left auricle was analyzed separately, so that from 43 patient samples, 86 ear samples from the right and left sides were obtained. In this case, the severity profile of microtia based on the Hunter classification from 86 ear samples showed that 56 ear samples (65.1%) had microtia and 30 ears were normal (34.9%). Of the 56 microtia samples, 7 (8.1%) were Grade I, 28 (32.6%) were Grade II, 18 (20.9%) were Grade III, and 3 (3.5%) were Grade IV.

3.1.3. Ossicular Malformation Profile. Of the 86 samples, 35 (40.7%) had a normal malleus, 33 (38.4%) had a deformity, and 18 (20.9%) had an absent malleus. The dimensions of the 35 samples with a normal malleus were measured. The dimensions measured included the manubrium length, the head-neck length, and the malleus angle. The mean manubrium length was 3.512 mm, the head-neck length was 3.2 mm, and the malleus angle was 131.226 degrees.

Of the 86 samples, 34 (39.5%) had a normal incus, 34 (39.5%) had a deformity, and 18 (20.9%) had an absent incus. The dimensions of the 34 samples with a normal incus were measured. The mean total incus length was 4.704 mm, the head-neck length was 3.359 mm, and the incus angle was 51.933 degrees.

Of the 86 samples, 33 (38.4%) had a normal stapes, 24 (27.9%) had a deformity, and 29 (33.7%) had an absent stapes. There were 33 samples with a normal stapes whose dimensions were measured. The mean head-to-footplate distance was 3.249 mm, the head-neck length was 2.273 mm, and the incus-stapes angle was 51.637 degrees.

3.1.4. External Auditory Canal (EAC) Profile and Middle Ear. The External Auditory Canal (EAC) is the canal connecting the outside world to the middle ear. The EAC profile characteristics from the 86 samples showed that 35 ear samples (40.7%) had a normal EAC, 14 samples (16.3%) had EAC deformity, and 37 samples (43.0%) had an absent EAC.

The middle ear, also referred to as the tympanic cavity, is an air-filled space within the petrous portion of the temporal bone located between the tympanic membrane (outer ear) and the inner ear. Of the 86 samples, 52 ear samples (60.5%) had adequate middle ear aeration and 34 samples (39.5%) had inadequate aeration.

3.1.5. Oval Window Profile. Of all samples, 52 ear samples (60.5%) had an open oval window and 34 samples (39.5%) had a closed oval window.

3.1.6. Round Window Profile. Of all samples, 49 ear samples (57%) had an open round window and 37 samples (43%) had a closed round window.

3.1.7. Mastoid Pneumatization Profile. Mastoid pneumatization is classified into three types: pneumatic, diploic, and sclerotic. In this study, 45 ear samples (52.3%) had a pneumatic-type mastoid, 12 samples (14.0%) were diploic type, and 29 samples (33.7%) had a sclerotic mastoid.

3.1.8. Hemifacial Microsomia Profile. The degree of hemifacial microsomia severity was measured using the Pruzansky-Kaban classification. The hemifacial microsomia profile characteristics show that of the 86 samples, 28 ear samples (32.6%) had hemifacial microsomia and 58 samples (67.4%) were normal. Of the 28 hemifacial microsomia samples, 9 (10.5%) were Grade I, 10 (11.6%) were Grade IIA, and 9 (10.5%) were Grade IIB. No hemifacial microsomia sample fell into Grade III.

3.2 Bivariate Correlation Analysis Between the Degree of Microtia Severity and Ossicular Malformation and the Degree of Hemifacial Microsomia

There were 86 samples in this study with ordinal data of two or more categories in both the independent and dependent variables. The independent variable was the degree of microtia severity, while the dependent variables were ossicular malformation and the degree of hemifacial microsomia. For ordinal data with two or more categories, Spearman's correlation test was used. Bivariate analysis was interpreted using a p value considered significant if $p < 0.05$ with a 95% confidence interval in this study. Correlation coefficient testing was also conducted, with correlation strength ranges divided into five groups: very weak (0.000-0.200), weak (0.201-0.400), moderate (0.401-0.600), strong (0.601-0.800), and very strong (0.801-1.000).

3.2.1. Correlation Test Between the Degree of Microtia Severity and Malleus Malformation. Data analysis was performed to examine the relationship between the degree of microtia severity and the degree of malleus ossicular malformation as listed in Table 1. The calculation used a 95% confidence interval and p values were considered significant if $p < 0.05$.

