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In the name of God a comparative study of the performance of wireless implantable implants in the head and neck area

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Abstract:
Aim: *With the increase of the elderly population in societies and the emergence of diseases and disabilities, especially in the head and neck area such as eyes, ears and brain, the need for implantable devices with the ability to help in hearing, vision and strengthening brain signals is increasing. Implantable implants with small size, high power and transmission of electrical signals can help improve the function of these organs. The purpose of this study is to investigate implants implanted in the head and neck area with wireless power transmission (WPT) and compare them with conventional wires and measure their performance.*
Method & Materials:In order to conduct this review, original articles in English language were collected from PubMed and Google Scholar databases. Articles were reviewed from 1993 to 2023. Unpublished studies and studies in non-English language were not reviewed. The review was done on all articles in which implants were placed in the head and neck area, including eyes, ears, and brain. In this study, the aim was to focus on the devices that had the ability to transmit power wirelessly, although the articles in which the power transmission was done conventionally or with wires were also discussed. Key words such as WPT, ear implant, eye and brain were used for the review. And the results were compared together.
Results: *High power wireless implantable implants are used in the brain region to guide neuronal messages in areas with neuron destruction. In the eye area, these implants are divided into two categories: intraocular implants for intraocular pressure detection and glaucoma treatment, where the sensor is installed inside the eyeball and the external sensor is installed on the eyeglass frame. And the implants embedded in the retina, which by amplifying the signal in the healthy nerve cells under or on the retina, receive the light and image messages sent from the glasses and wirelessly send the messages to the brain. And finally, there are cochlear implants, which by amplifying and sending electrical signals, increase the stimulation of the auditory nerve and treat problems in conductive-neural deafness patients.*
Conclusion: *With the spread of various diseases and the increase in the age of the world's population, implantable implants can be very efficient, especially with a small size design, high power, signaling capability and proximity to the tissue in the head and neck area.*
Key words:
implantabledevice - WPT - ear implant - eye implant - brain implant

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I. Introduction :

With increasing awareness in medical diagnostics and monitoring systems, research in medical engineering in various fields is increasing. In this context, sensors and implants implanted in the head and neck area can play a vital role in monitoring patients and helping to improve the performance of their body devices. (1), (2) At the beginning of the 21st century, some implantable medical devices such as heart pumps (3), hearing aids (4), pacemakers (5) and nerve-muscle stimulation (6,7) using Batteries were used. Batteries were associated

with problems such as increasing the weight of the device, a large number of batteries to increase the functionality of the implantable device, making batteries with a longer lifespan, biocompatibility with the body, etc. and time for patients have pushed power transfer systems in body implants to wireless power transfer (WPT). Low weight, small size of the devices and direct contact with the tissue are the advantages of this power transmission system. This technology has been widely used since 1880 from low power to high power implants. (10) (3 and (11-14)) The first material about WPT was in 1889 by Nikola Tesla using resonance. magnetism and power transmission through a pair of wires were presented. (15) Many studies were conducted to investigate various power transmission systems in body tissues. In 2017, in an article, power transmission through the skin of the body for implant systems was proposed. Due to the different thicknesses of the body tissues and the lack of the skin's general ability to conduct high electrical power in different tissue thicknesses, the skin can be considered a poor conductor. Wireless, ultrasonic, radiofrequency and heat inducers were performed, 2 electrodes were used simultaneously to stimulate the auditory nerves. (17) What is discussed in this article is the use of implants in the head and neck region The function of the wireless type of these devices and the ability to transmit power in them is due to the occurrence of various diseases and the involvement of body organs, especially the vital organs in the head and neck area, such as the eye with visual function, the ear with hearing function, and the brain with various sensory functions. , motor, cognitive and thinking and information processing, obtaining comprehensive information about the progress of the auxiliary devices of these members in the head and neck area will not be without grace.

II. Method &Materials :

In order to conduct this review, original articles in English language were collected from PubMed and Google Scholar databases. Articles were reviewed from 1993 to 2023. Unpublished studies and studies in non-English language were not reviewed. The review was done on all articles in which implants were placed in the head and neck area, including eyes, ears, and brain. In this study, the aim was to focus on the devices that had the ability to transmit power wirelessly, although the articles in which the power transmission was done conventionally or with wires were also discussed. Key words such as WPT, ear implant, eye and brain were used for the review. And the results were compared with each other.

III. Results :

In order to check the implants to be implanted in the head and neck area, 3 fields of activity of the implants are checked.

Eye:

The human eye is a sensitive organ and part of the sensory nervous system that reacts to light and has the ability to process and receive information and see objects. In fact, the eye is an almost round visual system, the outer surface of which is the sclera, the inner layer of which is the choroid, and the cone-like end of which contains the optic nerve. Other components such as lens, cornea, pupil, iris and retina are also present in it, which is the place of light reception, light accumulation and its processing and image creation. (18)

Implants implanted in the eye are divided into two categories: retinal implants and intraocular implants.

