International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

The Bionic Eye…A New Vision of the Future

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Abstract: ***Artificial vision is new emerging revolutionary technique that allows blind people to see. This can be possible by visual implants like either camera or photoreceptors array. A specialist can perform the best supernatural art of providing new vision to individual who has lost his/her visualizing power or eye sight. A visual prosthesis or bionic eye is a type of neural prosthesis expected to mostly re-establish lost vision or intensify existing vision brought about by a visual observation in patients with retinal pathologies like retinitis pigmentosa and age-related macular degeneration. In this article we have represented the different aspects related to technological advancement in implanting bionic eye. The essential capacity of the gadget to get the pictures utilizing a camera, convert it to electric signs and in the long run animate the left-over more advantageous pieces of the visual pathway. The embed visual prosthesis depends on a little chip that is precisely embedded behind the retina, at the rear of the eye ball. Virtual protheses like automated retinal systems are a new and innovative solution to extreme vision impairment care. We have also included the history of advancement in prosthetic and surgical process of embedding bionic eye.***

Keywords: Bionic eye, Prosthesis, Retinitis pathologies, Pigmentosa.

1. Introduction

Photoreceptors are the distinct neurons in the eye that turn photons into neuronal signals. The photoreceptors are a fragment of the retina, a neuronal is multilayer structure of about 200µm thick that lines the back of the eye (J. D. Weiland and M. S. Humayun, 2008). The sign from the photoreceptors is supplied by specific cells in the retina procedure. Retinal ganglion cells transmit the treated symbol through the optic nerve from the eye to the brain. Visual impairment can result when any piece of this visual pathway or retina is harmed by injury or infection. Electronic visual prostheses or bionic eye are being built up that can be embedded in various anatomical areas along the visual pathway. While the last usage of the embed will rely upon the life structures of the focused-on zone, visual prostheses or bionic eye (Figure 1) have regular necessities for an equal neural interface and force effectiveness that make certain designing provokes imperative to every single visual embed.

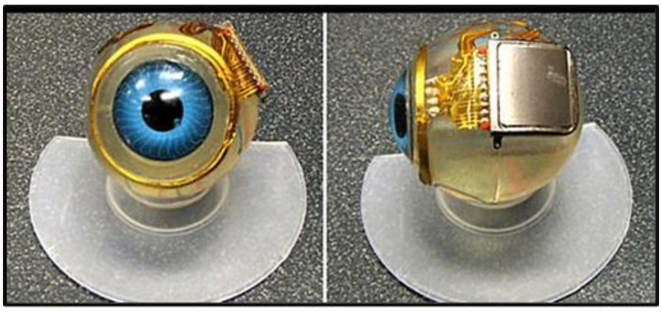

Figure 1: Bionic Eye

The researchers and engineers are working together to develop the advanced prosthetic that can surely help people to provide artificial vision who lost them during any accident. Now Artificial Vision's responsibility lies with Bionic Eyes. The Chips are the main parts which are designed accordingly to depict the characteristics of damaged retina. Chips are implanted carefully with a microsurgery. Not only Bio-medical Engineers but Computer and Electrical Engineers also play significant role in personification of Bionic Eyes (Deeksha and Sandeep, 2016).

Specialists working for the Boston Retinal Embed Undertaking have been building up a Bionic eye embed that could re-establish the visual perception of individuals who experience the ill effects old enough related visual impairment. The word Bionic Eye is utilized to allude to an electronic gadget empowering the re-foundation of eyesight absence because of issues in the proper visualization. Bionic eye replaces the usefulness of a section or entire of the eye. The embed depends on a little chip that is carefully embedded behind the retina, at the rear of the eye ball. The implant relies on a tiny chip that is carefully inserted at the back of the eye ball, behind the retina. The implantation is of two forms, an embedded epiretinal and a subretinal insert, depending that the insert is mounted on or behind the retina. In our proposed bionic eye procedure, a compact and impressive nanogenerator-fuelled camera is implanted in the patient's head, rather than wearing pair of glasses which is mandatory to wear.