Table 1: Results of the Correlation Test Between the Degree of Microtia Severity and Malleus Malformation

Degree of Microtia Severity	Malleus Malformation			Total	r	P Value
	Normal	Deformity	Absent			
Normal	29 (96.7%)	1 (3.3%)	0	30	0.748	0.000*
Grade I	1 (14.3%)	6 (85.7%)	0	7		
Grade II	4 (14.3%)	15 (53.6%)	9 (32.1%)	28		
Grade III	1 (5.6%)	10 (55.6%)	7 (38.9%)	18		
Grade IV	0	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, $p < 0.05$

In the profile of microtia severity, the majority of samples with a normal auricle did not have malleus malformation, totaling 29 samples (96.7%). Only a small number of samples had deformity, specifically one sample (3.3%). For samples with low severity (Grade I), there was 1 sample (14.3%) with a normal malleus, 6 samples (85.7%) with deformity, and no samples with malleus agenesis. The rates of malleus deformity and agenesis increased in samples with Grade II and Grade III microtia severity, with malleus deformity samples numbering 15 (53.6%) and 10 (55.6%) respectively, and malleus agenesis samples numbering 9 (32.1%) and 7 (38.9%) respectively. In this study, only 3 samples had Grade IV microtia severity or anotia, with 1 sample (33.3%) having malleus deformity and 2 samples (66.7%) with malleus agenesis.

Analysis via bivariate methods revealed a p-value of 0.000, which is less than 0.05 and confirms a significant association between microtia severity level and malleus ossicle deformity. Furthermore, the correlation statistic, $r = 0.748$, lies within the 0.601 to 0.800 interval, which is categorized as a strong correlation.

3.2.2. Correlation Test Between the Degree of Microtia Severity and Incus Malformation. The data were analyzed to assess the association between microtia severity and the extent of incus ossicular malformation, as presented in Table 2. All computations applied a 95% confidence interval, and a p value below 0.05 was the criterion for statistical significance.

Table 2: Results of the Correlation Test Between the Degree of Microtia Severity and Incus Malformation

Degree of Microtia Severity	Incus Malformation			Total	r	P Value
	Normal	Deformity	Absent			
Normal	28 (93.3%)	2 (6.7%)	0	30	0.732	0.000*
Grade I	0	7 (100%)	0	7		
Grade II	5 (17.9%)	15 (53.5%)	8 (28.6%)	28		
Grade III	1 (5.6%)	9 (50.0%)	8 (44.4%)	18		
Grade IV	0	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, $p < 0.05$

In the profile of microtia severity, the majority of samples with a normal auricle did not have incus malformation, totaling 28 samples (93.3%). Only a small number of samples had deformity, specifically 2 samples (6.7%). For samples with low severity (Grade I), all 7 samples (100%) had deformity and no samples had a normal incus. The

rates of incus deformity and agenesis increased in samples with Grade II and Grade III microtia severity, with incus deformity samples numbering 15 (53.6%) and 9 (50.0%) respectively, and incus agenesis samples numbering 8 (28.6%) and 8 (44.4%) respectively. In this study, only 3 samples had Grade IV microtia severity or anotia, with 1 sample (33.3%) having incus deformity and 2 samples (66.7%) with incus agenesis.
The bivariate test produced a p value of 0.000, which is below the 0.05 significance threshold. This finding confirms a meaningful association between microtia severity grade and incus ossicular malformation. The resulting correlation coefficient, r = 0.732, places this relationship into the strong correlation bracket, as it lies within the 0.601 to 0.800 range.

3.2.3. Correlation Test Between the Degree of Microtia Severity and Stapes Malformation. To assess how the degree of microtia severity relates to the degree of stapes ossicle deformity shown in Table 3, an analysis of the data was undertaken. All computations incorporated a 95% confidence level, and p values less than 0.05 were treated as significant.

Table 3: Results of the Correlation Test Between the Degree of Microtia Severity and Stapes Malformation

Degree of Microtia Severity	Stapes Malformation			Total	r	P Value
	Normal	Deformity	Absent			
Normal	28 (93.3%)	2 (6.7%)	0	30	0.722	0.000*
Grade I	0	4 (57.1%)	3 (42.9%)	7		
Grade II	4 (14.3%)	12 (42.9%)	12 (42.9%)	28		
Grade III	1 (5.6%)	5 (27.8%)	12 (66.7%)	18		
Grade IV	0	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, $p < 0.05$

In the profile of microtia severity, the majority of samples with a normal auricle did not have stapes malformation, totaling 28 samples (93.3%). Only a small number of samples had deformity, specifically two samples (6.7%). For samples with low severity (Grade I), there were 4 samples (57.1%) with stapes deformity, 3 samples (42.9%) with stapes agenesis, and no samples with a normal stapes. The rates of stapes deformity and agenesis increased in samples with Grade II and Grade III microtia severity, with stapes deformity samples numbering 12 (42.9%) and 5 (27.8%) respectively, and stapes agenesis samples numbering 12 (42.9%) and 12 (66.7%) respectively. In this study, only 3 samples had Grade IV microtia severity or anotia, with 1 sample (33.3%) having stapes deformity and 2 samples (66.7%) with stapes agenesis.
The bivariate analysis yielded a p value of 0.000, which falls below the 0.05 significance level. This outcome confirms a statistically meaningful relationship between microtia severity grade and stapes ossicular malformation. With a correlation coefficient of r = 0.722, the association is classified as strong, since the value sits within the 0.601 to 0.800 range.

