Palestine Polytechnic University

College Of Applied Sciences

Applied Physics Introduction

A Holistic Initiative for Improving Hearing Care in Infants with Cochlear Implants

Students:

Areej Makhamra

Morjan Hzazah

Supervisor:

Dr. Othman Zalloum

2023 -2024

إهداء

إلى ذلك الصّرح التعليميّ الأصيل الذي احتضنَنا على طول مسيرتنا التعليميّة. جامعة بوليتكنك فلسطين العريقة ، بطاقمها .

هذا العمل مُهدى أيضاً لجميع الأساتِذة الذين اجتهدوا في تدريس كل مساقات التخصص ، لأساتذة اللجنة الدكتور "عثمان زلوم " والدكتور "مصطفى أبو الصفا " و الدكتور "أيمن سويطي ". وأخُصّ بالذكر الدّكتور "عثمان زلوم " المُشرف على استكمال مشروعنا هذا ، إهداءً ذاخراً بالامتنان لما كان له من دور وافٍ في تذليل العقبات وتقديم الارشادات التي من شأنها انجاح هذا المشروع وارتقائه .

أمّا ومَن كانوا لنا في السنون العِجاف نوراً وبصيرةً ، إليكِ أمي العظيمة ، إليكَ أبي الحنون أُهديكم نجاحي هذا ، الذي لا يساوي قطرةً من بحور جهودكم لأجلنا . أملاً أن تقُرّ عيناكم وتَسعد .

إلى الطّفل "سمير حزازة " فكرة المشروع الحيّة الذي ألهمنا وزاد اصرارنا إصرار على إنجاح هذا العمل . دُمتَ في خيرٍ وسلام .

إلى وطَني المكلوم ، إلى غزّةَ الحبيبة النازفة منذ السابع من اكتوبر ولا تزال صامدة ، الأرض الطّاهرة السبّاقة في الدفاع عن هذه الأرض.
إلى حُماة هذه البلاد .. الأكرم منّا جميعاً ، شهدائنا الأكارِم وأسرانا البواسل وذويهم الذين قدّموا من أجل البلاد كما لم يقدّم أحد ..إلى مثلكم تُهدى النجاحات ، وفي مثلكم تُسطَر الأساطير . عساكم الآن في الفردوس الأعلى .

كما وأودّ التعبير أنا أُم الطفل سمير عن شكري الجزيل للدكتور عادل عدوان على جهوده الكبيرة ودعمه المتواصل لنا خلال العملية الجراحية لطفلي ، هذا الدعم الكبير كان جزءً مهماً من إنجاح هذه العملية .

كما وأشكر خصّيصا الحاج مازن زغير المدير العام لشركة رويال ، على دعمه الكريم ومساهمته في تحمل جزء من تكاليف جهاز القوقعة الأمر الذي جعل العملية أقل عبئاً , وأشكر أيضًا مركز الإمارات للسمع على دعمهم وتعاونهم المثمر أثناء فترة إجراء الفحوصات وبرمجة الجهاز.

ونحن ممتنّين أيضًا لجمعية الأمل الخيرية التي استضافتنا خير استضافة ورحبت بفكرة إقامة الندوة التوعوية عن زراعة القوقعة، وتقديم جلسات تأهيل لسمير ، وأرجو أن يكون شكرنا كافياً لهذه الجهود السخيّة .
ولا ننسى جهود مدرسة افتح في تقديم جلسات التأهيل لسمير وتعبئة الاستبيانات الهامة بخصوص المشروع ، لكم منا كل الشكر والتقدير.

Contents

List of Figures

List of Tables

Abstract:

In our research study titled "A Holistic Initiative for Improving Hearing Care in Infants : with Cochlear Implants," we aimed to explore a comprehensive approach to optimize hearing care for infants with cochlear implants. The study focused on spreading awareness about the importance early diagnosis, early intervention, post-treatment rehabilitation, and the importance of these components in enhancing outcomes for this population, Also researching the most important developments that improve the quality of hearing .The research employed various methods, including questionnaire distribution, interviews, and comparative analysis, to gain insights into the effectiveness of early treatment and the significance of rehabilitation in maximizing the development and quality of life for infants with cochlear implants. The findings of this study will contribute to a better understanding of the holistic approach in hearing care and provide valuable information for healthcare professionals, educators, and families involved in the care of infants with cochlear implants. Additionally, the study also examined important advancements in cochlear implants that improve the quality of hearing.

Keywords:
Cochlear Implants, Rehabilitation, Early diagnosis and intervention

Chapter One:

Introduction

1.1 Background:

In our society, there are fascinating cases of hearing loss. These cases primarily involve individuals who have been experiencing hearing loss since birth, which is often discovered at later stages. One of the causes of this hearing loss is sensorineural hearing loss. Several solutions have been discovered for this problem.

However, in this research, we will focus on cochlear implants. Before delving into that, let us first provide an overview of sound and sound waves, explore the mechanism of hearing in the auditory system, and understand the process of auditory perception and the conversion of mechanical energy into electrical signals. Subsequently, we will discuss some of the problems associated with this process and their solutions. Then, we will discuss cochlear implants in detail.

1.1.1 Overview of Sound and Sound Waves

1.1.1.1 Definition of Sound and Sound Waves:

Sound is created when an object's vibrations travel through a medium such as air, water, or solid matter. Sound waves are pressure waves produced by these vibrations, causing the surrounding air molecules to vibrate. These waves can exist independently of whether they are perceived by individuals, as recognized in the physical definition of sound. [1]

1.1.1.2 Characteristics of Sound Waves:

Frequency: This refers to the number of vibrations or cycles per second of a sound wave, measured in Hertz (Hz). [2]

Wavelength: The wavelength is the distance between two consecutive points in a wave that are in phase, and it is inversely proportional to the frequency. [2]

Velocity: The velocity of sound is the speed at which sound waves travel through a medium, depending on the medium's properties such as temperature and density. [2]

Sound intensity measures the amount of energy carried by a sound wave per unit area, indicating how powerful or loud a sound is. The intensity is directly related to the amplitude, which is the maximum displacement of particles in the medium through which the sound wave is traveling. Higher amplitude results in higher sound intensity.

Sound intensity is typically measured in decibels (dB), a logarithmic scale that compares the intensity of a sound to a reference intensity. This scale provides a convenient way to represent the wide range of sound intensities that humans can perceive.

The formula for calculating sound intensity level in decibels is [3]:

$$\beta(\text{dB}) = 10 \times \log_{10}\left(\frac{I}{I_0}\right)$$

Where:

$\beta(\text{dB})$ is the sound intensity level in decibels.

I is the sound intensity in watts per meter squared (W/m^2).

I_0 is the reference intensity, typically set at $10^{-12}\ \text{W/m}^2$.

The reference intensity of $10^{-12}\ \text{W/m}^2$ corresponds to the threshold of hearing for an average human ear at a frequency of 1000 Hz, meaning any sound with an intensity below this threshold is considered inaudible.

***1.1.1.3 Frequency Range of Human Hearing*:**

The frequency range of human hearing encompasses the range of frequencies that the human ear can detect. This range, known as the audible range, is where the human ear is most sensitive to sounds. Typically, the audible range for humans spans from approximately 20 Hz to 20,000 Hz (or 20 kHz). However, this range can vary among individuals and tends to diminish with age. Younger individuals usually have a broader hearing range compared to older individuals.

Sounds with frequencies below the audible range are referred to as infrasound, while those above the audible range are called ultrasound. Although infrasound and ultrasound are not perceivable by the human ear, they can be detected using specialized equipment.

Sounds with frequencies below the audible range are known as infrasound, while those above the audible range are called ultrasound. Although infrasound and ultrasound cannot be perceived by the human ear, they can still be detected using specialized equipment.

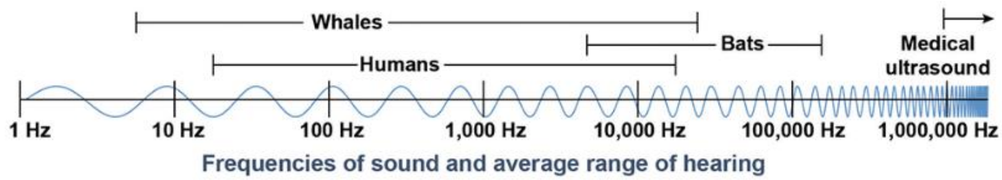


Figure (1) Frequency Frequencies of sound and average range of hearing [1]

1.1.1.4 Types of Sound Waves:

Audible Waves: These are sound waves that fall within the range of human hearing, typically between 20 Hz and 20,000 Hz. [1]

Ultrasonic Waves: Sound waves with frequencies higher than 20,000 Hz are called ultrasonic waves. They are inaudible to the human ear but have various applications in fields such as medicine and communication. [1]

Infrasonic Waves: Sound waves with frequencies below 20 Hz are called infrasonic waves. They are also inaudible to humans but are used by certain animals for communication and detection. [1]

1.1.2 Mechanism of Hearing in the Auditory System:

The physics of sound wave propagation plays a crucial role in our ability to hear and is closely related to the structure of the ear. Sound waves, as mechanical waves, travel through a medium such as air or water in a series of compressions and rarefactions. When these sound waves reach our ears, they are detected and processed by different parts of the ear, allowing us to perceive and interpret sound.

The structure of the ear can be divided into three main parts: the outer ear, the middle ear, and the inner ear.

1. Outer Ear:

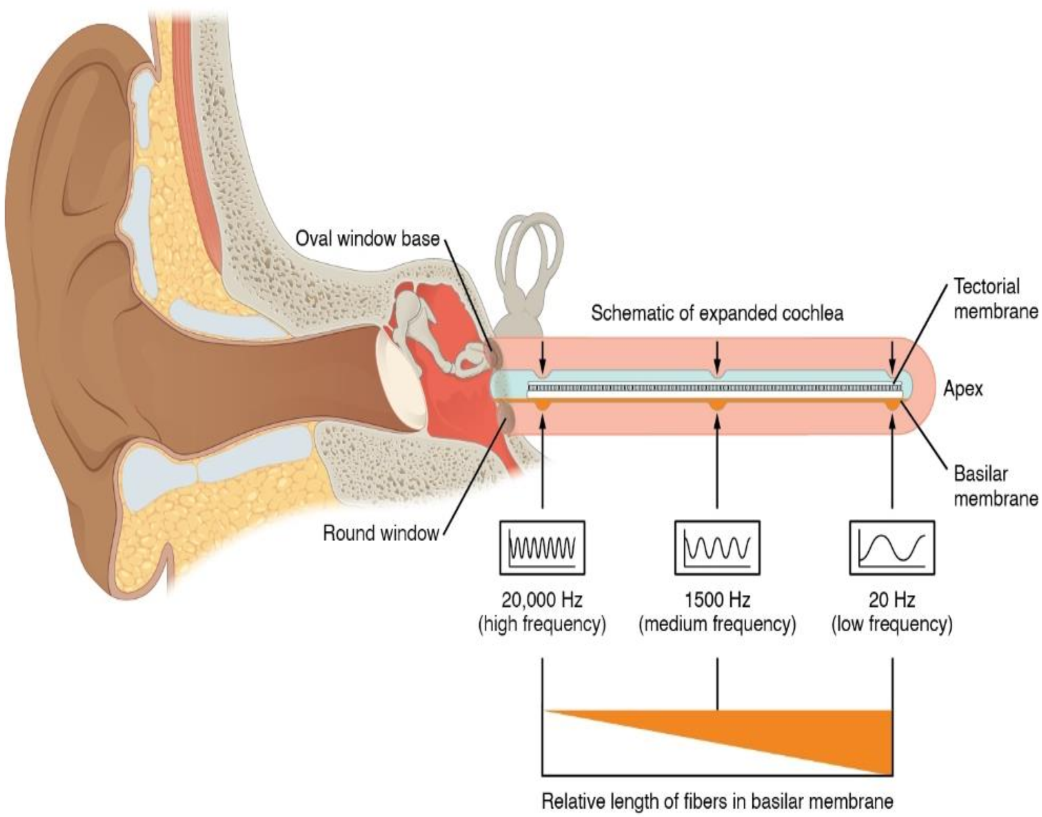
The outer ear consists of the earflap and the ear canal. The earflap helps protect the middle ear and prevent damage to the eardrum. The ear canal collects and channels sound waves to the eardrum. The length of the ear canal allows for the amplification of sounds with frequencies around 3000 Hz. [4]

2. Middle Ear:

The middle ear is an air-filled cavity that contains the eardrum and three tiny interconnected bones: the malleus (hammer), incus (anvil), and stapes (stirrup).When sound waves reach the eardrum, it vibrates in response. These vibrations are transmitted to the three bones of the middle ear. The bones act as levers, amplifying the vibrations. The stirrup bone is connected to the inner ear and transmits the vibrations to the fluid of the inner ear. The middle ear also contains the Eustachian tube, which helps equalize the pressure within the ear. [4]