The camera is little and expends exceptionally low force. Camera sends the pictures in advanced structure to the radio recipient set in the eye. The radio beneficiary is connected to the implant chip on the retina (Praveenkumar Narayanan, 2011). An ultra-slim wire fortifies the harmed optic nerve; its motivation is to transmit light and pictures to the mind's vision framework, where it is ordinarily handled. Other than the embedded chip and wire, the majority of the gadget sits outside the eye. The new device is required to be very sturdy, since the chip is encased in a Titanium packaging, making it both water-confirmation and erosion verification. The inquiries about gauge that the gadget will keep going for in any event 10 years inside the eye. In the improvement of prosthetic vision, it is additionally conceivable to animate the visual pathway at different locales other than the retina to increase visual observations.

2. History

Visual deficiency implies loss of vision. Bars and Cones, a great many them are in the rear of each solid natural eye. They are organic sunlight-based cells in the retina that convert light to electrical driving forces motivations that movement along the optic nerve to the mind where pictures are framed. Without them, eyes lose the ability to see, and are proclaimed visually impaired. Degenerative retinal ailments bring about death of photoreceptors–bar formed cells at the retina's fringe answerable for night vision and cone-molded cells at its inside liable for shading vision (Yvonne et. al., 2014).

Around the world, 1.5 million individuals experience the ill effects of retinitis pigmentosa (RP) and is the common deficiency which leads to weakness in visualizing power (Artificial Vision, 2020). In the Western world, age related macular degeneration (AMD) is the significant reason for vision misfortune in individuals over age 65, and the issue is getting increasingly basic as the populace ages. Every year, 700,000 individuals are determined to have AMD, with 10 percent getting legitimately visually impaired, characterized by 20/400 vision. Numerous AMD patients hold some level of fringe vision.

1929, Foerster, a German sensory system expert and neurosurgeon, found that y electrically enlivening the occipital shaft, his topic would depict the impression of a little spot of light (phosphene). The possibility of an electronic prosthetic gadget can be followed to a patent granted to an Australian, Graham Tassicker, who in 1956 depicted how a photosensitive selenium cell put behind the retina of a visually impaired patient came about in phosphenes. Brindley and Dobelle initiated the concept of artificial vision in the 1960s and 1970s by adding electrodes in the visual cortex and demonstrating they could start successful phosphenes. Uematsu further discussed the plausibility of a visual prosthesis at that time, and found out how to motivate phosphenes that squinted or rippled, and those that stayed fixed in place. Elicited phosphenes likewise changed from plain white to vibrant complex built.

Further improvement in the field was constrained until the 1990s when propels in biomaterials, microfabrication, gadgets and retinal medical procedure prompted a course of advancements in the field focused predominantly on the counterfeit retina yet in addition in the scaling down of cortical invigorating gadgets. The preclinical examinations completed in this decade would prompt the enormous number of clinical tests and preliminaries in the decade from 2000 to 2010 that will be talked about later. At present two retinal prosthetic gadgets are in huge scope clinical preliminaries with proof of all around exhibited useful vision. These are the most developed prostheses to date and subtleties of them, one epiretinal and the other subretinal will be talked about.

Spite of the fact that Luigi Galvani is deemed the first to depict bioelectricity by discovering that when the muscles of a dead frog are affected by power, they jerk; about three decades before his revelation in 1780, Benjamin Franklin predicted a falsified vision system that is also based on a similar law where the retinal cells are invigorated in comparison to the muscles in 1751. Also, in 1755, Charles Leroy even played out an examination in this viewpoint by releasing electricity produced via friction from an antecedent capacitor of those days-a Leyden container into a patient who was visually impaired because of high fever for a quarter of a year utilizing two wires-one over the eyes around the head and the other around the leg, the patient encountered a fire like thing passing downwards in before his eyes.