3.2.4. Correlation Test Between the Degree of Microtia Severity and the Degree of Hemifacial Microsomia. The relationship between the severity of microtia and the severity of hemifacial microsomia, as detailed in Table 4, was examined through statistical analysis. This evaluation applied a 95% confidence interval for computations, with p values less than 0.05 considered statistically meaningful.

Table 4: Results of the Correlation Test Between the Degree of Microtia Severity and the Degree of Hemifacial Microsomia

Degree of Microtia Severity	Degree of Hemifacial Microsomia				n	r	P Value
	Normal	Grade I	Grade IIA	Grade IIB			
Normal	26 (86.7%)	3 (10.0%)	1 (3.3%)	0	30	0.410	0.000*
Grade I	5 (71.4%)	1 (14.3%)	0	1 (14.3%)	7		
Grade II	18 (64.3%)	4 (14.3%)	3 (10.7%)	3 (10.7%)	28		
Grade III	9 (50.0%)	1 (5.6%)	5 (27.8%)	3 (16.7%)	18		
Grade IV	0	0	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, $p < 0.05$

In this study, of the 86 available samples, only 28 samples (32.6%) also had hemifacial microsomia, with details of 9 samples (10.5%) at Grade I, 10 samples (11.6%) at Grade IIA, and 9 samples (10.5%) at Grade IIB. In the profile of microtia severity, the majority of samples with a normal auricle did not have hemifacial microsomia, totaling 26 samples (86.7%). Conversely, all samples with Grade IV microtia severity had hemifacial microsomia, with 1 sample (33.3%) having Grade IIA hemifacial microsomia and 2 samples (66.7%) having Grade IIB hemifacial microsomia. The percentage of hemifacial microsomia increased in line with the increasing degree of microtia severity, with percentages of 28.6% at Grade I microtia severity, 35.7% at Grade II microtia severity, 50% at Grade III microtia severity, and 100% at Grade IV microtia severity.

Results from the bivariate assessment showed a p value of 0.000, less than the 0.05 level, which demonstrates a statistically significant relationship between the degree of microtia severity and the extent of hemifacial microsomia. The correlation coefficient was measured at r = 0.410, a value that falls into the moderate correlation bracket, defined as 0.401 to 0.600.

3.2.5. Correlation Test Results Between the Degree of Microtia Severity and External Auditory Canal Anatomy. To examine how the degree of microtia severity relates to the anatomical features of the External Auditory Canal shown in Table 5, a data analysis was conducted. All computations incorporated a 95% confidence level, and results were considered significant when p values fell under 0.05.

Table 5: Results of the Correlation Test Between the Degree of Microtia Severity and EAC Anatomy

Degree of Microtia Severity	EAC Anatomy			Total	r	P Value
	Normal	Deformity	Absent			
Normal	26 (86.7%)	4 (13.3%)	0	30	0.733	0.000*
Grade I	1 (14.3%)	2 (28.6%)	4 (57.1%)	7		
Grade II	8 (28.6%)	6 (21.4%)	14 (50%)	28		
Grade III	0	2 (11.1%)	16 (88.9%)	18		
Grade IV	0	0	3 (100%)	3		

*declared to have a bivariate relationship, p < 0.05

In the profile of microtia severity, the majority of samples with a normal auricle did not have EAC malformation, totaling 26 samples (86.7%). Only a small number of samples had EAC deformity, specifically 4 samples (13.3%). For samples with low severity (Grade I), there were 2 samples (28.6%) with EAC deformity, 4 samples (57.1%) with EAC agenesis, and one sample with a normal EAC. The rates of EAC deformity and agenesis increased in samples with Grade II and Grade III microtia severity, with EAC deformity samples numbering 6 (21.4%) and 2 (11.1%) respectively, and EAC agenesis samples numbering 14 (50%) and 16 (88.9%) respectively. In this study, only 3 samples had Grade IV microtia severity or anotia, all three of which had EAC agenesis.

The bivariate test generated a p value of 0.000, which sits below the 0.05 significance threshold. This outcome confirms a statistically meaningful association between microtia severity grade and External Auditory Canal anatomy. The correlation coefficient was calculated as r = 0.733, a value that classifies this relationship as strong, since it falls within the 0.601 to 0.800 range.

3.2.6. Correlation Test Results Between the Degree of Microtia Severity and Middle Ear Aeration. A statistical evaluation was conducted to explore the association between microtia severity grade and middle ear aeration, with data provided in Table 6. The analysis employed a 95% confidence interval, and p values below 0.05 were established as the threshold for significance.