3. Inner Ear:

The inner ear consists of the cochlea, semicircular canals, and the auditory nerve. The cochlea is a snail-shaped organ filled with fluid and lined with over 20,000 hair-like nerve cells. When vibrations from the middle ear reach the cochlea, the hair cells are set in motion. Each hair cell has a natural sensitivity to a particular frequency of vibration. When the frequency of the sound wave matches the natural frequency of a hair cell, it resonates with a larger amplitude of vibration. This increased vibrational amplitude induces the hair cell to release an electrical impulse that is transmitted along the auditory nerve to the brain [4]



Figure(2) Frequency Coding in the Cochlea [5]

1.1.3 How Hearing (Auditory Process) Works:

The cochlea is essential in the process of sound processing and the conversion of mechanical energy into electrical signals. This fluid-filled, spiral-shaped cavity located in the inner ear is where sound waves are transformed into electrical impulses that the brain can interpret as distinct sound frequencies.
Here is a detailed explanation of the cochlea's role in sound processing and the conversion of mechanical energy into electrical signals:

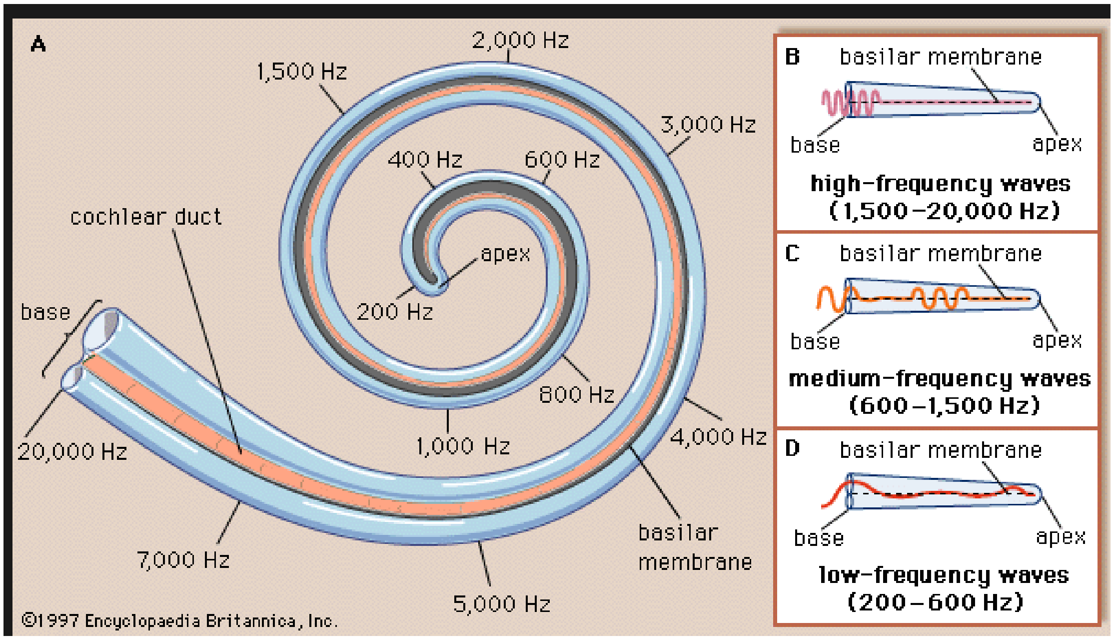
Transmission of Sound Waves:
Sound waves enter the cochlea through the oval window, set into motion by the vibrations of the eardrum and ossicles in the middle ear. These vibrations create pressure waves in the perilymph of the scala vestibuli, one of the cochlea's fluid-filled chambers. The pressure waves travel around the tip of the cochlea through the helicotrema into the scala tympani and eventually dissipate as they reach the round window. [6]

Movement of Fluid and Vibrations:
As the pressure waves move through the cochlea, they cause the fluid inside the cochlear duct, called endolymph, to move. This fluid movement leads to the vibration of the basilar membrane, a thin and flexible membrane running along the cochlea's length. The basilar membrane is crucial for analyzing sound frequency. [6]

Organ of Corti:
The vibrations of the basilar membrane cause the organ of Corti, located on top of the basilar membrane, to move against the tectorial membrane.
The organ of Corti contains specialized sensory cells called hair cells, which convert mechanical energy into electrical signals. [6]

Hair Cell Activation:
The movement of the organ of Corti against the tectorial membrane stimulates the hair cells. These hair cells are arranged in rows and have hair-like projections called stereocilia on their surface. When the stereocilia bend due to the movement of the basilar membrane, ion channels open, allowing ions to enter the hair cells, generating electrical signals. [6]

Generation of Nerve Impulses:
The electrical signals generated by the hair cells are transmitted to the brain via the auditory nerve, also known as the eighth cranial nerve.
The auditory nerve carries these electrical impulses to the brainstem, where they are further processed and interpreted as sound. [7]



Figure(3) Basilar membrane; human ear [6]

1.1.4 Hearing Loss And Its Solutions

Hearing loss

Hearing loss is a complex phenomenon affecting individuals in various forms, categorized into:

- Conductive Hearing Loss.
- Sensorineural Hearing Loss.
- Mixed Hearing Loss.

Hearing loss Solutions

There are several solutions available for hearing loss, depending on the type and severity of the condition. Here are some common options:

Removable Hearing Aids:

Analog hearing aids: These convert sound into electrical signals and make them louder. They can be programmed for different environments [8].

Digital hearing aids: These convert sound into a code of numbers and amplify only the frequencies where you have hearing loss. They offer more flexibility than analog devices .

Figure (4) Hearing Aids [9]

Surgically Implanted Hearing Devices:

Middle ear implants: A small device is attached to one of the bones of the middle ear to directly move them, sending stronger sound vibrations to the inner ear. They are almost completely hidden and can stay in place during activities like swimming [8].

Bone-anchored hearing aids: These devices transmit sound into the inner ear through the skull. They can be implanted or worn externally, depending on the type. They are recommended for people with single-sided deafness, ear canal problems, or conductive/mixed hearing loss [8].

Cochlear implants: These bypass damaged parts of the ear and send signals directly to the auditory nerve. They consist of a microphone, transmitter, and electrodes placed in the inner ear through surgery. Cochlear implants are suitable for severe hearing loss and can help improve speech and language skills [8].

Figure(7) Middle Ear Implants [10]

Figure (6) Bone-Anchored Hearing Aids [10]

Figure (5) Cochlear Implants [10]

1.1.5. How Cochlear Implants Work:

Cochlear implants are devices designed to help individuals with severe hearing loss or deafness regain some level of hearing by bypassing damaged parts of the ear and directly stimulating the auditory nerve. This allows sound signals to be sent to the brain for interpretation. [11]

Here's a breakdown of how cochlear implants function:

External Sound Processor:

The cochlear implant system has two main parts. The first is the external sound processor, worn behind the ear, which captures sound from the environment using a microphone and converts it into digital signals. [12]

Speech Processor:

These digital signals are then sent to a speech processor, a small external device. The speech processor analyzes and encodes the signals into electrical impulses representing different frequencies and sound intensities. [11]

Transmitter Coil:

The encoded electrical impulses are transmitted wirelessly across the skin to the internal components of the cochlear implant. [11]

Internal Implant:

The internal implant is surgically placed under the skin behind the ear and consists of a receiver-stimulator and an electrode array. [11]

Receiver-Stimulator:

The receiver-stimulator receives the encoded electrical impulses from the external speech processor and converts them into electrical signals. [11]

Electrode Array:

The electrode array is a flexible, thin wire with multiple electrodes inserted into the cochlea, the spiral-shaped structure in the inner ear responsible for converting sound vibrations into electrical signals. [11]

Electrical Stimulation:

The electrodes in the array stimulate the remaining auditory nerve fibers within the cochlea. Each electrode corresponds to a specific frequency range of sound. [11]

Sound Perception:

The electrical stimulation of the auditory nerve fibers bypasses the damaged hair cells in the cochlea. The brain receives these electrical signals and interprets them as sound, allowing the individual to perceive and understand sound to varying degrees. [11]

The Auditory Nerve and Sound Transmission:

The auditory nerve is crucial in transmitting sound information from the ear to the brain. It converts mechanical vibrations of sound into electrical impulses for the brain to process and interpret.

Here's a detailed explanation of the auditory nerve's role in transmitting sound information:

Conversion of Sound Waves:

When sound waves enter the ear, they cause the eardrum to vibrate. These vibrations are transmitted through the middle ear to the cochlea, a spiral-shaped structure in the inner ear. [13]

Hair Cells:

Inside the cochlea, specialized sensory cells called hair cells convert the mechanical vibrations of sound into electrical signals. [13]

Basilar Membrane:

The sound waves' vibrations cause the basilar membrane, a flexible structure within the cochlea, to move, leading to the bending of the hair cells. [13]

Ion Channels:

When hair cells bend, ion channels on their surface open, allowing ions like potassium and calcium to enter the hair cells. [13]

Action Potentials:

The influx of ions generates electrical signals known as action potentials, which carry information about the sound. [13]

Auditory Nerve:

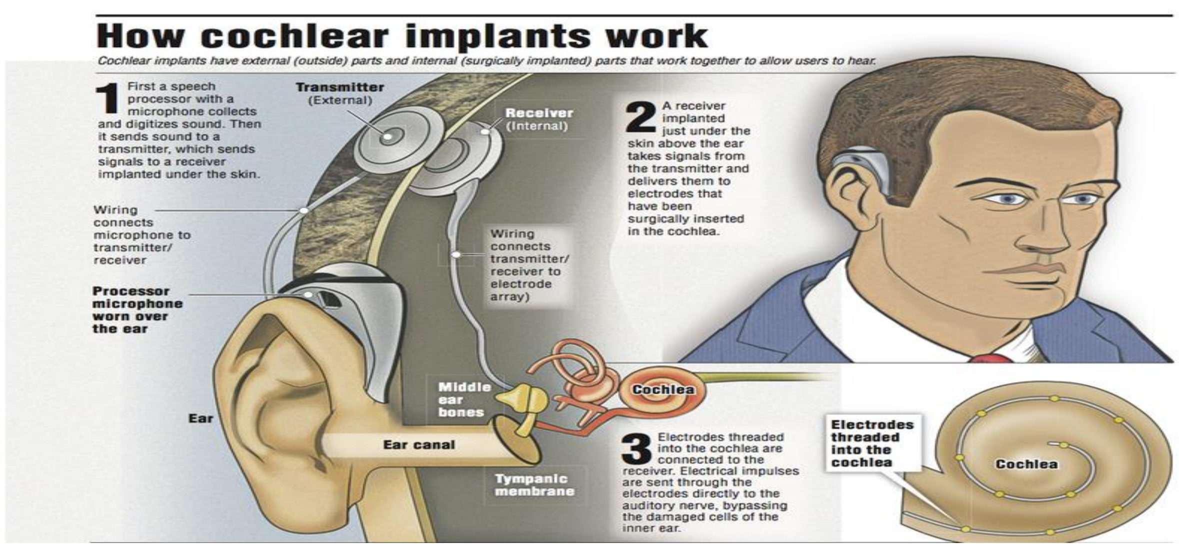
These action potentials are transmitted to the brain via the auditory nerve (eighth cranial nerve), composed of thousands of individual nerve fibers. [13]

Transmission to the Brainstem:

The auditory nerve fibers carry the electrical signals to the brainstem, specifically to a structure called the cochlear nucleus, where the signals are processed and relayed to higher brain regions involved in auditory perception. [13]

Auditory Cortex:

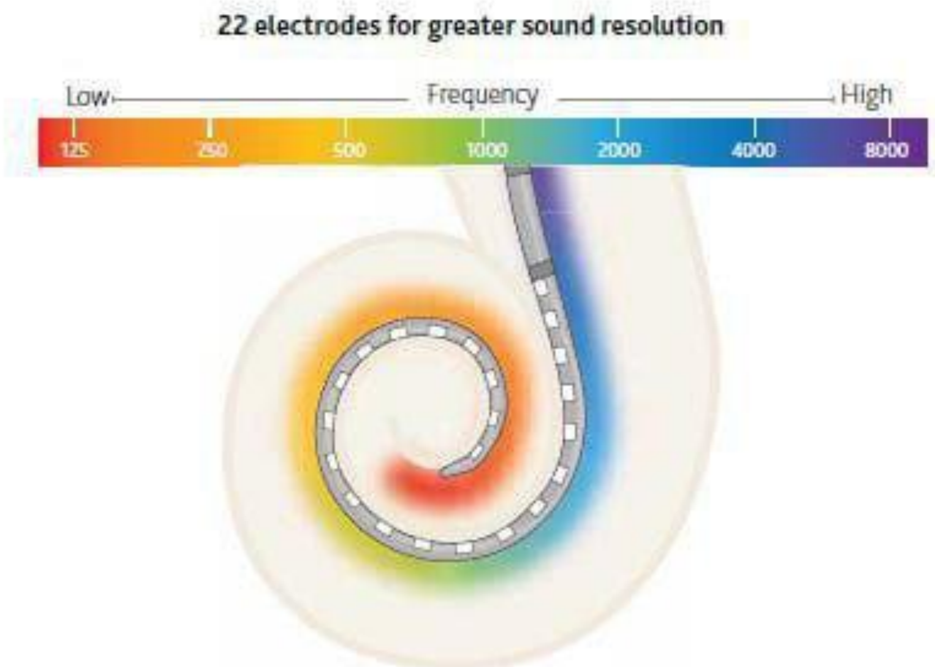
From the brainstem, the processed sound information is transmitted to the auditory cortex in the brain's temporal lobe. The auditory cortex is responsible for interpreting and perceiving various aspects of sound, such as pitch, loudness, and location. [13]



Figure(8) This graphic shows how cochlear implants work. [14]

The cochlea is differentially sensitive to sound frequencies, with low frequencies being more sensitive at the apex and high frequencies being more sensitive at the base. [15]

Each electrode in the array is designed to electrically stimulate auditory nerve endings. By stimulating electrodes at different regions along the cochlea, different pitches (frequencies) can be perceived. The number of electrodes in a cochlear implant varies by manufacturer, and the configuration and stimulation mode (monopolar or bipolar) can affect the spatial selectivity and loudness of the perceived sound. These principles and design features are crucial for the effective functioning of cochlear implants, enabling individuals with hearing loss to receive and process auditory information. [15]



Figure(9) Frequencies in electrodes [16]

1.1.6 Electrode length makes a difference

To successfully mimic sounds as naturally and precisely as possible, the cochlear implant electrode needs to be long enough to stimulate the entire cochlea up to the apex (720°). This allows access to the whole spectrum of sound. In the cochlea, every frequency is coded at a certain place: high frequencies are allocated at <240°, medium frequencies <480°, low frequencies <720°. Cochlear implants with shorter electrode arrays can also stimulate low pitches, but only in those cochlear regions they actually reach. [17] [18] This requires upward alterations of pitches. Consequently, low frequencies sound tinny and thin and the richness of sound is lost.

