BIONIC EYE PROSTHESIS

Dr. K. Lokesh Sai, Dr. Subhabrata Maiti

INTRODUCTION

Worldwide, At least 2.2 billion people suffer from near or far vision loss. Nearly 1 billion people have preventable or untreated blindness. The major cause of blindness worldwide is poor vision and cataracts. Worldwide, it is estimated that only 36% of people with farsightedness due to nearsightedness and only 17% of people with nearsightedness due to cataracts receive appropriate care.

Visual impairment is a burden on the global economy with an estimated annual global production cost of $411 billion. Visual Impairment affects people of all ages; But most people who are blind are over the age of 50. [1]

In atleast half of these cases, vision impairment could be prevented . Among these 1 billion people, diseases that cause vision impairment or blindness include cataracts (94 million), refractive errors (88.4million), macular degeneration (8 million), diabetic retinopathy, glaucoma [2]. The leading cause of near vision impairment is presbyopia (826 million) [3].

Retinal diseases such as retinitis pigmentosa (RP), which affects 1 in 4000 or 0.025% of the population, occur mainly in macular degeneration which is usually age related (AMD), which affects approximately 5% of working age [4,5]. It is an important cause of blindness in the world [6,7] Cone dystrophy, anchoroidemia, and Stargardt's disease are special areas where researchers work on the bionic eye [8,9]. There are currently many research groups worldwide working to develop optical systems that cover all possible areas in the visual pathway. It is reported that nearly 20 research groups based in the United States, Australia, Germany, Japanand France are working on the spinal cord in different plants. Clinical trials of these devices have shown that they can improve visual acuity and/or the ability to perform activities of daily living [10]