Table 6: Results of the Correlation Test Between the Degree of Microtia Severity and Middle Ear Aeration

Degree of Microtia Severity	Middle Ear Aeration		Total	r	P Value
	Aerated	Non-aerated			
Normal	28 (93.3%)	2 (6.7%)	30	0.448	0.000*
Grade I	4 (57.1%)	3 (42.9%)	7		
Grade II	12 (42.9%)	16 (57.1%)	28		
Grade III	7 (38.9%)	11 (61.1%)	18		
Grade IV	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, p < 0.05

In the profile of microtia severity, the majority of samples with a normal auricle did not have middle ear aeration disturbances, totaling 28 samples (93.3%). Only a small number of samples had aeration disturbances, specifically

two samples (6.7%). For samples with low severity (Grade I), there were 4 samples (57.1%) with adequate middle ear aeration and 3 samples with a middle ear found to have no aeration. The rate of aeration disturbance increased in samples with Grade II and Grade III microtia severity, with samples having middle ear aeration disturbance numbering 16 (57.1%) and 11 (61.1%) respectively. At Grade IV, there were 2 patients (66.7%) with aeration disturbance and 1 patient (33.3%) with adequate middle ear aeration.
With a p value of 0.000 from the bivariate analysis, the result fell under the 0.05 cutoff and therefore established a significant connection between the severity level of microtia and the level of middle ear aeration. The correlation statistic of 0.448 corresponds to a moderate degree of association, since it falls within the 0.401 to 0.600 range.

3.2.7. Correlation Test Results Between the Degree of Microtia Severity and the Oval Window. To assess how the degree of microtia severity relates to the anatomical features of the oval window shown in Table 7, a data analysis was conducted. All computations incorporated a 95% confidence level, and results were considered significant when p values fell under 0.05.

Table 7: Results of the Correlation Test Between the Degree of Microtia Severity and the Oval Window

Degree of Microtia Severity	Oval Window		Total	r	P Value
	Open	Closed			
Normal	28 (93.3%)	2 (6.7%)	30	0.476	0.000*
Grade I	5 (71.4%)	2 (28.6%)	7		
Grade II	13 (46.4%)	15 (53.6%)	28		
Grade III	5 (27.8%)	13 (72.2%)	18		
Grade IV	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, $p < 0.05$

In the profile of microtia severity, the majority of samples with a normal auricle did not have oval window anomalies, totaling 28 samples (93.3%). Only a small number of samples had a closed oval window, specifically two samples (6.7%). For samples with low microtia severity (Grade I), there were 5 samples (71.4%) with an open oval window and 2 samples with oval window anomalies. The rate of closed oval window increased in samples with Grade II and Grade III microtia severity, with samples having oval window disturbance numbering 15 (53.6%) and 13 (72.2%) respectively. At Grade IV, there were 2 patients (66.7%) with a closed oval window and 1 patient (33.3%) with an open oval window.
Results from the bivariate analysis revealed a p value of 0.000, less than the 0.05 level, which establishes a significant relationship between the degree of microtia severity and the anatomy of the oval window. The correlation coefficient was measured at $r = 0.476$, falling squarely within the moderate correlation bracket, defined as 0.401 to 0.600.

3.2.8. Correlation Test Results Between the Degree of Microtia Severity and the Round Window. To investigate how the degree of microtia severity relates to the anatomical features of the round window shown in Table 8, a data analysis was performed. All computations applied a 95% confidence level, and results were deemed significant when p values fell under 0.05.

Table 8: Results of the Correlation Test Between the Degree of Microtia Severity and the Round Window

Degree of Microtia Severity	Round Window		Total	r	P Value
	Open	Closed			
Normal	25 (83.3%)	5 (16.7%)	30	0.381	0.006*
Grade I	4 (57.1%)	3 (42.9%)	7		
Grade II	13 (46.4%)	15 (53.6%)	28		
Grade III	6 (33.3%)	12 (66.7%)	18		
Grade IV	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, $p < 0.05$

In the profile of microtia severity, the majority of samples with a normal auricle did not have oval window anomalies, totaling 25 samples (83.3%). Only a small number of samples had a closed round window, specifically 5 samples (16.7%). For samples with low microtia severity (Grade I), there were 4 samples (57.1%) with an open round window and 3 samples with round window anomalies. The number of samples with a closed round window increased in samples with Grade II and Grade III microtia severity, with samples having round window disturbance numbering 15

(53.6%) and 12 (66.7%) respectively. At Grade IV, there were 2 patients (66.7%) with an anomalies round window and 1 patient (33.3%) with an open round window.
The bivariate test produced a p value of 0.006, which falls below the 0.05 significance threshold. This result confirms a statistically meaningful association between microtia severity grade and round window anatomy. The correlation coefficient was calculated as r = 0.381, placing this relationship into the weak correlation category, which spans 0.201 to 0.400.