Figure (10) Electrode length makes a difference [19]

The typical block diagram for a cochlear implant system is shown in the figure (11).

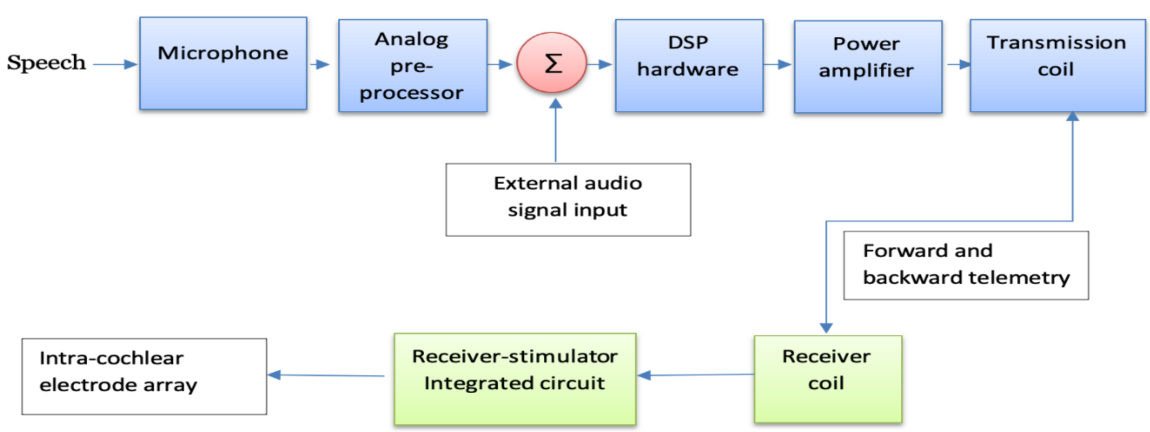


Figure (11) Block diagram of the CI system. External speech processor and implantable unit

The diagram of the external speech processor system and implantable unit with DSP hardware consists of two main parts: the external speech processor system and the implantable unit. [20] Let's take a closer look at each part:

External Speech Processor System:

The external speech processor system is responsible for processing the audio signal and transmitting it to the implantable unit. It includes the following components connected in a flow:

1. Speech Input: The system takes in the speech signal as the input.

2. Microphone: A microphone captures the external sound and converts it into an electrical signal.

3. Analog Pre-processor: The analog pre-processor further processes the electrical signal to enhance its quality and prepare it for digital processing.

4. DSP Hardware: The signal is then passed through the Digital Signal Processing (DSP) hardware, which performs various signal processing operations on the input signal. This may include operations like A/D conversion, Fast Fourier Transform (FFT), average power calculation, nonlinear mapping, and determination of stimulation levels for each channel.

5. Power Amplifier: The processed signal is amplified to an appropriate level for transmission.

6. Transmission Coil: The amplified signal is then transmitted wirelessly to the implantable unit using a transmission coil.

Implantable Unit:

The implantable unit consists of two main components:

1. Intra-cochlear Electrode Array: This component is surgically implanted in the cochlea and consists of multiple electrodes. These electrodes stimulate the auditory nerve fibers in the cochlea with electrical pulses based on the processed signal received from the external speech processor system.

2. Receiver-Stimulator Integrated Circuit: This circuit is connected to the receiver coil, which receives the forward and backward telemetry signals from the external transmission coil. The receiver-stimulator integrated circuit processes these signals and generates the electrical pulses to be delivered to the intra-cochlear electrode array.

1.2 Problem Statement :

The problem with the research lies in the lack of public awareness of the importance of early detection of hearing loss, especially in children. More efforts are needed to raise awareness about the importance of starting early treatment as soon as the condition is diagnosed. It is also necessary to conduct a study to measure the hearing levels and quality of life of individuals who underwent rehabilitation programs after treatment.

1.3 Research Objectives:

1. Raising awareness about early detection of hearing loss

2. Promoting awareness on the importance of early treatment.

3. Evaluate Rehabilitation Impact to measure the hearing levels and quality of life in children who undergo rehabilitation programs post-treatment .

Chapter Two:

Literature Review:

2.1 Historical Context:

The historical development of cochlear implants spans several centuries, with significant advancements and milestones along the way.

Pre-Modern Times:

- In 1790, Alessandro Volta conducted an experiment where he placed metal rods in his ears and connected them to a 50-volt circuit, resulting in the first known attempt at using electricity to hear [21].
- Around 1855, there were further attempts to stimulate the ear electronically, along with other experiments in using electrical treatment for ear problems [21].

Silver Age:

- In the 1930s, researchers discovered that placing a current near the ear can create auditory sensations [21].
- During this time, the scientific community gained a better understanding of how the cochlea works, and it was found that electrical energy can be transformed into sound before reaching the inner ear [21].
- In 1957, scientists Djourno and Eyries achieved the first stimulation of an acoustic nerve with an electrode [21].

Introduction of Single Channel Cochlear Implants:

- In 1972, the first single-channel cochlear implant, the 3M/House cochlear implant, was introduced. Over 1000 people, including several hundred children, were implanted with this device, which provided significant speechreading enhancement and limited open set word recognition [22].

Multichannel Cochlear Implants:

- In 1984, Cochlear Corporation introduced the first multichannel cochlear implant system, the Nucleus 22. This system consisted of an implanted receiver/stimulator and an intracochlear electrode array with 22 banded contacts [22].
- Around the same time, the Ineraid device, developed in Utah, also became a multichannel cochlear implant system. It had six intracochlear electrodes connected to an externally worn speech processor [22].

Technological Advancements:

- Over the past few decades, extensive research has been dedicated to improving cochlear implant design, intracochlear arrays, stimulation modes, processing strategies, and miniaturizing the hardware [22].
- Currently, there are three FDA-approved multichannel cochlear implant systems available in the United States: Nucleus Cochlear Implant System, Clarion device, and Med-El device [22].
- Average performance with these systems has significantly improved, with the best cochlear implant users achieving sound-only word recognition scores of 80% or higher [22].

2.2 Current state of cochlear implants:

Cochlear implants have undergone significant advancements in recent years, both in terms of technology and surgical techniques. These advancements have led to improved outcomes and expanded applications for cochlear implantation.

- Robotic Innovations in Cochlear Implant Surgery

Traditionally, cochlear implant surgery involved manual insertion of the electrode array into the cochlea. However, recent developments in medical technology have introduced robotics into the procedure. Robotic assistance allows for more precise and controlled insertion of the electrode array, enhancing surgical outcomes. [23]

- Expanded Patient Selection Criteria

In the past, cochlear implants were primarily offered to patients with severe-to-profound sensorineural hearing loss in both ears who did not benefit from traditional hearing aids. FDA guidelines have now broadened to include individuals with moderate-to-profound hearing loss in both ears who do not receive sufficient benefit from traditional hearing aids. The criteria have also expanded to include people with unilateral hearing loss and children younger than one year of age. Electro-acoustic stimulation, or hybrid devices, have received FDA approval, providing a solution for individuals who hear too well for a conventional cochlear implant but cannot use a traditional hearing aid. [24]

- Preservation of Residual Hearing

Surgical techniques have significantly improved, allowing for better preservation of residual hearing during cochlear implantation. Surgeons strive to save as much of the patient's residual low-frequency acoustic hearing as possible, enabling sound awareness when the cochlear implants are removed. Hybrid devices, which combine acoustic hearing for low frequencies and electric stimulation for mid-to-high frequencies, have shown excellent outcomes in patients who have some residual hearing. [24]

- Improved Outcomes

Studies have demonstrated positive outcomes for cochlear implant recipients. Patients with hybrid devices (combining a hearing aid and a cochlear implant) tend to hear better in background noise and have improved music appreciation compared to those with a cochlear implant alone. Clinical trials have shown that a significant percentage of patients with residual low-frequency hearing and severe-to-profound hearing loss in the mid-to-high frequencies experienced improvements in speech perception and word recognition. [24]

2.3 Limitations and Challenges

The benefits of cochlear implantation in deaf children have been extensively documented, but the extent of these benefits varies among individuals and depends on several factors, such as the demographic and auditory characteristics of the child, as well as the characteristics of the implant itself. Studies to date have primarily focused on how variables like age of implantation, amount of residual hearing, mode of communication, and family support impact the outcomes. Regarding implant characteristics, the majority of research has concentrated on the effects of speech coding strategies within the device, with limited emphasis on children who lost their hearing before acquiring language. [25]. There are certain limitations and challenges associated with cochlear implants in infants. Here are some of them

- Surgical Risks: The implant surgery carries certain risks, including a potential reduction in balance function, increased tinnitus (ringing in the ears), and a slight chance of damage to the facial nerve or the chorda tympani nerve. [26]
- Medical Procedures: Cochlear implant recipients may be restricted from undergoing certain medical procedures, such as electrosurgery, electroconvulsive therapy, and ionizing radiation therapy. It is important to consult with the surgeon before conducting an MRI on a child with a cochlear implant. [26]
- Risk of Meningitis: Children with cochlear implants have a higher risk of contracting meningitis caused by Streptococcus pneumonia compared to those without implants. Vaccinations are recommended to reduce this risk. [26]

- Problems with Internal Components: Although rare, there is a chance of a problem occurring with the internal portion of the cochlear implant system. However, the current cochlear implant manufacturers report a high success rate for internal devices. [26]
- Static Electricity: Static electricity can potentially damage the electrical components of the internal devices or erase programs saved to the speech processor. Precautions should be taken to prevent static electricity from affecting the speech processor. [26]
- Childhood Activities: In general, children with cochlear implants can participate in common childhood activities. However, precautions should be taken to protect the device from trauma and damage, such as wearing a helmet during certain activities and using a waterproof case during bath time or swimming. [26]

It is important to note that while cochlear implants have limitations and challenges, they have also shown significant benefits in improving hearing and speech development in infants with severe or profound hearing loss. [27]

2.4 Technological Advancements:

1. Smaller and Smarter Sound Processors: Cochlear, a leading manufacturer of cochlear implants, has introduced the Nucleus 8 Sound Processor, which is smaller and smarter than previous models. [28] This advancement allows for a more discreet and comfortable wearing experience for users.
2. Bimodal Solutions: The Smart Hearing Alliance, a collaboration between Cochlear and ReSound, offers bimodal solutions for individuals with a cochlear implant and a ReSound hearing aid. [29] This combination provides superior sound quality and improved speech recognition in noisy environments.
3. 3. Connectivity: Cochlear and ReSound share wireless technology, enabling users to stream audio directly to their cochlear implant and hearing aid simultaneously from compatible iOS or Android devices [29] This wireless connectivity enhances the overall listening experience and allows for seamless integration with modern technology.
4. Rechargeable Batteries: The Cochlear Nucleus Kanso 2 Sound Processor features a built-in rechargeable battery, providing all-day hearing for users [29]. This eliminates the need for frequent battery changes and enhances convenience.