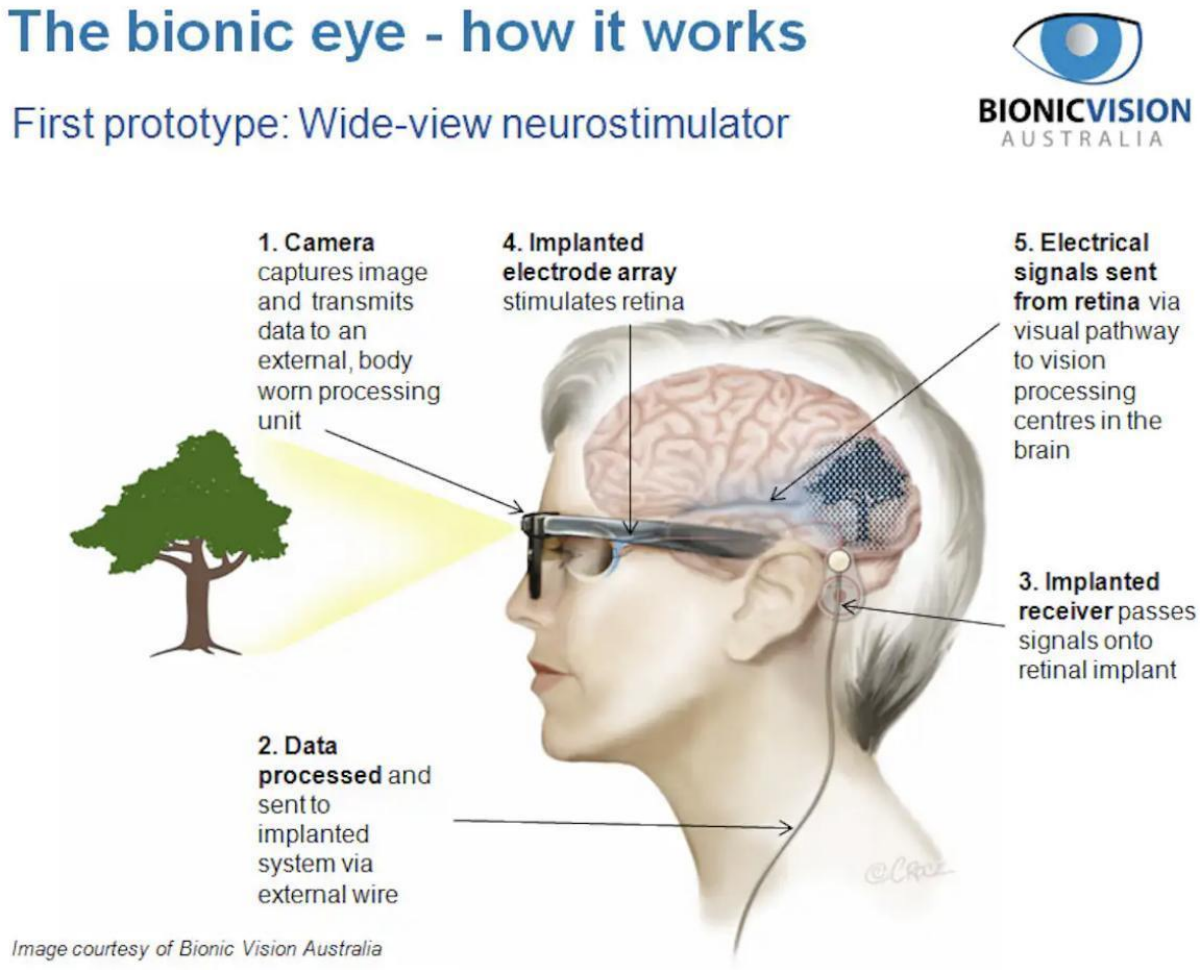
Natural Vision principles

To develop a bionic eye, it is very important to learn about the process in which light is absorbed, and is converted into electrical impulses and encoded into nerve signals. Light passes through the cornea, iris, and lens, helping the light focus on the photosensitive retina. Retinal cells have photoreceptors (PRs), rods, and cones, through which photochemical reactions convert light into electrical nerve signals through stimulation of retinal ganglion cells (RGC). Each eye contains 120 million rods that are sensitive to dim light.[11], while the 6 million cones responsible for color vision work best in bright light [12]. RGCs have 1 million axons that run from the optic nerve to the lateral geniculate nuclei (LGN) in the thalamus. LGN is a complex hierarchical structure in which each segment receives axons from a particular ganglion cell type. Before projecting to the first visual cortex, where all the higher cognitive processing takes place, a certain degree of

vision occurs [13] by affecting the power of the retina, and high spatial and temporal solutions can be obtained in various colors and contrasts. .
Recognition of objects and geometric patterns, appreciation of distance, direction, and movement, and coordination of visual interpretation with other senses and motor skills may be due to integration of the neural cortex. In the space of one millisecond, a vast amount of visual information is captured, assimilated, compressed, and processed.

What is the working principle of the bionic eye?

The bionic eye, also known as visual prostheses, is a device designed to help blind people see again. There can be different types of bionic eyes, but the working principle for all the types of bionic eyes remains the same which uses electrical stimulation to stimulate vision in the brain.



This image demonstrates bionic vision technology, which is based on a camera that takes pictures, analyses them, and transmits information to an implanted retina. The electrodes in this implant stimulate the retina's surviving cells to produce the perception of vision.

(Image source: Bionic vision Australia)

The most common types of bionic eyes are retinal implants designed to substitute the activity of damaged photo-receptor cells in the retina. The retina is a thin layer of tissue that contains special cells called photoreceptors. These cells convert light into electrical signals that are sent to the brain and translated into visual images[14,15,16]. In people with damaged retinas, photoreceptor cells cannot function properly, resulting in vision loss. The retinal implant works by crossing the damaged photoreceptor cells and directly supporting the cells that remain in the retina. A retinal implant consists of a series of small electrodes that are implanted into the retina. These electrodes are connected to a small camera mounted on the patient's glasses. The camera captures the image and sends it to a small computer that the patient wears, which processes the image and sends a signal to the electrodes on the implant. When the electrodes in the implant are stimulated, they produce small electrical currents that activate other cells in the retina. These cells then send signals to the brain, where they are interpreted as visual images.