That was the first run through when a simple prosthesis effectively re-established a glimmer of visual discernment in an outwardly denied person. From that point forward till date, there are different coming and going in the improvement of bionic eye. The previous two decades kept on demonstrating fast movement in this field. The accompanying course of events would assist us with bettering comprehend the key angles throughout the entire existence of advancement of Bionic Eye. The history of technological advancement regarding prosthetic is shown in Table 1.

Table 1: History of technological advancement

Sr. No.	Year	Research work done
1.	1751*	Benjamin Franklin reported Artificial Vision “advance prosthetic system” in the report of his Kite and Key Experiment
2.	1755*	Charles Leroy first used an electronic tool as a primitive prosthesis to creates a little light sensation in blind eye.
3.	1780*	An essay on theory and practice of medical electricity written by Tiberius Cavallo
4.	1929*	The occipital poles generate electrically stimulating perception of a tiny light spot, called Phosphene was noticed by Foerster
5.	1931*	Krause and Schum mentioned that the visual cortex maintains function despite long-term visual input deficiency
6.	1956*	Patent for photosensitive selenium cell containing phospene obtained by Graham Tassick
7.	1968*	Virtual Vision was able to generate clear phosphenes through cortical stimulation was discovered by Brindely and Dobelle
8.	1983*	Joao Lobo Antunes first embedded a visual or Bionic eye in blind born patient
9.	1989*	Massachusetts Eye and Ear intensive care unit along with MIT proved that Retinal prosthesis is possible
10.	1990*	Argus Retinal Prosthesis was invented in early 1990s by, Mark Humayun, Eugene Dejuan, Howard D Phillips and Wentai liu
11.	1995*	The Subretinal prothesis with microphotodiode arrays is recorded by Eberhart Zrenner, South Germany University in Tubingen
12.	1996*	Electrically evoked cortical possibilities were distinguished by incitement of retina with a microfabricated terminal
13.	1998*	Advancement of Epiretinal stimulation studied in Harvard and MIT
14.	2000*	Experiment have been carried out on isolated retina, that are multi-terminal incitement and multi-site incitement
15.	2002*	Claude Veraart establish microsystem-based visual prosthesis at Louvain University and Artificial Silicium Retina (ASR device) was developed.
16.	2003*	Experiments have been carried out on approach needed for extracellular retinal incitement, design recognition and visual

		resolution with retinal prosthesis Apparatus
17.	2004*	Suprachoroidal terminal was gone after for transretinal incitement and Electronic retinal prosthesis was proposed for the treatment and recovery of outwardly tested
18.	2007*	Argus II trials with 60 terminals began in 2007
19.	2010*	1500 terminals or electrodes with retinal implant originate in Germany
20.	2011*	Argus-II is licensed for commercial use in Europe
21.	2012*	Photovoltaic Retinal Prosthesis with high pixel intensity got develop by technological advancement in collaboration with Oxford University and King`s College hospital
22.	2013*	Argus -II received FDA approval and was registered as the First FDA Allowed Bionic Eye
23.	2014*	Argus-II was embedded in a Retinitis Pigmentosa Patient and proceeded to be utilized for the equivalent
24.	2015*	Argus - II was effectively embedded in a patient with age-related macular
25.	2016	A project was carried out by Lucy Burscough and Professor Stanga that showed the possible combination of artificial and natural sight
26.	2019	The world`s most detailed genetic map of human retina got developed that can help to deal with blindness diseases.

*Source: *Usha Nandini, (2016), Nigel Barlow, (2016) and Hope in sight, (2019)*

At last by combining clinical science in building field Imprint Humayun's creation is a supernatural occurrence for individuals experiencing acquired retinal degenerative infection that prompts visual deficiency in mature age. retinal embed is a prosthetic gadget that maps visual pictures to control signals, in view of which it invigorates the enduring retinal hardware. Picture pressure for bionic eye packs and resizes the pictures safeguarding the item discovery pace of the picture. There measured picture got has a practically identical item location rate to that of unique picture. This surely diminishes the preparing over head on embed inside the body in eye the visual data from the retina. McMillin was then given unique glasses with a camera. The camera records pictures and sends them to a wearable video handling unit. The gadget in the eye gets the pictures, animates the retina and the mind deciphers it as a vision “The vision depends on differentiate" (Merabet Lotfi, 2011).