Retinal implant: It is used in the treatment of disabled patients with problems of destruction of the outer surface of the retina or age-related macular destruction (19,20) and especially in countries with an elderly population. (21) This device performs the function of vision through the electrical stimulation of healthy cells and the bypass of damaged cells and then increasing the transmission power of the electrical signal in them. Information through a miniature transmitter on the eyeglass frame (22,23) done and the implant receives and processes the signals. Wireless implants are placed in two ways: subretinal and epiretinal. (20)

Intraocular implant: It is an inductive connection to check intraocular pressure for glaucoma treatment. An internal coil around the lens to measure intraocular pressure and an external coil in the glasses are provided wirelessly to transmit power and receive information. (24)

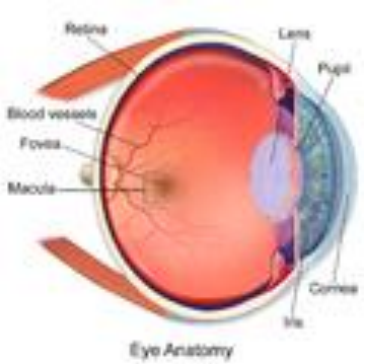

Figure1,eye anatomy

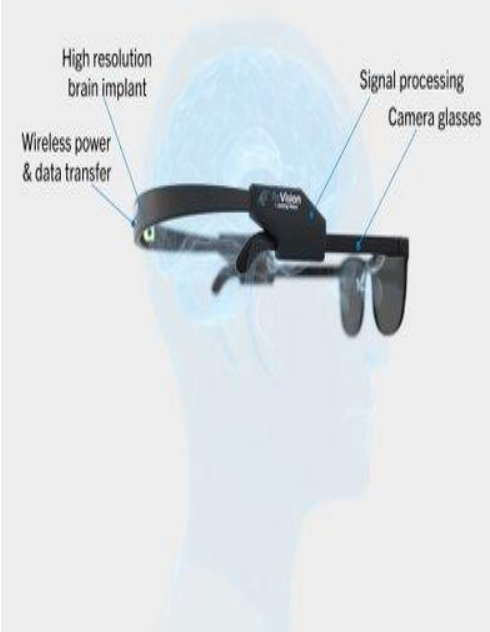

figure2, eye implant

ear:

The ear is a sensitive auditory-balance organ that by receiving information from the surrounding environment and hitting the tympanic membrane and causing vibration and passing through the barrier of the middle ear bones, malleus, anvil and stapes, and after amplifying and transmitting the sound, it finally reaches the inner ear. And the thin hair cells in the inner ear convert the vibrations into electrical energy and transmit them to the brain as a signal. The ear is located in the temporal bone and includes the outer ear (cartilage and wax), the middle ear (eustachian tube and ossicles) and the inner ear (cochlea and semicircular canals). (25)

For the use of ear implants and signal amplification, they use cochlear implants that bypass the damaged hair cells by direct stimulation of the auditory nerves inside the cochlea with modulated electrical pulses (Article 5-i) and by increasing the power through placement Giving the outer part of the device behind the ear and receiving the sound with a microphone and the inner part including the processor and amplifier in the ear can cause hearing information to be received in sensorineural or conduction deaf patients. (26,27) Kim and his colleagues designed a WPT system for hearing aid implants, which uses an electromagnetic actuator to charge the device's batteries, and the batteries are in two small box and bubble shapes. (28) Kumar and his colleagues designed a high-quality four-coil implant system, which compared to the two-coil system, can improve power transmission and receive signals or batteries. (29) In the study conducted by Dr. Rezaey and myself about ear implants, a pair of electrodes in the form of a power transmission channel was used for power transmission. The electrodes had different inputs and were placed in close contact with the ear tissue. Investigations showed that the closer the distance between the tissue and the implant, the greater the wireless energy transfer and the lower the power loss.

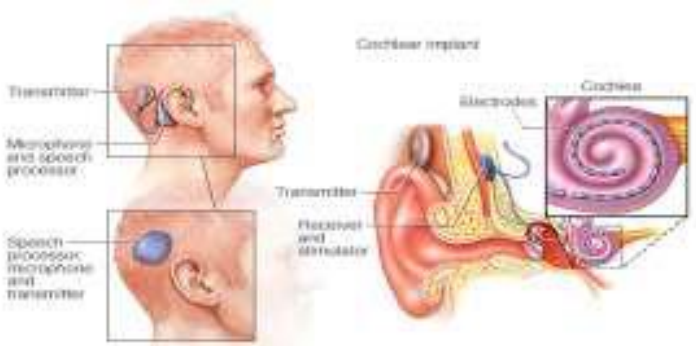

Figure 3, Ear anatomy

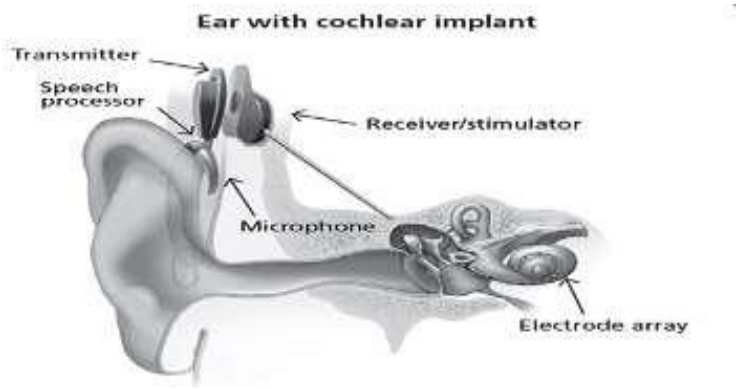

Figure4, Structure and characteristics of cochlear implants

the brain :