The quality of the visual images produced by retinal implants can vary depending on many factors such as the number and location of the electrodes, the resolution of the camera, and the technique of working with the computer. Most retinal implants currently only produce very low resolution images, but scientists are trying to develop technology that will provide detailed and natural vision. In addition to retinal implants, there are other types of bionic eyes that work differently. For example, optic nerve implants are designed to directly support the brain, bypassing the damaged retina. Cortical implants, on the other hand , are designed to directly support the visual cortex of the brain, bypassing the retina and optic nerve.
Regardless of the specific type of bionic eye, all of these devices work by using electrical stimulation to stimulate vision in the brain. While the technology is still in its early stages, the bionic eye has the potential to improve the lives of the blind and could one day lead to fully functional vision.

Types of Bionic Eyes.

There are many types of bionic prostheses, each targeting a specific field of view [17,18,19,20,21]. The are retinal, optic nerve, and cortical implants, each with their own advantages and disadvantages [22,23,24,25,26].

A. Retina Implants

Retina implants are the most commonly used type of bionic eye. It is intended to treat people who have retinal degenerative illnesses such retinitis pigmentosa and age-related macular degeneration who have become blind.. A retinal implant consists of a small camera which is mounted between two glasses and an array of electrodes implanted into the retina. The camera captures the image, which is then processed and sent to electrode device.

The array supports the retina, creating visual images that are sent to the brain. Retinal implants have shown promising results in clinical trials; many patients reported improvement in visual function. However, the quality of the images produced by this device is still limited and this technology is not suitable for all types of vision loss.