3. Mechanism

The working of Retinal embed framework is portrayed in Figure 2. Ordinarily the vision begins when the light beam's falls on the cones and rods and deciphered by the retina through optic nerves.

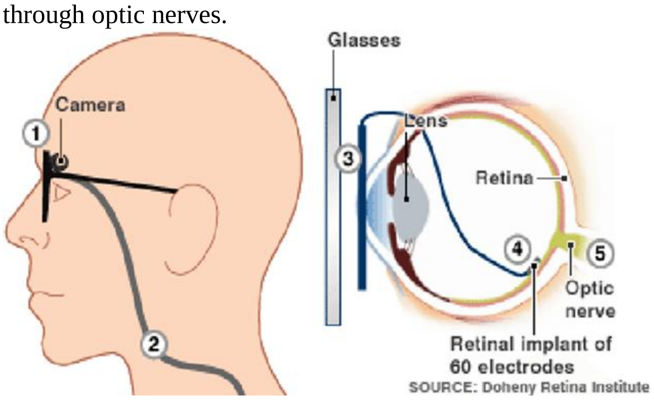

Figure 2: Source- Doheny Retina Institute

These smallest unit of our body convert optical signs into electric driving forces that are sent by means of optic nerve to the mind. Retinal sicknesses like ARM degeneration and RP demolish sight by cracking these cells. With the prosthetic bionic eye, a little camera mounted on the eye-gear catches the pictures and remotely sends the data to a small-scale controller unit that changes over the information to an electronic sign and re-transmits it to a recipient on the eye (Neelima and Yogesh, 2016). The systematic explanation of Multiple-Unit Artificial Retina Chipset is given in Figure 3. The beneficiary imparts the signs through an optic link to the microelectrode cluster, which triggers the beat outflow. The counterfeit retinal gadget accordingly sidesteps default photoreceptor cells and it is transmitted as electrical signals straightforwardly to the retina's staying feasible cells. These heartbeats make a trip along optic nerves to mind. At that point mind recovers examples of light and dull spots that compare to the terminal’s incitement. Patients figure out how to decipher these visual examples. It takes some preparation for the subjects to really observe a tree. From the start, they see for the most part light and dull spots. In any case, after a proper way of time, they figure out how to decipher what the cerebrum is demonstrating them. In the long run they see those examples of light and dull as a tree.

- The Camera implanted on glasses to view image
- The Signals will send to the handheld apparatus
- Processed information is returned to implanted frames and retransmitted remotely under the eye surface receiver sends data to electrodes in retinal embed
- Receiver sends the data to retinal implanted electrodes
- Electrodes invigorate retina to send information to brain.