2.5 Post -Implant Rehabilitation

Post-implant rehabilitation plays a crucial role in optimizing outcomes for cochlear implant (CI) users. It involves a comprehensive and individualized approach to help CI recipients develop their listening skills, adapt to the new auditory input, and maximize their communication abilities. Here are some rehabilitation programs and strategies that can contribute to optimizing outcomes in CI users:

- Auditory Training Exercises: Auditory training exercises are designed to improve speech perception and sound recognition abilities. These exercises can be completed with a practice partner or through self-guided mobile apps. [30] They focus on tasks such as identifying specific environmental sounds, word recognition, and listening in different listening environments.
- Listening in Noise: CI users often face challenges in understanding speech in noisy environments. Rehabilitation programs include exercises that gradually expose CI users to increasing levels of background noise, helping them develop strategies to enhance speech understanding in challenging listening conditions. [31]
- Music Training: Rehabilitation programs also focus on maximizing music enjoyment for CI users. Melodic contour training, instrument identification, familiar melody recognition, and rhythm practice are some of the activities that can improve the perception of melody and enhance music appreciation [31]
- Telephone Speech Training: Using the telephone can be challenging for CI users. Rehabilitation programs provide specific strategies and exercises to improve telephone communication skills, such as practicing with different speaking rates, using active listening techniques, and making specific suggestions to callers [31]
- Communication Strategies: Rehabilitation programs emphasize the development of effective communication strategies. CI users are taught techniques to enhance speechreading, use visual cues, and understand non-verbal communication to supplement auditory input [32]
- Counseling and Support: Rehabilitation programs often include counseling and support services to address the emotional and psychological aspects of adjusting to life with a CI. These services provide guidance, information, and support to both the CI user and their family members [32]

- Device-Specific Guidance: Rehabilitation programs provide device-specific guidance to help CI users optimize the use of their cochlear implant. This includes understanding the features and settings of the device, troubleshooting common issues, and maximizing the benefits of the technology. [31]

It is important to note that rehabilitation programs should be tailored to the individual needs and goals of each CI user. The programs may vary depending on factors such as age, duration of hearing loss, and previous experience with hearing aids. Regular follow-up appointments with audiologists and speech-language pathologists are essential to monitor progress, make necessary adjustments, and provide ongoing support.

Chapter Three:

Research Methodology

3.1 Study Design

Mixed methods convergent design will be utilized to collect both quantitative and qualitative data concurrently but analyzed separately.

3.2 participants

Table (1) participants

	Inclusion Criteria	Exclusion Criteria
Awareness Survey	Caregivers of children residing in urban areas.	Unwilling or unable to complete the survey.
Semi-structured interviews	Audiology specialists with experience in cochlear implantation.	Unavailable for or declining participation in interview.
Visit to rehabilitation centers	All children diagnosed with hearing loss who are receiving rehabilitation programs at rehabilitation centers.	Children who have not been diagnosed with hearing loss

3.3 Data Collection

Online and Paper Surveys:

- Development of a Standardized Questionnaire: Creating a comprehensive and validated questionnaire to assess awareness, treatment initiation, and rehabilitation outcomes.
- Distribution:
  - Online: Through major social media platforms to reach a broad audience.
  - Paper: Distributed at rehabilitation centers to ensure participation from those who may not have online access.
- Informed Consent: Obtained from all participants to ensure ethical standards are met.

Interviews with Parents of Patients:

- Conducting Interviews: Structured interviews with the parents or guardians of children receiving treatment for hearing loss to gain in-depth insights into their experiences and perceptions.
- Data Collected: Information on the child's hearing loss diagnosis, treatment history, rehabilitation progress, and quality of life.

3.4 Data Analysis Plan:

1. Manually collect data in Excel sheet

2. Import data to SPSS for analysis using SPSS.

The results will be plotted using SPSS and then the equivalent codes will be written in Python.

3. Present results in tables and plots

4. Discuss findings and conclusions

5. Conducting an educational seminar in one of the rehabilitation centers

Chapter Four:

Ethical Considerations

4.1 Informed Consent

This template has been provided to facilitate obtaining informed Consent from participants. It serves as a comprehensive document that outlines the research, its objectives, the procedures involved, and the rights of the participants. By reviewing and signing this form, participants demonstrate their understanding of the study and voluntarily agree to participate.

Informed Consent Form

Title of Study: A Holistic Initiative for Improving Hearing Care in Infants with Cochlear Implants

Principal Investigator: A Holistic Initiative for Improving Hearing Care in Infants with Cochlear Implants

Introduction:

Thank you for considering participation in our study. This form provides detailed information about the research, its purpose, procedures, and your rights as a participant. Please read the entire document carefully and feel free to ask any questions before deciding to participate.

Purpose of the Study:

This study aims to gather information from the doctor regarding the early treatment of hearing loss and its significance, as well as the early detection of this disorder. The collected information will be used to enhance awareness of the benefits and importance of early treatment in improving patient outcomes, as well as to promote awareness of the importance of early detection and encourage patients to seek timely screening and treatment. The study will also gather information on patients before and after receiving post-treatment rehabilitation to evaluate the benefits of post-treatment rehabilitation and its impact on their quality of life.

Procedures:

As a participant in this study, you will be involved in Personal Interview, you will have a personal interview with the specialized doctors to exchange information and experiences related to early treatment and early detection of hearing loss, as well as rehabilitation after receiving treatment. The interview will take place at a location and time convenient for you and is expected to last approximately 30 minutes. The interview will be recorded with your prior consent for research purposes and data analysis. Please feel free to ask any questions or express any concerns related to the study before or during the interview

Risks and Benefits:

There are potential risks associated with this study, including- Loss of privacy and no guarantee of absolute data protection. However, we have taken steps to minimize these risks, such as Privacy Protection Security measures will be implemented to ensure the confidentiality of the provided information. Additionally, potential benefits of participating in this study include Increased awareness and knowledge about early treatment and early detection of hearing loss. Contribution to medical advancement and improvement of treatment and healthcare practices.

Confidentiality:

We will handle your personal data with utmost confidentiality. Any information collected during the study will be securely stored and accessible only to authorized personnel. To protect your privacy, we will. Any information shared in research publications or presentations will be anonymized to ensure confidentiality.

Voluntary Participation:

Participation in this study is entirely voluntary. You have the right to refuse or withdraw at any time without facing any consequences. Your decision to participate or not will not affect your current or future relationship with the researchers or institutions.

Contact Information:

If you have any questions, concerns, or would like further information about the study, please contact to (0567510136,0569214550)

Statement of Understanding:

I have read and understood the information provided in this consent form. I have had the opportunity to ask questions, and I am satisfied with the answers provided. I voluntarily agree to participate in this study.

Participant's Signature: ________ Date: ______

Researcher's Statement:

I have explained the nature, purpose, potential risks, and benefits of the study to the participant. I have answered their questions, and they have voluntarily consented to participate.

Researcher's Signature: ________ Date: ______

By signing this consent form, you acknowledge that you have read and understood the information, had the chance to ask questions, and voluntarily agree to participate in the study

Time Table

I first weak ,II second weak ,III third weak ,IV fourth weak

The first period: Introduction of graduation project (2023)

Research phase	Duration in months															
	September				October				November				December			
weeks	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
Find a research problem																
Read previous studies about the problem																
Introduction																
Literature review																
Methodology																

The second period: Graduation project (2024)

Research phase	Duration in months																		
	January				February				March				April				May		
Weeks	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III
Designing questionnaires and obtaining consent for conducting interviews																			
Collecting data																			
Analyze the result																			
Visiting rehabilitation centers																			
Writing the research																			
Finish search details																			

Chapter Five :

Results and Discussion :

The aim of this study is to explore the improvement of hearing through early encouragement of cochlear implantation for children, as well as the importance of early detection and post-treatment rehabilitation. Data was collected from rehabilitation centers to investigate various aspects related to this topic in general. The findings from this research will provide valuable insights into enhancing hearing outcomes by promoting early cochlear implantation, early disease detection, and implementing effective post-treatment rehabilitation. This knowledge can inform the development of strategies and interventions to support the overall well-being and quality of life for individuals seeking to improve their hearing abilities.

The study sample:

The study recruited participants from various rehabilitation centers, including Ephpheta School (Bethlehem), Istiqlal School(yatta), and MED-EL Center. A total of 60 questionnaires were distributed among the individuals from these centers, along with two additional electronic questionnaires. However, upon data collection, only 47 questionnaires were collected and deemed suitable for inclusion in the final sample.

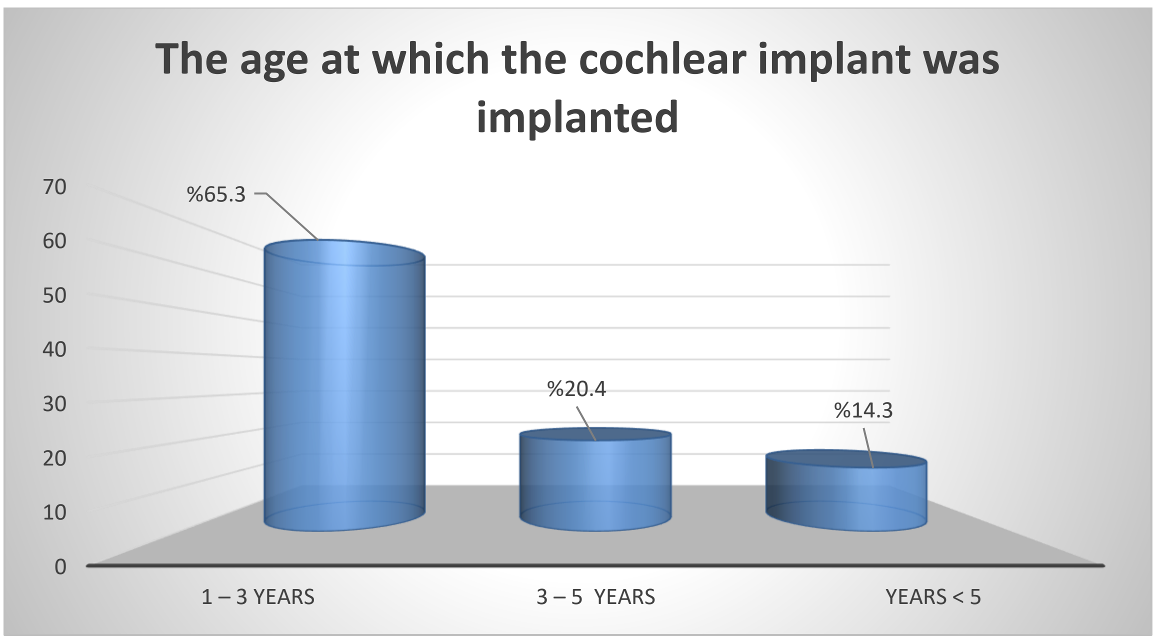
Information collection sources

Basically there are two types of data Primary and secondary data were used in this study. Primary data is the data collected using a questionnaire tool used to represent the study population by taking a sample. Secondary data was collected from many books, articles, and published scientific research.

Describe the variables of the study sample members

Table (2) The age at which the cochlear implant was implanted

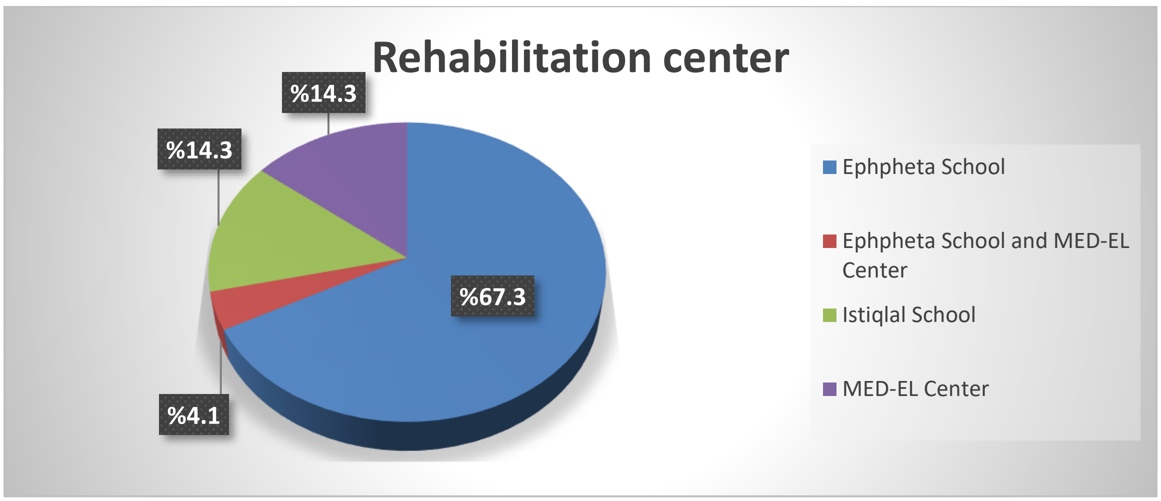
Variables	number	Missing values
The age at which the cochlear implant was implanted		
1 – 3 years	32	-
3 – 5 years	10	
Greater than 5 years	7	



Figure(12) The age at which the cochlear implant was implanted

Table (3) Rehabilitation center

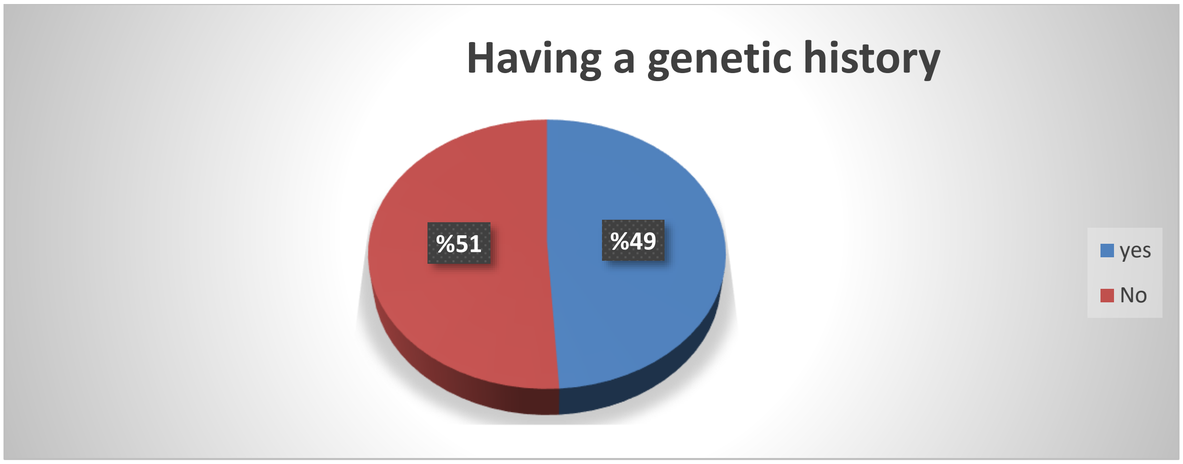
Variables	number	Missing values
Rehabilitation center		
Ephpheta School	33	-
Ephpheta School and MED-EL Center	2	
Istiqlal School	7	
MED-EL Center	7	



Figure(13) Age at which the cochlear implant was implanted

Table(4) Having a genetic history

Variables	number	Missing values
Having a genetic history		
Yes	24	-
No	25	



Figure(14) Having a genetic history

Based on these results, we can conclude that cochlear implantation at an early age (1-3 years) brings children with hearing impairment closer to their healthy peers in their abilities. The earlier the intervention is done, the greater the benefits, highlighting the importance of early detection and prompt intervention for children with hearing impairment.