3.2.9. Correlation Test Results Between the Degree of Microtia Severity and Mastoid Pneumatization. A statistical evaluation was carried out to investigate the association between microtia severity grade and mastoid pneumatization, with data provided in Table 9. The analysis applied a 95% confidence interval, and p values below 0.05 were designated as the criterion for statistical significance.

Table 9: Results of the Correlation Test Between the Degree of Microtia Severity and Mastoid Pneumatization

Degree of Microtia Severity	Mastoid Pneumatization			Total	r	P Value
	Pneumatic	Diploic	Sclerotic			
Normal	26 (86.7%)	2 (6.7%)	2 (6.7%)	30	0.545	0.000*
Grade I	4 (57.1%)	1 (14.3%)	2 (28.6%)	7		
Grade II	11 (39.3%)	5 (17.9%)	12 (42.9%)	28		
Grade III	4 (22.2%)	3 (16.7%)	11 (61.1%)	18		
Grade IV	0	1 (33.3%)	2 (66.7%)	3		

*declared to have a bivariate relationship, p < 0.05

In the profile of microtia severity, the majority of samples with a normal auricle had a pneumatic-type mastoid appearance, totaling 26 samples (86.7%). Only a small number of samples showed a diploic or sclerotic mastoid appearance, 2 samples each (6.7%). For samples with low severity (Grade I), there were 4 samples (57.1%) with a pneumatic mastoid appearance, 1 sample (14.3%) with a diploic mastoid, and 2 samples with a sclerotic mastoid (28.6%). The number of samples with a sclerotic mastoid increased in samples with Grade II and Grade III microtia severity, numbering 12 (42.9%) and 11 (61.1%) respectively. In this study, only 3 samples had Grade IV microtia severity or anotia, with one sample having a diploic mastoid and two samples having a sclerotic mastoid.
Results from the bivariate analysis revealed a p value of 0.000, less than the 0.05 level, which establishes a significant relationship between the degree of microtia severity and the extent of mastoid pneumatization. The correlation coefficient was measured at r = 0.545, a value that falls into the moderate correlation bracket, defined as 0.401 to 0.600.

4 Discussion

4.1 Demographic Analysis

The gender distribution of microtia patients in this study demonstrated male predominance, with a male-to-female ratio of 1.69:1. This ratio is consistent with several other studies indicating slight male dominance. The distribution of clinical characteristics of microtia patients in this study was unilateral dominance on the right side. International research similarly demonstrates that approximately 90% of microtia patients have a unilateral characteristic, with the remainder being bilateral microtia. The unilateral right-sided dominance characteristic is also consistent with previous research conducted by Gunadiputri et al. [4].
The age range at which temporal HRCT was performed in microtia patients in this study was most frequently within the 1-to-10-year age range. This is consistent with several references stating that temporal HRCT examination in microtia patients for reconstructive surgical planning is optimally performed when the patient is 5 to 6 years of age. This is because at this age range, the temporal bone has developed well. This age range is also consistent with the timeline for planning auricular reconstruction and atresiaplasty surgery [9].
In this study, the dimensions of the ossicles of all samples were measured. The malleus was measured for manubrium dimensions, head-neck distance, and the angle between the manubrium and head-neck, referred to as the malleus angle. The incus was measured for total length, total width, and the angle formed between the short process and long process, referred to as the incus angle. The stapes was measured for head-to-footplate distance, footplate length, and the angle between the anterior and posterior crura, referred to as the stapes angle.
Several previous studies have been conducted regarding ossicular dimension measurements. Among them is the study by Jain et al., which used temporal HRCT on living patients and cadavers. Another study by Mudhol et al.

performed ossicular dimension measurements directly on ossicles extracted from cadavers using standardized measuring instruments [10], [11].
Considerable differences are apparent between this study and the other two studies. The studies by Jain et al. and Mudhol et al. were conducted in India, which naturally differs ethnically from the sample population of this study. Differences in population may also account for differences in measurement results, as the population of this study consisted of microtia patients, whereas the populations of Jain et al. and Mudhol et al. were drawn from individuals without ear complaints. Differences in measurement methods between imaging-based temporal HRCT measurements and direct measurements may yield considerably different results. Differences in the CT scanner used may also lead to significant discrepancies between studies [12].
In addition to the ossicles, several other middle ear structures were also examined in this study, including the oval window, the round window, middle ear aeration, the External Auditory Canal, and mastoid pneumatization. The prevalence of abnormalities found in patients tended to increase significantly in patients with Grade II microtia and above. This tendency means that patients with Grade II microtia and above require particular attention, especially in the screening of ear anomalies.
Microtia patients with associated hemifacial microsomia were found in 28 samples, or 32.6% of the total sample. This distribution of hemifacial microsomia is consistent with the study by Keogh et al., which found in their study that 40% of microtia samples were accompanied by hemifacial microsomia [1]. This finding is also consistent with research by Gunadiputri et al., which found that hemifacial microsomia is one of the primary anomalies accompanying microtia [4].