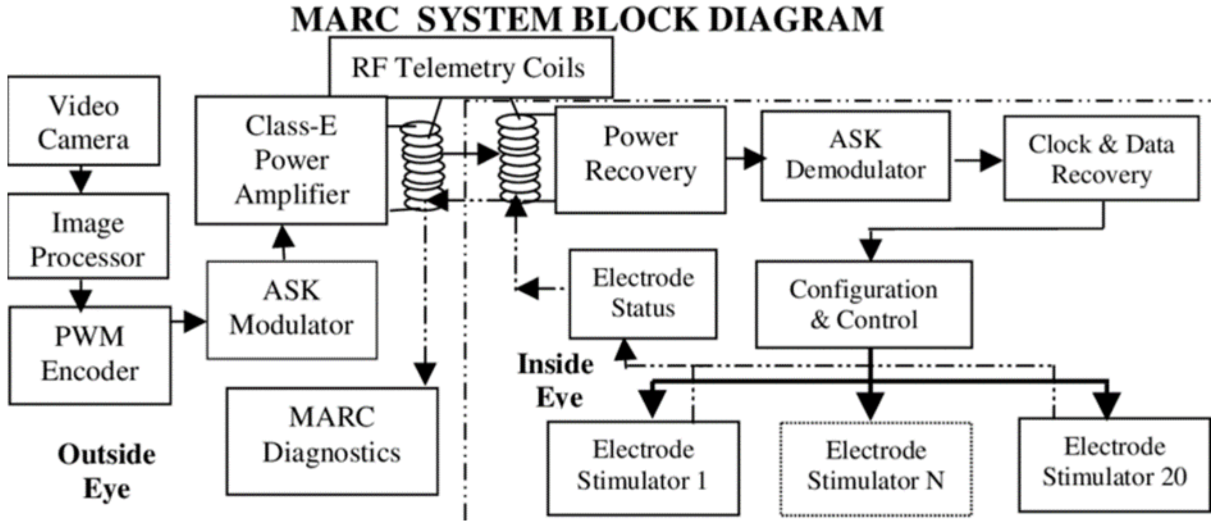

Figure 3: Circuit diagram of working of MARC system (Multiple-Unit Artificial Retina Chipset) Liu et al., 2020

4. Surgical Technique

The essential parts in Bionic Eye are picture sensors, processors, transmitters, recipients, retinal embed, and cortical inserts. Picture sensor is a gadget like a camera and catches the pictures before the eye. Processors process the picture acquired and convert them into electric motivations or signs. Transmitters transmit the sign and beneficiaries get it and move it to the terminals embedded in the retina the retinal embed. Cortical inserts are little cathodes embedded straightforwardly into the visual cortex of the mind. The geography of the embed fluctuates in various sorts of gadgets. There are various surgical techniques mentioned below in Figure 4.