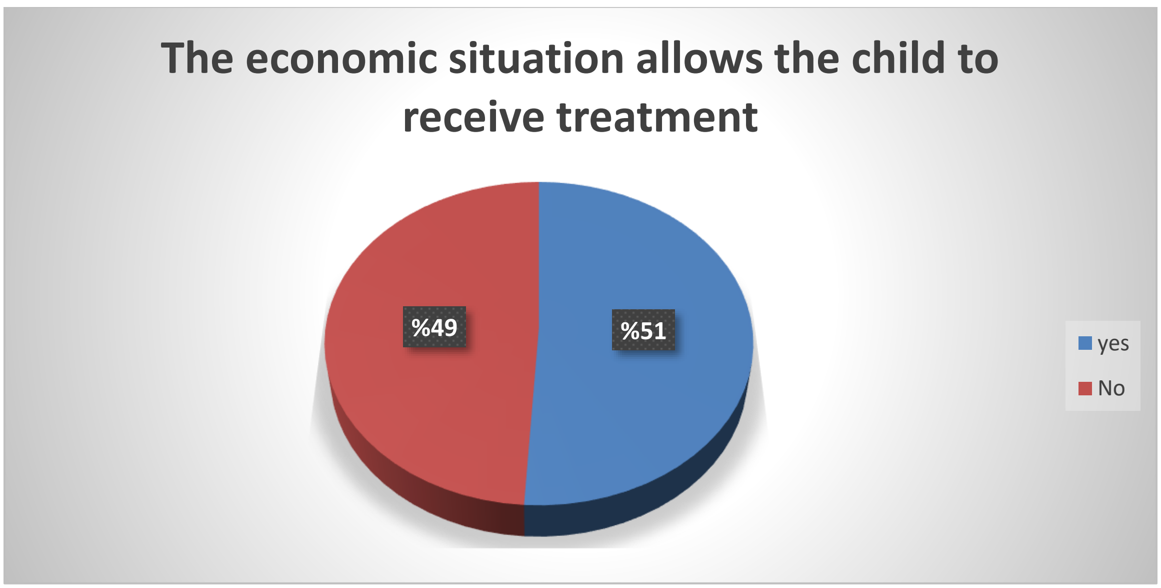
Based on the findings of the study, it is evident that genetic factors play a significant role in the occurrence of hearing impairment in newborns. Out of the 49 children included in the study, 24 children had a positive family history of the disease, while 25 children did not. These results align with previous research studies that have established a strong link between genetics and hearing impairment in newborns.

Studies published in reputable journals, such as "Google Scholar," "Science Direct," and "Web of Science," have consistently shown that genetic factors contribute to a substantial portion of hearing impairment cases in children. For instance, one study found that 50% of cases of hearing impairment in newborns have a genetic basis, while another study reported that 30% of cases are attributed to genetic mutations. Moreover, research has indicated that children with a family history of hearing impairment are three times more likely to be affected by the condition compared to those without such a history.

Given these well-established findings, it is crucial to take genetic factors into consideration when developing strategies and interventions for preventing hearing impairment in newborns. Additionally, providing appropriate support and resources to families with a genetic predisposition to hearing impairment is essential in ensuring early detection and intervention.

Table(5) The economic situation allows the child to receive treatment

Variables	number	Missing values
The economic situation allows the child to receive treatment		
Yes	**25**	-
No	**24**	



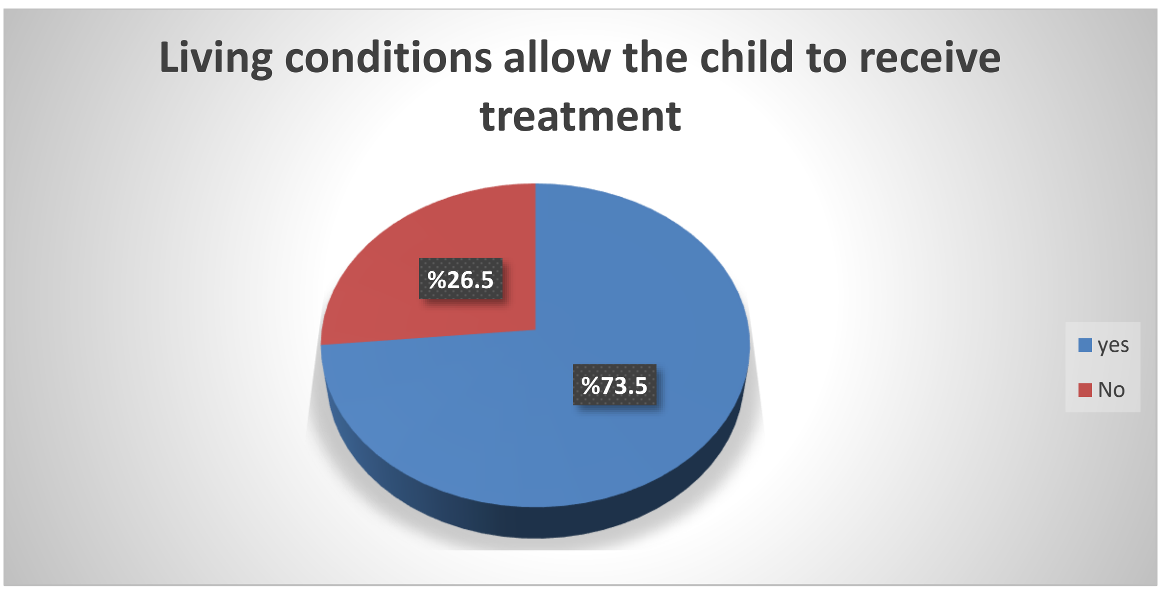
Figure(15) The economic situation allows the child to receive treatment

In a separate aspect of the study, the economic condition of families was found to significantly impact the child's ability to receive treatment and rehabilitation after cochlear implantation. Out of the 49 children surveyed, 25 children indicated that their family's economic condition allowed for treatment and rehabilitation, while 24 children stated otherwise. It was observed that children from low-income families faced greater challenges in accessing these essential services due to the high costs associated with cochlear implantation and post-surgery care.

However, there are encouraging initiatives that provide financial assistance to eligible families. Organizations like the Bethlehem Charity Association, the MED-EL Center, and the Istiqlal School in Yatta offer free or subsidized rehabilitation programs for children with hearing impairment. Additionally, some centers and companies partially cover the costs of cochlear implantation, alleviating the financial burden on families. These resources should be further promoted and expanded to ensure equitable access to treatment and rehabilitation services for all children, regardless of their economic background.

Table (6) Living conditions allow the child to receive treatment

Variables	number	Missing values
Living conditions allow the child to receive treatment		
Yes	**36**	-
No	**13**	



Figure(16) Living conditions allow the child to receive treatment

Another crucial finding from the study emphasizes the role of the child's living and family conditions in their ability to receive treatment and rehabilitation after cochlear implant surgery. Out of the 49 children included, 36 children reported that their living and family circumstances allowed for treatment and rehabilitation, while 13 children reported otherwise. It became evident that children from stable and supportive families were more likely to receive the necessary care following the surgery, compared to those in unstable or unsupportive family environments. Strong parent-child relationships and a safe, clean living environment were also identified as contributing factors to better post-surgery outcomes.

These findings underscore the importance of holistic support systems for children undergoing cochlear implant surgery. Creating stable and supportive family environments, strengthening parent-child relationships, and ensuring a safe and clean living environment are crucial elements in facilitating the child's recovery and minimizing the risk of post-surgery complications. Healthcare professionals and policymakers should consider these factors when developing comprehensive care plans for children with hearing impairment.

Table(7) The recent war affected the child's access to treatment through difficulty of access

Variables	number	Missing values	
The recent war affected the child's access to treatment through difficulty of access			
Yes	**42**	-	
No	**7**		

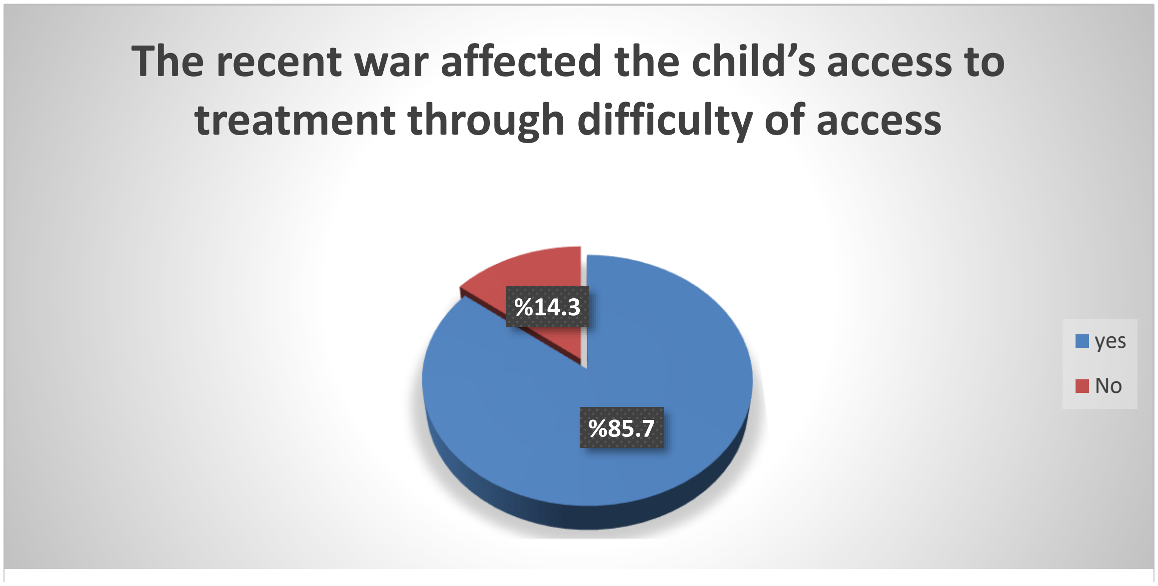


Figure (17) The recent war affected the child's access to treatment through difficulty of access

Lastly, the study revealed the significant impact of the recent war in Gaza on children's access to treatment and rehabilitation centers. Out of the 49 children surveyed, 42 children reported facing difficulties in reaching these facilities due to the barriers imposed by the occupier between Palestinian cities. The resulting challenges included limited access to rehabilitation sessions, delayed attendance, and the adverse economic consequences experienced by affected families.

In light of these findings, it is imperative to address the barriers hindering children's access to treatment and rehabilitation services in conflict-affected areas. Efforts should be made to remove the imposed barriers, establish safe passage for families, and provide necessary financial support to alleviate the economic burden caused by the conflict. By doing so, we can ensure that children receive the vital treatment and rehabilitation they require for their overall well-being and development.