4.2 Bivariate Correlation Analysis Between the Degree of Microtia Severity and Ossicular Malformation

The results of the bivariate correlation test between the degree of microtia severity and ossicular malformation in this study showed a significant and strong relationship between microtia grade and each ossicle, namely the malleus, incus, and stapes, with the strongest correlation shown by the malleus, followed by the incus and stapes. This indicates that there is a linear relationship between the degree of microtia severity and the degree of ossicular malformation, with the malleus and incus (malleus-incus complex) demonstrating more consistent anomalies in line with microtia grade compared to the stapes.
Several previous studies have shown varied results. Studies by Kountakis et al. and Mayer et al. demonstrated that microtia grading has a significant relationship with ossicular malformation [13], [14]. Meanwhile, other studies by Patil et al. and Gautam et al. noted that the relationship between the two variables was significant [15], [16].
In embryological development, the ossicles and the auricle originate from the same embryological tissue, namely the first branchial arch. The auricle derives from the first branchial cleft, while the ossicles, consisting of the malleus, incus, and stapes, have the malleus and incus originating from the neural crest of the first branchial arch, and the stapes originating from the neural crest of the second branchial arch. Disruption during embryological development may allow the simultaneous occurrence of microtia and ossicular malformation. If the disruption only affects the first and second branchial clefts without involving the neural crest portion of the first branchial arch, then the abnormality occurs only in the auricle. Conversely, if the disruption only occurs in the neural crest without involving the first branchial cleft, ossicular malformation may occur without accompanying microtia. This sequence also explains why the correlation between the degree of microtia severity and the malleus and incus are more consistent compared to the stapes [17]. On the other hand, this study also found individual variation in which mild-grade microtia sometimes presented with complex ossicular malformation. This finding implies that the degree of microtia severity cannot be used as a fully accurate criterion for anticipating the presence and severity of associated ossicular malformation. Temporal HRCT remains a mandatory modality to be performed, because even though the clinical correlation found is evident, internal anatomical appearance does not always correspond to the degree of microtia severity visible externally [18].

4.3 Bivariate Correlation Analysis Between the Degree of Microtia Severity with the EAC and Middle Ear Structures

In addition to ossicular malformation, other outer and middle ear structures were also analyzed in this study. The outer ear structure examined was External Auditory Canal patency. The middle ear structures examined in this study included middle ear aeration, oval and round window anomalies, and mastoid pneumatization.
Bivariate analysis results showed that the degree of microtia severity has a strong and unidirectional relationship with EAC anatomical anomalies. Frequency data demonstrated a contrasting profile between normal ears and microtia ears. In the normal ear group, all samples (100%) had a normal EAC. In contrast, in Grade II microtia, variation began to appear, with 14.3% having deformity (stenosis) and 42.9% having absent EAC (atresia). This

condition reached its peak at Grade III and Grade IV microtia, where absent EAC or atresia was found in 100% of samples. Embryologically, this close relationship can be explained through the process of outer ear formation. The EAC forms from the dorsal portion of the first branchial cleft. Around the 8th week of gestation, epithelial cell proliferation occurs, forming the meatal plug. If a developmental disturbance occurs at this time, which is also the critical period for auricle formation from the six hillocks of His, then the canalization of the EAC will fail or be incomplete. This is consistent with the literature from Wilson et al. and Johnson et al. regarding first and second branchial arch syndrome. Because the auricle and EAC share an embryological origin and a closely adjacent developmental timeline, a defect in one structure will almost certainly involve the other [17], [18].
Regarding the middle ear structures, the relationship between the degree of microtia severity and middle ear aeration and oval and round window anatomical anomalies showed a linear relationship of weak to moderate strength. The relationship between the degree of microtia severity and mastoid pneumatization showed a moderate linear relationship. This study also found individual variation in which mild-grade microtia sometimes presented with complex middle ear anomalies. From an embryological developmental perspective, the auricle and the middle ear structures both originate from the first branchial arches, with the distinction being that the auricle develops from the first branchial cleft while the middle ear and mastoid air cells originate from the first pharyngeal pouch. This explains why the relationship between the degree of microtia severity and the middle ear structures and mastoid shows a weaker and less consistent linear relationship compared to ossicular malformation or the EAC. The results of this study support the findings of research by Patil et al. and Gautam et al., which stated that the clinical grade of microtia does not always precisely reflect the complexity of internal malformation, so HRCT remains the gold standard in the evaluation of microtia patients [16]. However, the correlation found in this study affirms that initial clinical assessment of the auricle still plays an important role as a "red flag" for clinicians to be alert to the possibility of more severe middle ear anomalies. This is also in line with research by Ishimoto et al., which found that the more developed the auricle, the better developed the middle ear [19].