The brain is a complex organ for controlling thoughts, memory, feeling, touch, motor skills, vital actions, hunger and any process that needs regulation in the body. Together, the brain and spinal cord make up the central nervous system (CNS). The brain is the transmitter and receiver of electrical and chemical signals in the body, and different signals control different processes in the body. Neurons are responsible for transmitting messages from the sender to the receiver and from the brain to the whole body and vice versa. The brain is divided into the main parts of the cerebrum, brainstem, and cerebellum. (30)

An effective method in reducing the destructive effects of damaged neurons in the brain, spinal cord and peripheral nerves is the use of implants in these areas (31) (32).

Deep Brain Stimulation:

These implants can improve the destructive effects of neurons in diseases such as Alzheimer's, Parkinson's and amyotrophic lateral sclerosis (ALS) by sending signals and increasing transmission power through healthy neurons and bypassing defective neurons. Nerve stimulation is done by electrical signals that amplify them by receiving messages from neurons and wirelessly deliver them to the processing parts of the brain with high power, which can include cortical or deep stimuli, such as cerebrospinal fluid. The size of the implants is small and in close contact with the tissue as much as possible. (33-35)

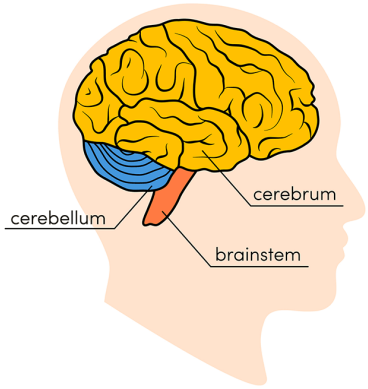

Figure 5, Brain anatomy

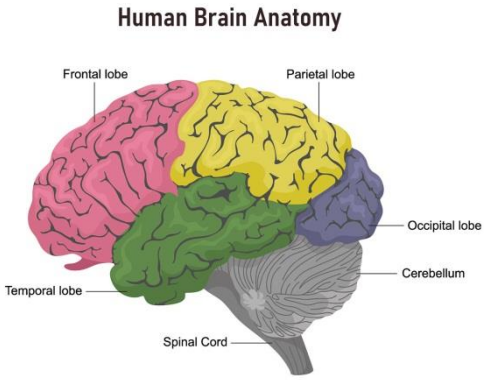

figure 6, Brain lobes

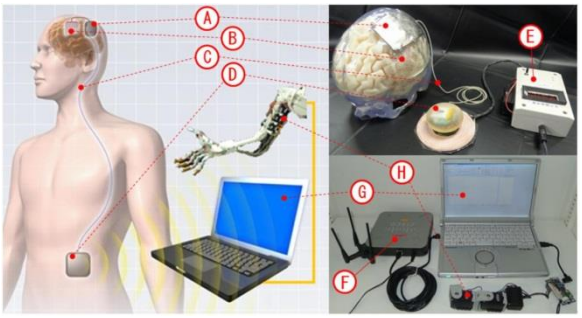

Figure 7, Brain stimulation devices

IV. Discussion &Conclusion :

What we investigated in this study was the use of implants in the head and neck area. The presence of vital organs in this area, such as ears, eyes, and brain, and having the main functions such as vision, hearing, perception, speech, motor activities, etc., has highlighted the importance of the head and neck area. The topic of high-power wireless transmission (WPT) implants has been researched since about 150 years ago. The use of small devices with high power capability and less energy loss in transmitting and receiving signals in tissues is known as the advantage of implantable devices with WPT. However, disadvantages such as the lack of compatibility of the device with the tissue or the limitation of too close contact with the tissue, for example in the brain area, are the challenges of some of these devices. On the other hand, increasing the distance can weaken the signaling and thus reduce the efficiency of the device. In 2021, an article titled Bone Conducted Cochlear Implant Microsystems with Multiple Stimulations was published. In this article, 2 electrodes with multiple stimulations created an electric field under the guidance of the ear bone, which was able to stimulate the auditory nerve. (36) Qi and his colleagues designed a biomedical device with WPT capability, with moving targets using seven coils and using a magnetic field to transmit information into the body of an animal. (37)

Xue and colleagues designed a high-frequency WPT technique for an implant in the nervous system. By increasing the power by using spiral coils and voltage regulation, they made a small device with high capability. (38) In addition to all these studies, there are still ways to develop new implantable devices in the head and neck area. The use of more advanced techniques, the possibility of using multiple targets with an implantable device and the possibility of remote control of these devices, show a new horizon of progress in this way.

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