Table (8) Answers to questionnaire questions from questions 1-10

# Q	1-3				4-5				Greater than 5			
ANS	Yes		no		Yes		no		Yes		no	
	number	%	number	%	number	%	number	%	number	%	number	%
1	32	100	0	0	10	100	0	0	7	100	0	0
2	30	93.7	2	6.3	10	100	0	0	7	100	0	0
3	31	96.8	1	3.2	10	100	0	0	7	100	0	0
4	32	100	0	0	7	70	3	30	7	100	0	0
5	32	100	0	0	10	100	0	0	7	100	0	0
6	30	93.7	2	6.3	10	100	0	0	7	100	0	0
7	32	100	0	0	10	100	0	0	6	85.7	1	14.3
٨	30	93.7	2	6.3	9	90	1	10	7	100	0	0
٩	13	40.6	19	59.5	8	80	2	20	2	28.5	5	71.5
10	32	100	0	0	10	100	0	0	7	100	0	0

Table (9) Answers to questionnaire questions from questions 11-20

#Q	1-3				4-5				Greater than 5			
ANS	Yes		no		Yes		no		Yes		No	
	number	%	number	%	number	%	number	%	number	%	number	%
11	20	62.5	12	37.5	8	80	2	20	3	42.8	4	57.2
12	32	100	0	0	10	100	0	0	7	100	0	0
13	28	87.5	4	22.5	9	90	1	10	7	100	0	0
14	32	100	0	0	9	90	1	10	7	100	0	0
15	28	87.5	4	22.5	9	90	1	10	7	100	0	0
16	31	96.8	1	3.2	10	100	0	0	7	100	0	0
17	30	93,7	2	6.3	9	90	1	10	7	100	0	0
18	32	100	0	0	9	90	1	10	7	100	0	0
19	31	96.8	1	3.2	10	100	0	0	7	100	0	0
20	32	100	0	0	7	70	3	30	7	100	0	0

Table (10) Answers to questionnaire questions from questions 21-30

#Q	1-3				4-5				Greater than 5			
ANS	Yes		no		Yes		no		Yes		no	
	number	%	number	%	number	%	number	%	number	%	number	%
21	26	81.2	6	18.8	9	90	1	10	7	100	0	0
22	31	96.8	1	3.2	8	80	2	20	5	71.4	2	28.6
23	29	90.6	3	9.4	10	100	0	0	6	85.7	1	14.3
24	30	93.7	2	6.3	10	100	0	0	7	100	0	0
25	28	87.5	4	22.5	10	100	0	0	7	100	0	0
26	32	100	0	0	10	100	0	0	6	85.7	1	14.3
27	32	100	0	0	10	100	0	0	7	100	0	0
28	28	87.5	4	22.5	10	100	0	0	7	100	0	0
29	32	100	0	0	7	70	3	30	7	100	0	0
30	32	100	0	0	10	100	0	0	6	85.7	1	14.3

The survey questions were divided into five main categories to measure different abilities in children, as follows:

1. Category One: Response to Familiar Sounds
    - Does your child show a positive response to familiar sounds?
    - Does your child enjoy playing with toys that make sounds, such as whistles or toy cars?
    - Does your child respond to the sound of the radio or recorder when it is played?
    - Does your child respond to sounds coming from a distance?
    - Does your child stop crying when you speak to them without them seeing you?
2. Category Two: Interaction with Sounds and Music
    - Does your child show interest in listening to people speaking?
    - Does your child show interest in talking to people?
    - Can your child be calmed down when sad or in a bad mood by listening to music?
    - Does your child show a fearful response when hearing an angry voice?
    - Does your child interact with musical tones through body expressions?
3. Category Three: Understanding Words and Simple Commands
    - Can your child produce appropriate sounds for a game while playing?
    - Does your child respond when called by name?
    - Does your child respond to short and simple commands like "come" or "give" without the need for additional cues?
4. Category Four: Associating Sounds with Events and Situations
    - Does your child attempt to locate the source of sounds coming from above or below?
    - Can your child associate specific sounds with particular events or occasions?
5. Category Five: Imitating Sounds and Words
    - Does your child imitate sounds when asked to do so?
    - Does your child try to imitate the sounds of the surrounding environment, such as animal sounds, doorbells, or police cars?
    - Does your child know the names of family members?

Also, the percentage of positive responses for each category was calculated to determine the strengths and weaknesses of children's abilities and study them.

The results were as follows:

Table(11) The percentage of children’s mastery of each ability

Category	Percentage%
Response to Familiar Sounds	90.2%
Interaction with Sounds and Music	85.3%
Understanding Words and Simple Commands	97,2%
Associating Sounds with Events and Situations	95.9%
Imitating Sounds and Words	94.5%

The survey results indicate that children at the rehabilitation center have shown positive auditory development overall. However, there is a need for improvement in the areas of auditory interaction and imitation. It is important to focus on activities that encourage interaction with sounds, utilize various imitation techniques, provide an environment rich in sounds, and train parents on how to support children's interaction with sounds.

Table(12) Question No. 22

عندما يتلقى الطفل اتصالًا هاتفيًا ويعرف من خلال صوت الأب أو الجدة أن الشخص الذي يتحدث هو أحدهم، يميل إلى أخذ السماعة والاستماع بانتباه إلى الصوت												
#Q	1-3				4-5				Greater than 5			
ANS	Yes		no		Yes		no		Yes		no	
22	31	96.8	1	3.2	8	80	2	20	5	71.4	2	28.6

Based on the responses to question 22, which assessed children's reaction to familiar voices over the phone, it was observed that children who received cochlear implants at ages 1-3 demonstrated a higher response rate of 96.8%, compared to those implanted at ages 4-5 with a response rate of 80%, and those implanted at age 5 and above with a response rate of 71.4%.

This decline in response rate with increasing age underscores the importance of early cochlear implantation in familiarizing children with voices. Young children undergo a critical period for auditory and language development, and implantation during this period allows them to leverage this sensitive learning period more effectively.

Research suggests that young children have a strong auditory and linguistic foundation from the start, making it easier for them to recognize familiar voices like those of family members. Conversely, older children may struggle more in identifying familiar voices due to missing this critical developmental window for auditory and linguistic growth.

These findings highlight the significance of early intervention and cochlear implantation at a young age to enhance children's auditory and linguistic capabilities, improve their response to familiar voices, and contribute to better quality of life and social interaction.

We distributed a questionnaire at hearing and speech rehabilitation centers, consisting of 30 questions to measure the abilities of children aged 1-3 years. The questionnaire was distributed to children of different ages, and the results were as follows:

Table(13) Children who received a cochlear implant and Their percentage of "yes" answers to the questions

Children who received a cochlear implant at ages	**Their percentage of "yes" answers to the questions**
1-3 years	56.7%
4-5 years	56.7%
Greater than 5 years	56.8%

Interpretation of the Results

The results indicate that children who received a cochlear implant at ages 1-3 acquired the abilities of healthy children of the same age with a rate of 56.7%. Similarly, children who received a cochlear implant at ages 4-5 acquired the abilities of healthy children aged 1-3 with a rate of 56.7%, and children who received a cochlear implant at age 5 and above also acquired the abilities of healthy children aged 1-3 with a rate of 56.8%.

These results can be interpreted as follows:

1. **Importance of early timing for cochlear implantation:** The results suggest that children who received a cochlear implant at an early age (1-3 years) acquired the abilities of healthy children at that age with a significant rate (56.7%). This indicates that early intervention has a significant positive impact on improving the child's abilities. With continued rehabilitation lessons, it is expected that their acquisition rate of abilities will increase until they become similar to their healthy peers.
2. **Effect of cochlear implantation at older ages:** Children who received a cochlear implant at ages 4-5 and 5 and above acquired the abilities of healthy children with rates of 56.7% and 56.8% respectively. This means that their abilities (auditory and speech) became younger than their chronological age. Although these rates are high, they indicate that the impact is less effective compared to cochlear implantation at a younger age.
3. **Convergence in response rates:** Despite the age differences at cochlear implantation, the acquisition rates of abilities are very close (56.7% and 56.8%). This indicates the effectiveness of rehabilitation centers in improving children's abilities regardless of age, but it is preferable to do it at an early age to achieve better results.

Based on these results, we can conclude that cochlear implantation at an early age (1-3 years) brings children with hearing impairment closer to their healthy peers in their abilities. The earlier the intervention is done, the greater the benefits, highlighting the importance of early detection and prompt intervention for children with hearing impairment.

Age group of children who received cochlear implants

Table (14) The mean, median, and standard deviation for the current age of children with cochlear implants in the age group of 1-3 years

Age group of children who received cochlear implants	Current age of child	Number of children	% of children	Mean	Median	Std . deviation
1-3	2	3	9.4	4.42	4	1.700
	2.5	1	3.1			
	3	6	18.8			
	4	7	21.9			
	5	9	28.1			
	6	4	12.5			
	9	2	6.3			
	total	32	100			

Table (15) The mean, median, and standard deviation for the current age of children with cochlear implants in the age group of 4-5years

Age group of children who received cochlear implants	Current age of child	Number of children	% of children	Mean	Median	Std . deviation
4 - 5	4	1	10	7.30	6	2.791
	5	1	10			

	6	4	40			
	7	1	10			
	9	1	10			
	12	2	20			
	total	10	100			

Table (16) The mean, median, and standard deviation for the current age of children with cochlear implants in the age group of Greater than 5 years

Age group of children who received cochlear implants	Current age of child	Number of children	% of children	Mean	Median	Std . deviation
Greater than 5	6	2	28.6	7.71	8	1.496
	7	1	14.3			
	8	2	28.5			
	9	1	14.3			
	10	1	14.3			
	total	7	100			

Chapter Six:

Limitations and Recommendations:

1. Limited Sample Size: As the study focuses on services for children with hearing impairments, the sample size may be limited, potentially affecting the generalizability of the findings to a broader population.
2. Focus on a Specific Geographic Area: The study may be concentrated in a particular geographic region, potentially not reflecting regional variations in programs and services available to these children in other areas.
3. Variation in Available Services and Resources: The availability of services and resources to support children with hearing impairments may differ across regions, potentially impacting the generalizability of the findings.
4. Reliance on Self-Reported Data: There is a possibility of bias in self-reported data from families and service providers, potentially affecting the accuracy of the collected information.
5. Changes in Policies and Legislation: Policies and legislation related to the care of children with hearing impairments may change during the study period, potentially impacting the applicability of the recommendations.
6. The recent war in Gaza has posed a major obstacle to our ability to access rehabilitation centers to collect the necessary data. It has also impeded a large number of children from reaching the rehabilitation centers to receive the required treatment and rehabilitation .The closure of roads and the difficulty of movement due to the tense security situation have restricted our mobility as well as the mobility of the children in need of care, negatively impacting our capacity to provide the required support and services.

Recommendations for Improving Outcomes for Children with Hearing Impairment:

1. Early Detection and Intervention: Implement universal newborn hearing screening programs and provide timely access to cochlear implantation and other appropriate interventions for children with identified hearing loss. Develop

comprehensive early intervention programs that address the child's auditory, speech, language, and cognitive development.

2. Genetic Counseling and Testing: Offer genetic counseling to families with a history of hearing impairment and consider genetic testing for newborns with suspected hearing loss to identify potential genetic causes and guide treatment decisions.

3. Financial Assistance and Accessibility: Establish financial assistance programs to cover the costs of cochlear implantation, rehabilitation, and other necessary services for children from low-income families. Explore innovative financing mechanisms and advocate for policies that promote equitable access to healthcare services for all children.

4. Family Support and Empowerment: Provide training and support to families of children with hearing impairment, create parent support groups, and promote positive attitudes towards hearing impairment and inclusion in mainstream educational and social settings.

5. Focus on Auditory Interaction and Imitation: Develop activities and programs that specifically target auditory interaction and imitation skills, utilize a variety of techniques to engage children in active listening and sound exploration, and provide an environment rich in diverse sounds. Train parents on strategies to support their children's auditory interaction and imitation skills in daily routines and home environments.

7. Early Cochlear Implantation: Advocate for early identification of hearing loss and timely access to cochlear implantation, ideally before the age of 3. Emphasize the importance of early intervention during the critical period for auditory and language development and provide resources and support to families considering cochlear implantation for their children.

8. Continued Monitoring and Evaluation: Regularly monitor children's progress in auditory development, conduct periodic assessments to identify areas of strength and weakness, and collaborate with families to develop individualized goals and strategies for supporting children's auditory and communication development.

9. Promote the use of assistive listening devices and technology, encourage inclusive educational settings, and advocate for policies that promote accessibility and inclusion for individuals with hearing impairment in all aspects of society.

Conclusion:

Despite our efforts, it's evident that our outreach initiatives fell short of achieving comprehensive community awareness. However, we successfully conducted an educational seminar and established a Facebook page to promote the importance of early diagnosis, timely intervention, and post-treatment rehabilitation.

This research aims to enhance public understanding and improve health outcomes for children with hearing loss. The findings will be instrumental in shaping future awareness campaigns, treatment protocols, and support mechanisms, ultimately fostering a more inclusive and supportive environment for affected children.

These endeavors represent important steps forward in our mission. The educational seminar provided valuable information to participants, potentially influencing their understanding and actions regarding early intervention. Similarly, the Facebook page serves as an ongoing platform for sharing information and engaging with a broader audience.

While our outreach may not have reached every corner of the community, these initiatives have laid the groundwork for future advocacy and awareness campaigns. As we move forward, we will continue to reflect on our experiences, refine our strategies, and collaborate with stakeholders to expand our impact.

In conclusion, while there is still work to be done, our commitment to improving awareness and support for childhood hearing loss remains unwavering. With persistence and dedication, we will continue to strive towards a society where every child receives the care and resources they need for optimal hearing health and overall well-being.