4.4 Bivariate Correlation Analysis Between the Degree of Microtia Severity and Hemifacial Microsomia

The results of the correlation test between the degree of microtia severity and the degree of hemifacial microsomia in this study showed a significant correlation of moderate strength. Several previous studies have shown the same finding. Research by Gautam et al. demonstrated a significant correlation between microtia grading and dysplastic temporomandibular joint. Mayer et al. also stated in their study that a relationship exists between mandibular condyle dysplasia and the degree of microtia severity [14].
In syndromic microtia cases, screening for hemifacial microsomia must be conducted, because epidemiologically, hemifacial microsomia is the congenital anomaly most frequently accompanying microtia, with 72% of syndromic microtia cases accompanied by hemifacial microsomia as one of the associated congenital anomalies. Of that percentage, in 44.8% of cases hemifacial microsomia is the sole associated congenital anomaly [20].
From an embryological developmental perspective, the auricle and the mandible, particularly the temporomandibular joint through the condyle and mandibular ramus, originate from the same embryological tissue. The auricle derives from the first branchial cleft, while the mandible derives from the neural crest of the first branchial arch. Disruption during embryological development may allow the simultaneous occurrence of microtia and ossicular malformation. If the disruption involves the first branchial cleft and the neural crest of the first branchial arch, then the clinical picture of hemifacial microsomia may accompany microtia. These data imply that microtia has a significant relationship with hemifacial microsomia, but cannot be used as a predictor of hemifacial microsomia severity. In line with the findings of Paul et al., this study also affirms that because microtia is often part of a syndromic condition such as hemifacial microsomia, clinicians in practice must perform systematic screening and not focus solely on the ear [6]. If severe-grade microtia is found, the risk of other craniofacial malformations becomes very high, necessitating a diagnostic approach that goes beyond mere otoscopic examination.

4.5 Research Limitations

The study was conducted in a single center, so the results obtained may not reflect a more diverse patient population in terms of clinical or technical characteristics of the equipment. This study used a retrospective design, meaning the data analyzed had been previously available in medical records, which limited the researcher's control over variables that may have influenced the results, such as the age at which temporal HRCT was performed in patients.

5 Conclusion

Based on the study results, the characteristics of microtia patients demonstrated male predominance, with unilateral anomalies more frequently occurring on the right side, and Grade II microtia severity being the most frequently encountered. Analysis results showed that the presence of malleus, incus, and stapes malformation had a significant and strong linear relationship with the degree of microtia severity. Furthermore, anatomical anomalies of the External Auditory Canal (EAC) also had a significant and strong linear relationship with the degree of microtia severity. Meanwhile, the presence of hemifacial microsomia, middle ear aeration anomalies, oval window anatomical anomalies, and mastoid pneumatization anomalies showed a significant and moderate linear relationship with the degree of microtia severity. Round window anatomical anomalies had a significant and weak linear relationship with the degree of microtia severity in microtia patients.

Further research is recommended to be conducted in a multi-center setting involving hospitals across various regions in order to obtain more representative data and to improve the generalizability of the research findings.

References

[1] I. J. Keogh, M. J. Troulis, A. A. Monroy, R. D. Eavey, and L. B. Kaban, “Isolated Microtia as a Marker for Unsuspected Hemifacial Microsomia,” Arch. Otolaryngol. Neck Surg., vol. 133, no. 10, pp. 997–1001, 2007, doi: 10.1001/archotol.133.10.997.

[2] D. V. Luquetti, E. Leoncini, and P. Mastroiacovo, “Microtia-anotia: A global review of prevalence rates,” Birth Defects Res. Part A Clin. Mol. Teratol., vol. 91, no. 9, pp. 813–822, 2011, doi: 10.1002/bdra.20836.

[3] M. A. Kurniadi, “Description of the Understanding and Concern of Children With Special Needs for Ear Hygiene, Ear Infection, and Hearing Health at Government Special School II Banjarmasin,” Pharmacol. Med. REPORTS, Orthop. Illn. DETAILS, vol. 1, no. 3, pp. 32–41, Feb. 2023, doi: 10.55047/comorbid.v1i3.538.

[4] D. I. Gunadiputri, I. F. Aisyah, L. Zarasade, P. Lestari, and I. L. Putri, “Microtia in Indonesia: Characteristics and Family History Analysis on the Presence of Other Congenital Anomalies in Patients With Microtia,” Cleft Palate Craniofacial J., vol. 63, no. 4, pp. 796–803, Apr. 2026, doi: 10.1177/10556656251317798.