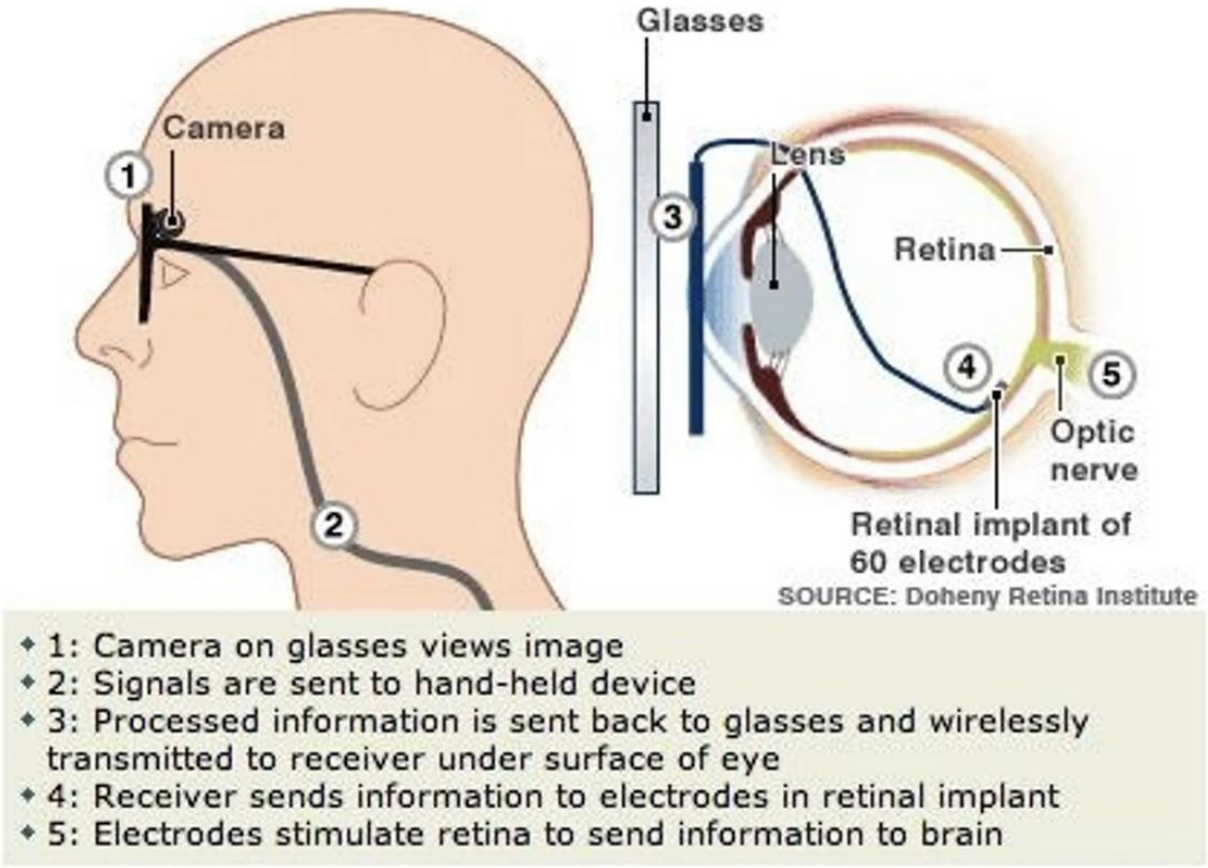


Image showing transmission of data in retinal implants
(Image source: Doheny Retina Institute)

Advantages

1. Retinal implants can restore some vision functions in people with degenerative diseases of retina such as retinitis pigmentosa and macular degeneration which is related to age.
2. Retinal implants are also non-invasive because the implant is placed inside the eye and it does not require brain surgery.
3. This technology has been around for a while and is maturing through clinical trials.

Disadvantages:

1. The image quality produced by the retina implant is limited and patients may experience degradation, lack of resolution, and difficulty seeing faces.
2. Not all forms of visual impairment are compatible with this prosthesis, and not all patients qualify for implants.
3. Retinal implants need surgery and it carries certain complications and risks.

B.Optic Nerve Implants

The Optic Nerve Implant is designed to assist in regaining vision in patients with optic nerve damage due to optic neuritis, glaucoma and/or other conditions. Optic nerve implants consist of an array of electrodes implanted in the brain. The array supports the nerves that produce visual images that are transmitted to brain. The Optic nerve implants are still under development and clinical trials have yet to yield results. But the technology shows great promise for people with brain damage whose treatments are currently limited.