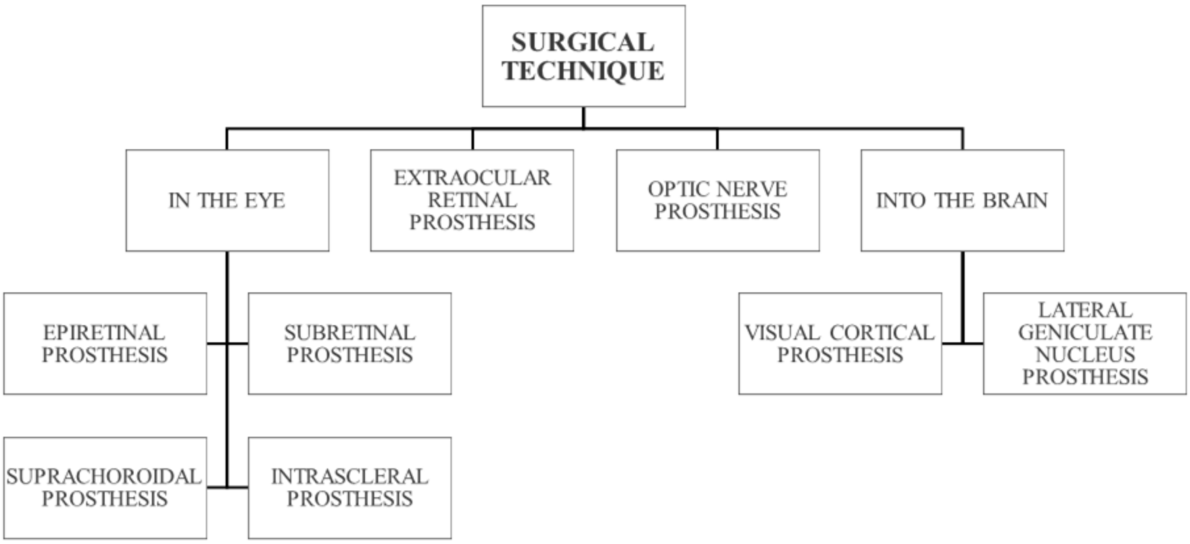

Figure 4: Various Surgical Technique

Epiretinal Prostheses

Epiretinal prostheses are set on the front surface of the retina, where they invigorate gangli-on cells. The present gathering of epiretinal prostheses consist of three fundamental parts. The first segment catches light pictures utilizing a camera. The subsequent part changes this picture into examples of electrical incitement. The third part, which lies on the inward surface of the retina, at that point animates the rest of the cells in the internal retina. There is an assortment of epiretinal gadgets being created (Ong JM and da Cruz, 2011). There are different epiretinal inserts like Argus II epiretinal prosthesis, learning retinal embed, EPI-RET3 embed, Epiretinal embed from Bionic Vision Australia, counterfeit retinal inserts utilizing fluid precious stone polymers (Usha Nandini., 2016).

The Learning Retina Embed Framework is an item evolved by Keen Clinical Inserts AG. It comprises of an extraocular and intraocular partition. A retinal encoder set on the edge of a couple of glasses shaped the extraocular partition. The intraocular divide is a retina trigger that lays on the internal surface of retina and situated utilizing retinal tacks. The array was situated transient to the fovea and fixed set up with a solitary spring-tensioned retinal tack that was embedded through the terminal cluster. The extraocular part comprised of an outside display mounted camera, which was utilized to catch pictures which were converted into pixilated pictures by a visual handling unit (Jean Show, 2016). The electrical sign was then conveyed by means of trans-scleral links associated with the multi-cathode cluster which is embedded in skull utilizing inductive connection telemetry framework.

Subretinal Prosthesis

Subretinal gadgets are put underneath the retinal colour epithelium in the photoreceptor layer. It is otherwise called ALPHA IMS. Boston Retinal Embed Undertaking's subretinal prosthesis comprises of a little hermetically encased, remote gadget. This cluster is embedded in the subretinal space utilizing an exceptionally planned careful method by an outer scleral entry point. It joins the main part of the prosthesis to the scleral surface or inside through the vitreous hole and retina. The embedded gadget incorporates a hermetic titanium case containing a 15-channel trigger chip and force gracefully parts. Feed throughs from the case associate with optional force and information getting loops. The gadget is experiencing creature considers.

This prosthesis, created by Retina Embed in Germany, has a 3×3-mm microchip that is embedded in a sub foveal position. The chip contains 1,500 light-touchy photodiodes that are joined to microelectrodes. The Alpha-IMS prosthesis doesn't utilize an outside camera; rather, the photodiodes are cou-pled to an outer force module that is implant-ed under the skin behind the ear and intensifies the signs created by the photodiode cluster. One advantage of the Alpha-IMS is that the patient doesn't have to utilize head examining to find objects; rather, ordinary eye developments can be utilized (Jean Show, 2016). "The picture moves with the eye in light of the fact that the chip is inserted precisely where the photoreceptors conventionally would lie," Concerning the implantation technique, "The medical procedure is unpredictable, yet any high-volume vitreoretinal specialist ought to have the option to learn it. Help is additionally required from a cochlear embed specialist to put the force gracefully under the skin behind the ear," said Dr. MacLaren, who is engaged with clinical preliminaries of a more up to date cycle of the gadget. For the retinal specialist, he stated, "The most troublesome part is situating the chip underneath the retina, yet this is significant on the grounds that in this position the electronic signals bestowed by the chip are coordinated toward the bipolar cells, which exploits the characteristic retinal preparing." This mechanism is shortly explained in Figure 5.