[5] R. Gautam, J. Kumar, G. S. Pradhan, R. Meher, and S. Arya, “Congenital Aural Atresia: What the Radiologist Needs to Know?,” Curr. Probl. Diagn. Radiol., vol. 51, no. 4, pp. 599–616, 2022, doi: 10.1067/j.cpradiol.2021.06.017.

[6] A. Paul et al., “Congenital abnormalities associated with microtia: A 10-YEARS retrospective study,” Int. J. Pediatr. Otorhinolaryngol., vol. 146, p. 110764, 2021, doi: 10.1016/j.ijporl.2021.110764.

[7] S. E. Henkemans, A. L. Smit, R. J. Stokroos, and H. G. X. M. Thomeer, “Congenital Anomalies of the Ossicular Chain: Surgical and Audiological Outcomes,” Ann. Otol. Rhinol. Laryngol., vol. 131, no. 4, pp. 388–396, 2021, doi: 10.1177/00034894211025405.

[8] I. L. Putri, A. Stephanie, R. Pramanasari, M. Kon, and C. D. K. Wungu, “The role of genetic factors in microtia: A systematic review,” F1000Research, vol. 11, p. 537, 2022, doi: 10.12688/f1000research.111995.2.

[9] T. Zhang et al., “International Consensus Recommendations on Microtia, Aural Atresia and Functional Ear Reconstruction,” J. Int. Adv. Otol., vol. 15, no. 2, pp. 204–208, 2019, doi: 10.5152/iao.2019.7383.

[10] S. Jain, S. Parveen, S. Kumar, and D. Talwar, “Validated Ossicular Measurements on High-Resolution Computed Tomography (CT) in Live and Cadaveric Temporal Bones,” Cureus, vol. 14, no. 2, p. e22410, 2022, doi: 10.7759/cureus.22410.

[11] R. S. Mudhol, S. Narahari, and R. Havaldar, “Morphological and Anthropometrical Features of Human Ear Ossicles,” J. Anat. Soc. India, vol. 71, no. 2, pp. 88–92, Apr. 2022, doi: 10.4103/jasi.jasi_67_21.

[12] D. V. Kumar, D. K. Chaitanya, V. Singh, and D. S. Reddy, “A morphometric study of human middle ear ossicles in cadaveric temporal bones of Indian population and a comparative analysis,” J. Anat. Soc. India, vol. 67, no. 1, pp. 12–17, 2018, doi: 10.1016/j.jasi.2018.01.001.

[13] S. E. Kountakis, E. Helidonis, and R. A. Jahrsdoerfer, “Microtia Grade as an Indicator of Middle Ear Development in Aural Atresia,” Arch. Otolaryngol. - Head Neck Surg., vol. 121, no. 8, pp. 885–886, Aug. 1995, doi: 10.1001/archotol.1995.01890080053010.

[14] T. E. Mayer, H. Brueckmann, R. Siegert, A. Witt, and H. Weerda, “High-Resolution CT of the Temporal Bone in Dysplasia of the Auricle and External Auditory Canal,” AJNR. Am. J. Neuroradiol., vol. 18, no. 1, pp. 53–65, 1997.

[15] A. R. Patil et al., “HRCT evaluation of microtia: A retrospective study,” Indian J. Radiol. Imaging, vol. 22, no. 3, pp. 188–194, 2012, doi: 10.4103/0971-3026.107181.

[16] R. Gautam, J. Kumar, G. S. Pradhan, J. C. Passey, R. Meher, and A. Mehndiratta, “High-resolution computed tomography evaluation of congenital aural atresia – how useful is this?,” J. Laryngol. Otol., vol. 134, no. 7, pp. 610–622, 2020, doi: 10.1017/s002221512000136x.

[17] J. M. Johnson, G. Moonis, G. E. Green, R. Carmody, and H. N. Burbank, “Syndromes of the First and Second Branchial Arches, Part 1: Embryology and Characteristic Defects,” Am. J. Neuroradiol., vol. 32, no. 1, pp. 14–

19, 2010, doi: 10.3174/ajnr.a2072.
[18] M. Wilson and M. Coyle, "Embryology of the Branchial Arches," 2019, Springer International Publishing. doi: 10.1007/978-3-319-26158-4_21.
[19] S. Ishimoto et al., "Correlation Between Microtia and Temporal Bone Malformation Evaluated Using Grading Systems," Arch. Otolaryngol. Neck Surg., vol. 131, no. 4, pp. 326–329, Apr. 2005, doi: 10.1001/archotol.131.4.326.
[20] C. Stoll, Y. Alembik, B. Dott, and M.-P. Roth, "Associated anomalies in cases with anotia and microtia," Eur. J. Med. Genet., vol. 59, no. 12, pp. 607–614, Dec. 2016, doi: 10.1016/j.ejmg.2016.10.012.