Appendices

Appendix One 1: Questionnaire

PALESTINE POLYTECHNIC UNIVERSITY

QUESTIONNAIRE

الأخ الكريم / الأخت الكريمة

تحية طيبة وبعد,

بفضل الله، نطلب منكم المشاركة في دراستنا البحثية المتعلقة بالتطور السمعي للأطفال بعد خضوعهم لعملية زراعة القوقعة وبرامج التأهيل المتبعة بعدها. يهدف هذا الاستبيان إلى جمع المعلومات الضرورية لتحليلها ودراستها في مشروع تخرجنا بعنوان

" A Holistic Initiative For Improving Hearing Care In Infants With Cochlear Implants"، والذي يشرف عليه الدكتور عثمان زلوم من جامعة بوليتكنك فلسطين. نرجو منكم ملء الاستبيان بدقة وصدق، حيث ستُستخدم البيانات في تحليلاتنا واستنتاجاتنا النهائية. نقدر تعاونكم ومساهمتكم القيّمة في هذه الدراسة المهمة. نتوقع أن تساهم إجاباتكم الصادقة والموثوقة في إثراء نتائجنا وتوصلنا إلى استنتاجات قيّمة. شاكرين لكم تعاونكم ومشاركتكم الثمينة في هذه الدراسة الهامة.

القسم الأول : معلومات عامة

يرجى وضع صح في الخانة التي تناسبك :

١. على أي عمر تم اجراء زراعة القوقعة ؟

☐ قبل السنة ☐ بين السنة والثلاث سنوات ☐ بين الأربع والخمس سنوات

☐ أكبر من خمس سنوات

٢. العمر الحالي للطفل :

كيف تملأ الاستبيان؟

يجب الإجابة على جميع الأسئلة عن طريق اختيار "نعم" أو "لا". يرجى اختيار:
.إذا لاحظت استجابة طفلك لنفس المؤثر السمعي مرة واحدة على الأقل نعم:
.إذا لم تلاحظ استجابة طفلك على المؤثر السمعي على الإطلاق، أو إذا لم تكن متأكدًا من الإجابة لا:

القسم الثاني : مجالات الدراسة

يرجى قراءة كل عبارة في هذا القسم ووضع اشارة صح في المكان المناسب الذي يمثل اجابتك :

الرقم	الأسئلة	نعم	لا
١.	هل يظهر طفلك استجابة إيجابية للأصوات المألوفة؟ مثل الابتسام، وتوجيه النظر نحو مصدر الصوت، والتفاعل بالتحدث؟		
٢.	هل يبدي طفلك اهتمامًا بالاستماع إلى الأشخاص الذين يتحدثون؟ مثل الانصات بانتباه، والانتظار بصبر، والتركيز على المتحدث بشكل مستمر؟		
٣.	هل يظهر طفلك اهتمامًا بالتحدث إلى الأشخاص؟ مثل التفاعل بالانتباه والتركيز عندما يتحدث شخص معين؟		
٤.	هل يستمتع طفلك باللعب بالألعاب التي تصدر أصواتًا، مثل الصفارات أو السيارات التي تصدر أصواتًا؟		
٥.	هل يحاول طفلك تحديد مصدر الصوت عندما يسمع شخصًا يتحدث ولكنه لا يراه؟		
٦.	هل يستجيب طفلك لصوت الراديو أو المسجل عندما يتم تشغيله؟ مثل الاستماع بانتباه، والتفاعل بالابتسام أو الغناء أو الكلام عند سماع الأصوات؟		
٧.	هل يستجيب طفلك للأصوات القادمة من مسافة بعيدة؟ مثل استجابته عندما يُنادى باسمه من غرفة أخرى؟		
٨.	هل يستطيع طفلك إصدار الأصوات المناسبة للعبة أثناء اللعب بها؟ على سبيل المثال، إصدار صوت "مياو" عند لعبه بالقطة، أو "بيب بيب" عند لعبه بالسيارة؟		
٩.	هل يمكن تهدئة طفلك عندما يكون حزينًا أو بمزاج سيء من خلال الاستماع إلى الموسيقى؟		

١٠.	هل يستطيع طفلك تنفيذ الأوامر البسيطة مثل "تعال" أو "اخلع الحذاء" عندما يطلب منه ذلك؟		
١١.	هل يتوقف طفلك عن البكاء عندما تتحدث معه دون أن يراك؟ مثل محاولتك لتهدئته بصوت لطيف أو غناء دون أن يراك؟		
١٢.	هل يستجيب طفلك عندما يتم ناديه باسمه؟		
١٣.	هل يستوعب طفلك الأسئلة البسيطة مثل "هل تريد اللعب؟" أو "هل تريد الطعام؟"		
١٤.	هل يقوم طفلك بتقليد الأصوات عندما يُطلب منه ذلك، مثل "اااه"، "اوووو"، "ايييبي"؟		
١٥.	هل يعرف طفلك أن لكل حيوان صوتًا مميزًا؟ مثل صوت القطة "مياو"، وصوت الديك "كوكوكو"؟		
١٦.	هل يظهر طفلك استجابة بالخوف عند سماعه لصوت غاضب؟ مثل الشعور بالحزن أو بدء البكاء؟		
١٧.	هل يحاول طفلك تحديد مصدر الأصوات التي تأتي من الأعلى أو الأسفل؟ مثل تحديد مصدر دقات ساعة الحائط، أو صوت كأس يسقط على الأرض؟		
١٨.	هل يتجاوب طفلك مع الأوامر القصيرة والبسيطة مثل "تعال" أو "هات" دون الحاجة إلى إشارة إضافية؟		
١٩.	هل يستطيع طفلك ربط أصوات معينة بأحداث محددة أو مناسبات معينة؟ مثل النظر إلى السماء عند سماع صوت الطائرة، أو الركض تجاه الباب عند سماع جرس المنزل؟		
٢٠.	هل يحاول طفلك تقليد أصوات البيئة المحيطة به، مثل أصوات الحيوانات أو جرس الباب أو سيارة الشرطة؟ على سبيل المثال، هل يقلد نباح الكلب أو صوت السيارة عند سماعها؟		
٢١.	فهم الأصوات التي تحمل دلالة خاصة؟ مثل فهم صوت الأذان كإشارة للصلاة؟		
٢٢.	عندما يتلقى الطفل اتصالًا هاتفيًا ويعرف من خلال صوت الأب أو الجدة أن الشخص الذي يتحدث هو أحدهم، يميل إلى أخذ السماعة والاستماع بانتباه إلى الصوت.		
٢٣.	هل يستجيب طفلك لكلمة "لا" ويتوقف عن الفعل الذي كان يقوم به، حتى لو كانت الكلمة مرتفعة بما يكفي لكي يسمعها الطفل حتى لو لم يستطع رؤيتك؟		
٢٤.	هل يستطيع طفلك جلب الأشياء التي تطلبها له باللفظ وبدون الحاجة إلى إشارة؟ مثل "أحضر الكتاب" أو "أحضر القلم"؟		
٢٥.	هل يمكن لطفلك تقليدك في نطق مقاطع قصيرة وطويلة عندما يُطلب منه ذلك؟ على سبيل المثال، نطق "لو" ؟		
٢٦.	هل يفحص طفلك مصادر الأصوات التي تأتي من اليسار، اليمين، أو من الخلف؟ على سبيل المثال، هل يلتفت ويحاول		

	تحديد موقع صوت شخص يناديه، أو عند سماع صوت بوق السيارة أو جرس الهاتف المحمول؟		
.٢٧	هل يتفاعل طفلك مع النغمات الموسيقية بتعبيرات جسمه؟ على سبيل المثال، هل يبدأ بالرقص أو يتحرك بإيقاع الموسيقى؟		
.٢٨	هل يعرف طفلك أسماء أفراد أسرته؟ على سبيل المثال، هل يستجيب بالنظر إلى الشخص المشار إليه عند سماع أسماء مثل "بابا" و"ماما"؟		
.٢٩	هل يمكن لطفلك تقليد الأصوات أو الكلمات التي تنطقها أنت؟ على سبيل المثال، هل يقلد صوت "سيارة" أو "دبدوب" عندما تنطقها؟		
.٣٠	هل يستطيع طفلك تكرار الكلمات التي تقولها، مثل قول "باي باي" لبابا؟		

الرقم	الأسئلة	نعم	لا
.١	هل هناك تاريخ وراثي للمرض في العائلة؟		
.٢	هل الحالة الاقتصادية للأسرة تسمح للطفل ب تلقي العلاج والتأهيل بعد العلاج ؟		
.٣	هل ظروف الطفل المعيشية والأسرية تسمح للطفل ب تلقي العلاج والتأهيل بعد العلاج ؟		
.٤	هل كانت الحرب الأخيرة على غزة تؤثر على وصول الطفل للعلاج ومراكز التأهيل بسهولة ؟		

يرجى الاجابة على الأسئلة التالية لغايات تهدف هذا البحث :

السؤال الأول : هل تلقى الطفل برامج تأهيل بعد الزراعة ؟ (نعم/لا)؟

إذا كانت الإجابة نعم, فضلاً قدم تفاصيل حول البرامج التأهيلية التي تلقاها الطفل.

....

....

....

السؤال الثاني : كيف وصفتم تطور السمع للطفل بعد الزراعة والتأهيل ؟

....

....

السؤال الثالث : هل لاحظتم أي تغيرات في سلوك الطفل بعد الزراعة ؟

إذا كانت الإجابة نعم, فضلاً أذكر/ي هذه التغيرات .

....

....

....

السؤال الرابع :هل هناك أي تحديات أو صعوبات تواجه الطفل أو واجهتكم قبل أو بعد الزراعة ؟ **إذا كانت الإجابة نعم, فضلاً أذكر/ي هذه التحديات أو الصعوبات .**

....

....

....

....

Appendix Two 2: Ethical Approval

University Graduates Union
Palestine Polytechnic University (PPU)

رابطة الجامعيين/ محافظة الخليل
جامعة بوليتكنك فلسطين

التاريخ: 2024/4/2

حضرة السيد مدير مدرسة الاستقلال المحترم

الموضوع: مساعدة طلبة مشروع تخرج

السلام عليكم ورحمة الله وبركاته،

اود اعلامكم بان الطالبتين :

أريج حاتم مخامرة	204540
مرجان نعيم حزازة	204526

تخصص الفيزياء التطبيقية/جامعة بوليتكنك فلسطين ترغبان في تنفيذ مشروع تخرجها بعنوان "مبادرة شاملة لتحسين العناية بالسمع عند الرضع الذين زُرعت لهم قوقعة الأذن" تحت إشراف الدكتور عثمان زلوم.

نطلب من حضرتكم السماح للطالبتين باخذ البيانات المطلوبة في مدرستكم لأغراض البحث. شاكرين لكم حسن تعاونكم معنا في خدمة الطلبة والمجتمع.

وتفضلوا بقبول فائق الاحترام

عميد الكلية

د. وليد الريماوي

فلسطين – الخليل – ص.ب: ١٩٨
مباني واد الهرية: تلفاكس: ٠٢-٢٢٣٣٠٥٠ / ٠٢-٢٢٣٠٠٦٨
مباني أبو رمان: تلفاكس: ٠٢-٢٢٣١٩٢١

P. O. Box: 198, Hebron, Palestine
Wadi Al Hareih Campus:Telefax: 00970-2-2233050, 2230068
Abu Roman Campus:Telefax: 00970-2-2231921
Email: president_office@ppu.edu www.ppu.edu

Figure(18) Ethical Approval 1

University Graduates Union
Palestine Polytechnic University (PPU)

رابطة الجامعيين/ محافظة الخليل
جامعة بوليتكنك فلسطين

التاريخ: 2024/4/2

حضرة السيد مدير مركز ألفا للسمع والنطق المحترم

<u>الموضوع: مساعدة طلبة مشروع تخرج</u>

السلام عليكم ورحمة الله وبركاته،

اود اعلامكم بان الطالبتين :

أريج حاتم مخامرة	204540
مرجان نعيم حزازة	204526

تخصص الفيزياء التطبيقية/جامعة بوليتكنك فلسطين ترغبان في تنفيذ مشروع تخرجها بعنوان "**مبادرة شاملة لتحسين العناية بالسمع عند الرضع الذين زُرعت لهم قوقعة الأذن**" تحت إشراف الدكتور عثمان زلوم.

نطلب من حضرتكم السماح للطالبتين باخذ البيانات المطلوبة في مركزكم لأغراض البحث. شاكرين لكم حسن تعاونكم معنا في خدمة الطلبة والمجتمع.