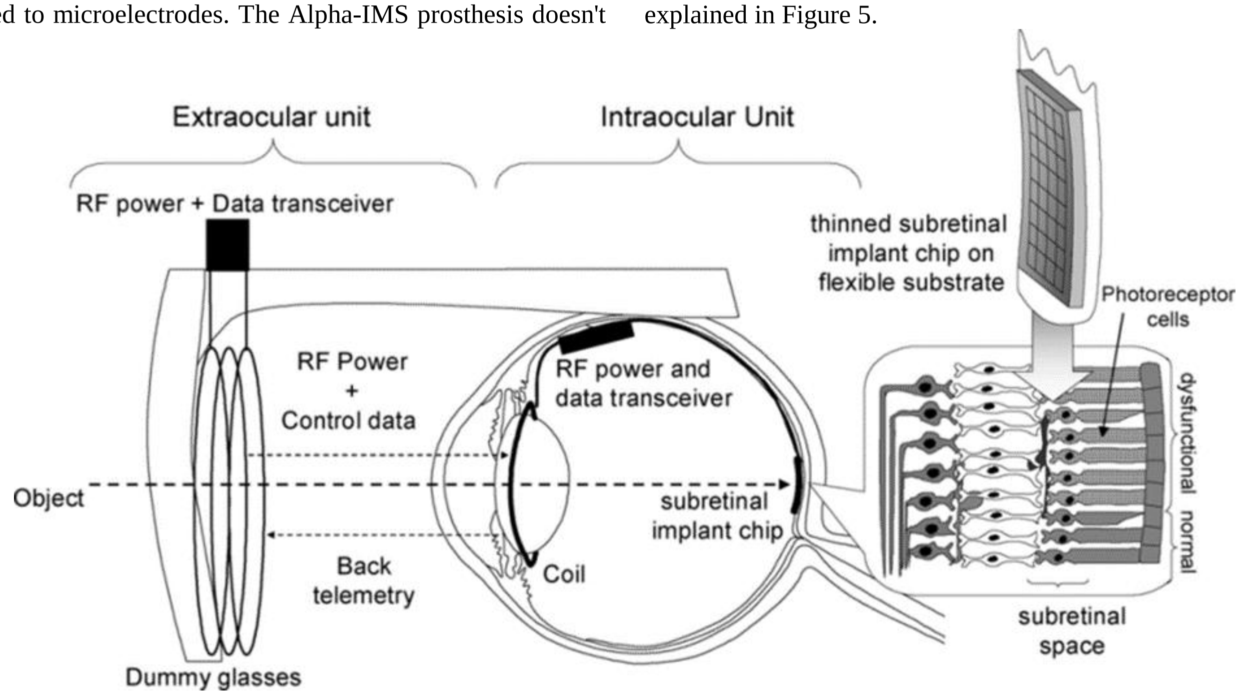

Figure 5: Schematic expression of the proposed subretinal prosthesis system (Ng et al., 2006)

Suprachoroidal Prosthesis

Suprachoroidal inserts were first researched in Australia during the 1950s. Suprachoroidal prostheses are intended to be put between the choroid and the sclera. In a variety of this methodology, a prosthesis known as the suprachoroidal-transretinal gadget is implanted between the layers of the sclera as opposed to in the suprachoroidal space (Lilach Bareket, 2016). Scientists with the BVA Exploration Consortium have built up a 24-channel model suprachoroidal prosthesis that contains an intraocular anode exhibit in a 19×8-mm silicone base. "The exhibit or array has 33 platinum invigorating electrodes and 2 return electrodes, and the external ring of terminals are ganged together to empower hexagonal incitement, implying that 20 terminals can be animated independently".

What's more, to take into consideration greatest adaptability in gadget incitement, "the exhibit is associated with a helical platinum/iridium lead wire to a percutaneous connector embedded behind the ear," Dr. Abbott said. "This permits direct incitement of the intraocular cluster with outer gadgets and has been utilized already in cochlear embed examines." The suprachoroidal area of this gadget presents 2 fundamental advantages "Right off the bat, the suprachoroidal medical procedure is far less testing than that required for epiretinal or subretinal embeds and doesn't penetrate the retinal tissue, accordingly discrediting the requirement for a vitrectomy or entry points into the retina. Besides, because of its position, the gadget has an astounding security profile."