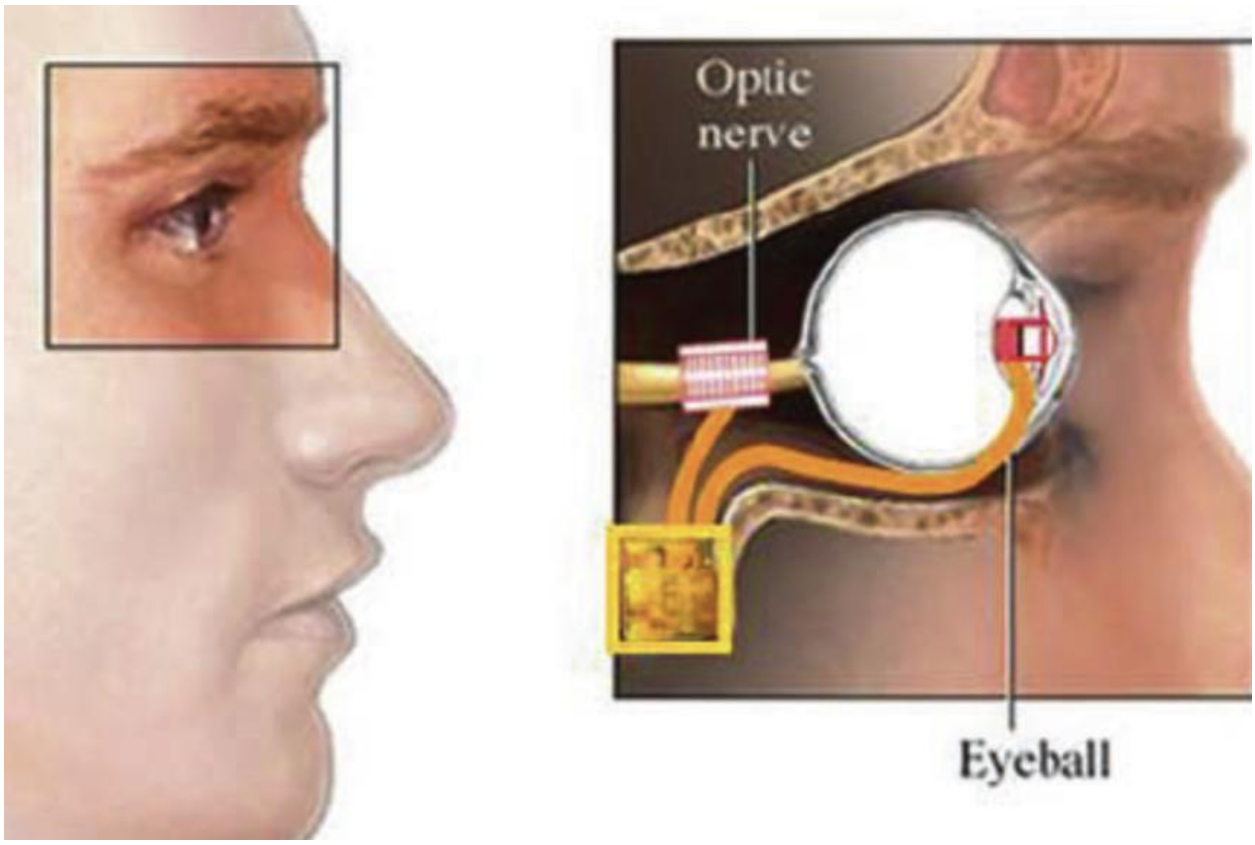


Figure shows Optic nerve visual prosthesis using penetrating microelectrode arrays

Advantages:

1. Optic nerve implants can restore some degree of visual function to patients with optic nerve injuries that are currently difficult to treat.
2. The implant is non-invasive as it is placed in the optic nerve and does not require brain surgery.
3. This device can provide better images than retinal implants.

Disadvantages:

1. The technology is still in the early stages of development and clinical trials have yet to show results.

2. Optic nerve implants may not be suitable for all types of optic nerve injuries and not all patients are candidates for optic implants.

C. Cortical Implants

Cortical implants are designed to help restore vision in people with damage to the visual cortex (the part of the brain that processes visual information). Cortical implants contain arrays of electrodes implanted in the eye cortex. The array creates visual images that the patient sees by stimulating the cortex.

Cortical implants are still in development and clinical trials have yet to yield results. But the technology holds great promise for people with facial damage whose treatments are currently limited.