وتفضلوا بقبول فائق الاحترام

عميد الكلية

د. وليد الريماوي

فلسطين - الخليل - ص.ب: ١٩٨
مباني واد الهرية: تلفاكس: ٠٢-٢٢٣٣٠٥٠ / ٠٢-٢٢٣٠٠٦٨
مباني أبو رمان: تلفاكس: ٠٢-٢٢٣١٩٢١

P. O. Box: 198, Hebron, Palestine
Wadi Al Hareih Campus:Telefax: 00970-2-2233050, 2230068
Abu Roman Campus:Telefax: 00970-2-2231921
Email: president_office@ppu.edu www.ppu.edu

Figure (19) Ethical Approval 2

Appendix Three 3 : Brochure

Figure (20) Brochure picture

Appendix Four 4 : Graphics codes

We plotted the results using SPSS but the equivalent cods in python are listed below:

1. Rehabilitation center

```
import matplotlib.pyplot as plt
labels = ['Ephpheta School', 'Ephpheta School and MED-EL
Center', 'Istiqlal School', 'MED-EL Center']
values = [67.3, 14.3, 4.1, 14.3]
fig, ax = plt.subplots(figsize=(8, 6))
ax.pie(values, labels=labels, autopct='%1.1f%%',
startangle=90)
ax.axis('equal')
plt.title('Rehabilitation center', fontsize=16,
fontweight='bold')
```

2. The age at which the cochlear implant was implanted

```
import matplotlib.pyplot as plt

ages = ['1 - 3 YEARS', '3 - 5 YEARS', 'YEARS < 5']
values = [65.3, 20.4, 14.3]

fig, ax = plt.subplots(figsize=(8, 6))
ax.bar(ages, values, color='skyblue')

ax.set_title('The age at which the cochlear implant was
implanted', fontsize=16, fontweight='bold')
ax.set_xlabel('Age Range', fontsize=12)
ax.set_ylabel('Percentage', fontsize=12)
ax.set_ylim(0, 100)

for i, v in enumerate(values):
    ax.text(i, v + 1, f'{v}%', ha='center', fontsize=10)

plt.tight_layout()
plt.savefig('age_cochlear_implant.png', dpi=300,
bbox_inches='tight')
plt.show()
```

3. Having a genetic history

```
import matplotlib.pyplot as plt

labels = ['yes', 'No']
values = [49, 51]

fig, ax = plt.subplots()

ax.pie(values, labels=labels, autopct='%1.1f%%',
startangle=90)

ax.axis('equal')
ax.set_title('Having a genetic history', fontsize=16,
fontweight='bold')
ax.legend(labels, loc='best')

plt.show()
```

4. The economic situation allows the child to receive treatment

```
import matplotlib.pyplot as plt

labels = ['yes', 'No']
values = [51, 49]

fig, ax = plt.subplots()

ax.pie(values, labels=labels, autopct='%1.1f%%',
startangle=90)

ax.axis('equal')
ax.set_title('The economic situation allows the child to
receive treatment', fontsize=16, fontweight='bold')
ax.legend(labels, loc='best')

plt.show()
```

5. Living conditions allow the child to receive treatment

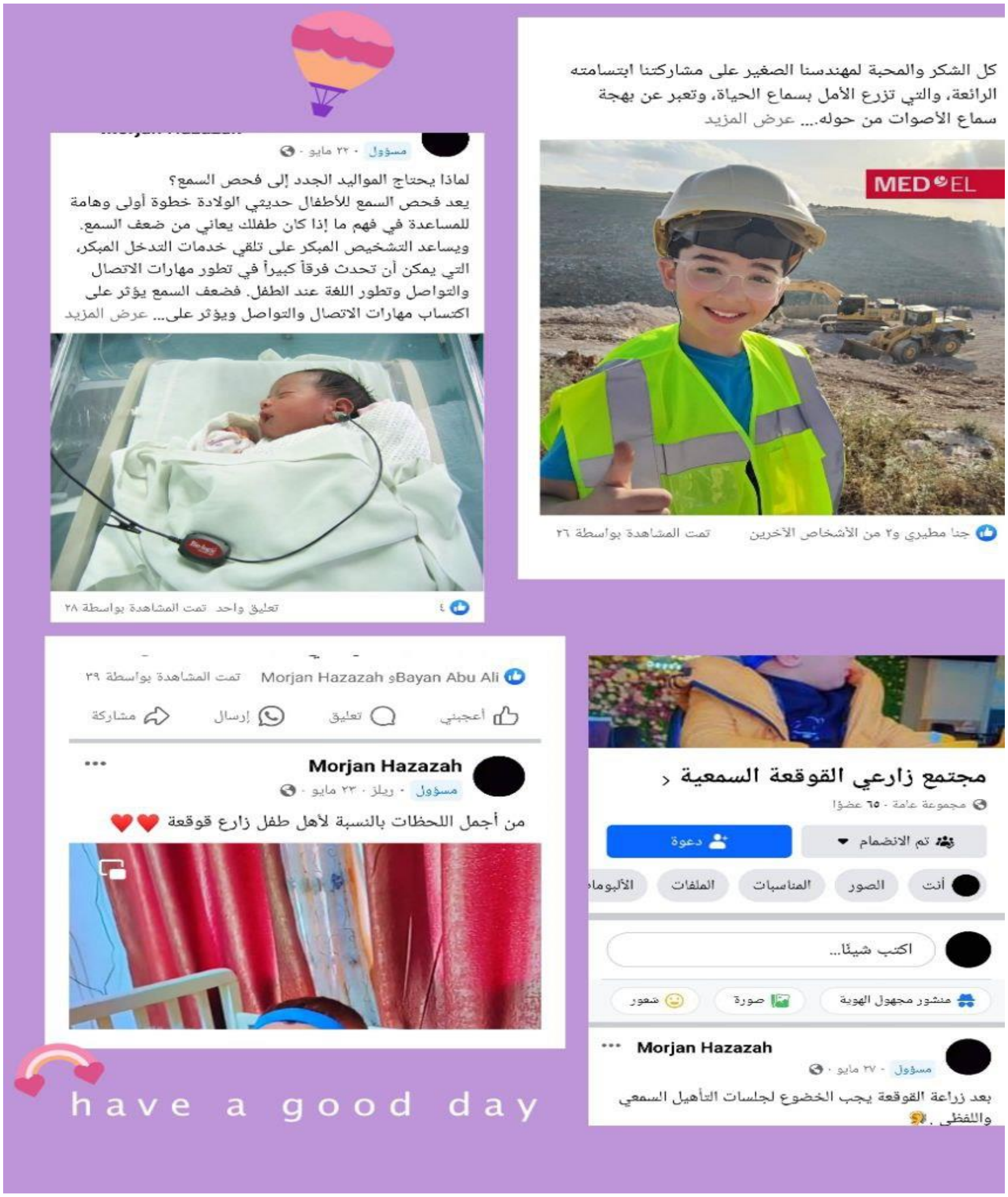
```
import matplotlib.pyplot as plt

labels = ['yes', 'No']
values = [73.5, 26.5]

fig, ax = plt.subplots()

ax.pie(values, labels=labels, autopct='%1.1f%%',
startangle=90)

ax.axis('equal')
ax.set_title(' Living conditions allow the child to receive
treatment ', fontsize=16, fontweight='bold')
ax.legend(labels, loc='best')

plt.show()
```

6. The recent war affected the child's access to treatment through difficulty of access

```
import matplotlib.pyplot as plt

labels = ['yes', 'No']
values = [85.7, 14.3]

fig, ax = plt.subplots()

ax.pie(values, labels=labels, autopct='%1.1f%%',
startangle=90)

ax.axis('equal')
ax.set_title(' The recent war affected the child's access
to treatment through difficulty of access', fontsize=16,
fontweight='bold')
ax.legend(labels, loc='best')

plt.show()
```

Appendix Five 5 : Ways to spread awareness

1. Facebook page



Figure(21) Facebook page picture

2. Conduct an educational seminar

Figure(22) Seminar picture

Figure (23) An awareness visit to Ephpheta school

References

[1] J. Hanna, "Sound Waves|PASCO," 17 2 2020. [Online]. Available: https://www.pasco.com/resources/article/sound-waves. [Accessed 21 5 2024].

[2] "Sound wave definition, characteristics, and use in acoustics," [Online]. Available: https://svantek.com/academy/sound-wave/.

[3] "Sound Intensity and Sound Level," [Online]. Available: https://courses.lumenlearning.com/atd-austincc-physics1/chapter/17-3-sound-intensity-and-sound-level/. [Accessed 21 5 2024].

[4] "Physics Tutorial:The Human Ear," [Online]. Available: https://www.physicsclassroom.com/class/sound/Lesson-2/The-Human-Ear. [Accessed 21 5 2024].

[5] "Anatomy and physiology 2e," 15 7 2023. [Online]. Available: https://openstax.org/details/books/anatomy-and-physiology-2e.

[6] "Human ear - Cochlea, Hair Cells, Auditory Nerve | Britannica," [Online]. Available: https://www.britannica.com/science/ear/Transmission-of-sound-within-the-inner-ear.

[7] [Online]. Available: https://www.hopkinsmedicine.org/health/conditions-and-diseases/how-the-ear-works.

[8] S. Felson, "Treatments for Hearing Loss," WebMD Editorial Contributors, 23 8 2022. [Online]. Available: https://www.webmd.com/a-to-z-guides/hearing-loss-treatment-options. [Accessed 6 6 2024].

[9] "Go supps.com," [Online]. Available: https://www.algeria.ubuy.com/ar/product/30TBAV3W-hearing-aids-for-seniors-invisible-rechargeable-hearing-amplifier-with-noise-cancelling-for-adults-h.

[10] "medel," 2023. [Online]. Available: https://www.medel.com/ar/about-hearing/types-of-hearing-loss.

[11] "Cochlear Implants," 6 3 2024. [Online]. Available: https://www.nidcd.nih.gov/health/cochlear-implants. [Accessed 2021 5 2024].

[12] "How cochlear implants work," [Online]. Available: https://www.cochlear.com/us/en/home/diagnosis-and-treatment/how-cochlear-solutions-work/cochlear-implants/how-cochlear-implants-work. [Accessed 21 5 2024].

[13] "Hearing | Introduction to Psychology," [Online]. Available: https://courses.lumenlearning.com/suny-intropsychmaster/chapter/hearing/. [Accessed 21 5 2024].

[14] C. Franco, "Cochlear implants give the gift of hearing, but they're not for everyone," 20 7 2015. [Online]. Available: https://www.arkansasonline.com/news/2015/jul/20/aural-awakening-20150720/. [Accessed 3 6 2024].

[15] A. Namasivayam, "Cochlear Implant Technical Issues: Electrodes, Channels, Stimulation Modes and more," 21 6 2004. [Online]. Available: https://www.audiologyonline.com/articles/cochlear-implant-technical-issues-electrodes-1081. [Accessed 21 5 2024].

[16] [Online]. Available: https://www.pinterest.com/pin/428616089549721025/.

[17] M. W. Canfarotta, . M. . T. Dillon, . E. Buss, . H. . C. Pillsbury and . K. D. Brown, "Frequency-to-place mismatch: Characterizing variability and the influence on speech perception outcomes in cochlear implant recipients.," *Ear & Hearing,* pp. 41(5), 1349–1361, 2020.

[18] D. M. Landsberger, . K. Vermeire, . A. Claes, V. V. Rompaey and . P. V. d. Heyning, "Qualities of single electrode stimulation as a function of rate and place of stimulation with a cochlear implant.," *Ear Hear,* pp. 37(3), 149–159, 2016.

[19] "Close to natural hearing – what does it need?," [Online]. Available: https://hearbetter.medel.com/en-int/close-to-natural-hearing-what-does-it-need/. [Accessed 2024].

[20] S. . K. An 1, S.-I. Park, . S. . B. Jun, . C. J. Lee, . K. . M. Byun, . J. H. Sung, B. S. Wilson, S. J. Rebsche and S. H. Oh, "Design for a simplified cochlear implant system," *Pubmed,* 6 2007.

[21] "History of the Cochlear Implant," *very well health,* 2020.

[22] "Cochlear Implants".*American Speech-Language-Hearing Association.*

[23] S. Miller, "Surgical advancements may lead to better outcomes for children and adults with severe or profound hearing loss.," *Jefferson Health,* 4 10 2023.

[24] D. G. Alexiades, "New Technology Expands Applications for Cochlear Implants".*NewYork-Presbyterian.*

[25] R. . T. Swead , . L. K. Liat , R. K. Neeman, C. Muchnik, J. Kronenberg and M. Hildesheimer, "Speech perception of children using Nucleus, Clarion or Med-El cochlear implants," *PMID,* 5 2 2005.

[26] "Risks and Limitations," [Online]. Available: https://www.babyhearing.org/devices/risks-and-limitations.

[27] W. J. Parkes, "Cochlear Implants".*namours kids health.*

[28] "FDA approves Cochlear's Nucleus 8 Sound Processor, smaller, smarter, better," 1 11 2022. [Online]. Available: https://pronews.cochlear.com/nucleus-8-sound-processor/.

[29] "Recent Innovation powering the Smart Hearing Alliance," 9 7 2020. [Online]. Available: https://pronews.cochlear.com/recent-innovation-powering-the-smart-hearing-alliance/.

[30] "Rehabilitation resources," [Online]. Available: https://www.cochlear.com/us/en/home/ongoing-care-and-support/rehabilitation-resources.

[31] D. Sorkin, "Tips for Using Rehab Apps to Improve Listening Skills with Cochlear Implants," *The Hearing Journal,* vol. 7, 2022.

[32] D. S. Wayner and . J. E. Abrahamson, "Learning to Hear Again: Cochlear Implant Audiologic Rehabilitation Guide for Adults," *AUDIOLOGYORLne a Continued family site,* 2002.