Intrascleral Prosthesis

An intrascleral embed for embedding inside the eye and for diminishing intraocular liquid weight, involving: a rounded body having a forward end, adjusted for arrangement inside a foremost office of an eye, and a rearward end, adjusted for situation inside the sclera of an eye, said cylindrical body being pipe formed and amplifying in cross-area along said cylindrical body toward a path from said forward end to said rearward end, said rearward end including liquid ways to constrain and control a progression of intraocular liquid through said cylindrical body from said front chamber to said sclera, said rounded body further including side segments and at any rate one embed dependability rib affixing hence and adjusted to balance out said rounded body against said sclera, said rounded body further including a situating edge situated on said forward end, said situating edge being easily completed and adjusted to space said rounded body from an inward surface of said front chamber (Junko Okabe et al., 2003).

Extraocular Prosthesis

We use Extraocular medical procedure for implantation of a functioning subretinal visual prosthesis with outer associations. An examination done at the College of New South Ridges; Australia showed the incitement of retina with a model additional visual retinal prosthesis put over sclera. This may prompt the improvement of a low goal's visual prosthesis. The upside of this sort of prosthesis is that it requires a negligibly intrusive medical procedure contrasted with different kinds of visual prosthesis. The examination was just a creature explore, this has far to go to be effectively accessible for implantation (Besch D et al., 2008).

Optic Nerve Prosthesis

In dazzle patients with useful retinal ganglion cells, the optic nerve is an option for electrical incitement. Be that as it may, accomplishing central incitement and unwinding the specific retinotopic dispersion inside it is testing. Veraart constantly embedded a self-measuring winding sleeve cathode around the optic nerve in two subjects. These subjects had the option to perceive straightforward examples anticipated onto a screen, limit and separate articles (Usha Nandini., 2016).

Microsystem based visual prosthesis was created at the college of Louvain by Claude Veraart The fundamental working of this embed is as per the following: The light beams are gotten by a remotely worn camera that imparts signs to a winding sleeve of anode twisted around the optic nerve and associated with a trigger embedded in the skull. The signs got are converted into electric signals that invigorates the optic nerve straightforwardly. Comparable incitement of the optic nerve can be accomplished by embeddings numerous infiltrating terminals through the optic nerve and optic circle. This needs to experience refining to be utilized as an option for retinal prosthesis.

Advantages of Bionic Eye

1) Helps correct vision
2) No longer has constrained access.
3) FDA approved American prosthetic.
4) Can be effortlessly embedded.
5) Exploration isn't restricted by spending plan.
6) The surgical methods are easier which lasts only for one and half hours.
7) The component of chip size is very small so can be easily placed.
8) This also leads to the reduced stress on the retina.
9) No Batteries implanted within body.
10) This can surely improve life of blind people at some extent

Disadvantages of Bionic Eye

1) Australian one is as yet being looked into.
2) The two eyes have look into cost in a large number of dollars.
3) Australian one needs to experience human preliminaries.
4) American one doesn't right vision to 100%.
5) Bionic eye technology can be implemented to only those who have a perfect optic nerve.
6) With our present technology natural vision is not possible.
7) Cannot implemented to person who are birth blind.
8) This new technology will not be helpful glaucoma patients.
9) Extra circuitry required for downstream electrical input
10) The small part damage will lead to total technique failure

5. Conclusion

After a long period of research, the idea of developing bionic eye to give falsified vision to blind patients has finally been recognized. Bionic eye (Bio-Electronic Eye) is another breakthrough in biomedical engineering that provides vision to those with partial or total visual loss. Researchers all over the world have aimed for solutions of artificial, bionic devices to enhance the lives of individuals. It is kind of an artificial gift that will surely help people to re-establish vision which lost due to some illness like muscular degeneration or retinitis pigmentosa. About 1.5 million individuals around the world have retinitis pigmentosa, and one of every ten individuals over 55 have age related macular degeneration. Independent of the geniuses and cons of this framework, if this framework is completely evolved with a front-line innovation will definitely going to change the lives of a large number of individuals worldwide. We probably won't re-establish the vision totally, however we can attempt to push them to at any rate discover their way, perceive faces, reading something or visualize certain things. This is the revolutionary technology in field of bioengineering that will be a leading technology advancement in near future that deals with weak visualization power.

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