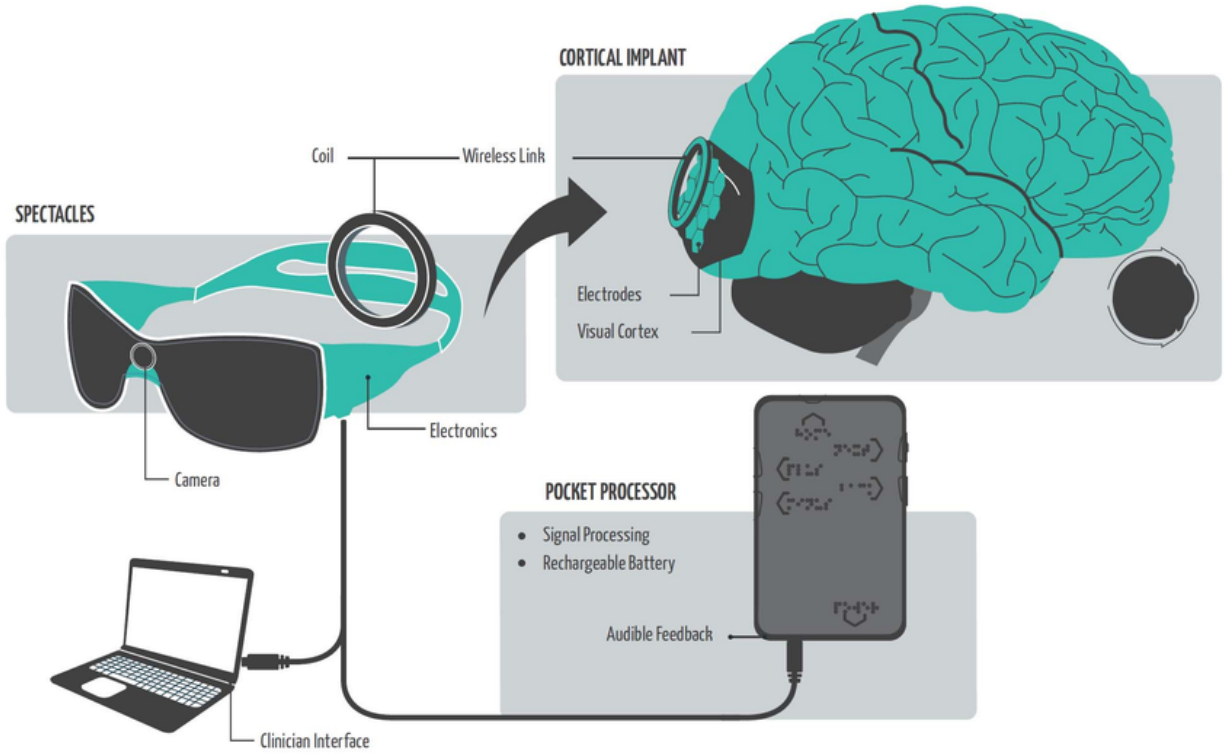


Image shows an overview of MVG cortical visual prosthesis

Advantages:

1. Cortical implants have the potential to treat blindness in people with the visual cortex, a condition that is very difficult to treat in present conditions.
2. Since the implant is inserted into the eye cortex without requiring eye surgery, it is non-invasive.
3. This technology can provide better images than nerve and nerve implants.

Disadvantages:

1. This technology is still in the initial stages of development and the clinical trials are yet to show results.
2. Cortical implants may not be suitable for all types of visual cortical damage and not all patients are candidates for cortical implants.

Challenges while developing bionic eye.

Despite advances in technology, some drawbacks need to be addressed in order for bionic eye prostheses to be considered a good treatment[27].Regarding the quantity of current that may be given to the target tissue in a safe position, the limitation of electrode geometry must be taken into consideration. The theoretical solution is adversely affected when the electrodes are placed close together. In addition, the effects of long-term and local electrical energy on the nervous tissue are still unknown due to the prosthesis being worn and used for a long time. Another problem to be solved is how to relate the captured image to the natural movement of the eye. Improper use of the eye may cause a sense of confusion, causing patients to incorrectly locate objects in the outside world. This confusion is especially true for designs that use external cameras. As a result, intricate eye tracking mechanisms have been suggested and created to provide the proper movements in the image.[28].

Future directions in bionic eye research.

Bionic eye research and development is a rapidly growing field with great potential to improve the lives of the visually impaired [29,30,31,32,33,34,35,36]. As technology continues to advance, bionic eye research will go in many directions in the future. Improved image quality: One of the main challenges of bionic eyes is the natural vision-like design of images. Future research will focus on improving image quality by increasing the number of electrodes, developing new stimulation strategies, and combining advanced image processing algorithms.

Wireless communication: Currently, most bionic eye implants require cables to transmit messages to and from the device. Future research will focus on the development of wireless communication devices to eliminate the need for cables and reduce the risk of infection and complications.

Miniaturization: As bionic eye technology continues to advance, researchers can focus on smaller implants to make them smaller, lighter, and more comfortable for patients.This will also reduce the risks associated with surgery [37].

Integration with intelligence: As we mentioned before, intelligence is used in the development of the bionic eye and design. Future research could expand intelligence with the bionic eye to improve imaging performance, extend device life, and improve overall implant function.

Multimodal sensory integration: Research is already underway to create sensory prostheses that can restore hearing, touch, and even smell. Future research will focus on combining the bionic eye with other sensory prostheses to create a multi-sensory experience.

Clinical and commercial trials: Despite significant advances in the use of the bionic eye, it is still largely experimental. Future research will focus on further clinical trials to evaluate safety and efficacy as well as the development of products that can be widely distributed to patients in need.

Conclusion.

Treatment for blindness and visual impairment has made significant strides.However, after loss of vision, the options are constrained. The visual prosthesis is a radical and ground-breaking method of giving these people their vision back.[38, 39].

The main purpose of visual prosthesis is to restore the vision of the blind, and when one is brave to believe, the challenges remain before it becomes reality. Based on recent developments and clinical research, there is good reason to believe that we are on the right path to achieve this goal.

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