Sight For Sore Eyes - Bionic Eye A Review Article

Authors

Ranjakumar T C, 1 Rahana Ashraf, 2 Lalith Sundaram, 3 Sruthi Swaminathan 4

1 Professor & Head in Department of Ophthalmology, Kannur Medical College – Kerala, India
2 Junior Resident in Department of Ophthalmology, Kannur Medical College - Kerala, India
3 Associate Professor in Department of Ophthalmology, Kannur Medical College - Kerala, India
4 Junior Resident in Department of Ophthalmology, Kannur Medical College - Kerala, India

Corresponding Author

Rahana Ashraf

Email- drranjakumar@gmail.com, rehnamilan@gmail.com, lalithsundaram1977@gmail.com, srutz27@gmail.com

ABSTRACT

Among all the senses we possess, Eye has a major role to play. However, there are many people in the world denied of this invaluable sense. Some are blind by birth, and some become eventually blind due to vision threatening diseases like Retinitis Pigmentosa (RP) and Age Related Macular Degeneration (ARMD). These diseases were incurable, until recently when a special type of prosthesis has been designed to be placed in the inner eye/ retina (IRP-Intra Retinal Prosthesis) to impart vision to these unfortunate individuals.

Keywords: Vision, Night blindness, Retinitis Pigmentosa, Macular Degeneration, Visual prosthesis, Bionic Eye

INTRODUCTION

In the normal visual system, light travels via the tear film, cornea, aqueous, pupil, lens, then through the vitreous to activate the light sensitive photoreceptors and set up trans-synaptic connections of retina. The study and advances in the field of bionic eye is very rapid. It has been quite successful and it restores vision to the people who have lost their vision for their lifetime. The bionic eye mimics the original functioning of the human eye by stimulating the optic nerve, which is activated by the electrical impulse. A small retinal implant is implanted into the human eye and a device is attached to the human body. This implant receives the radio signal and transfers it to the brain through the optic nerve. (1,2)

The device is implanted at any location in the visual pathway to set up a neuronal electrical stimulation. This device is called an Artificial Eye or a Bionic Eye. The vision imparted by the device is called Artificial Vision. (3,4) This has been of great importance for patients with blinding diseases like Retinitis Pigmentosa affecting around 1.5 million people around the world, and patients with Age Related Macular Degeneration (ARMD), 10% of these turn blind each year. 4

HISTORY

The pioneer in this field was a German Neurosurgeon Foerster. In 1929, he demonstrated that electrical stimulation of the visual cortex lead to the perception of light spot (phosphene) by subject. 5 However, the first prototype was deviced by Brindley in 1960s, who improvised a device on to the cerebral cortex.
Depending upon location along the visual pathway this prosthetic device could be placed in the visual cortex, on the optic nerve or at the retina. The following are the type of prosthesis available.

**Cortical Prosthesis (Figure - 1)**

Brindley and Dobelle did remarkable work in the development of the visual prosthesis. They demonstrated that phosphenes and patterned perceptions could be evoked, by electrically stimulating the occipital cortex by implanted electrodes. They implanted arrays with 50 electrodes subdurally over the occipital pole. Current models of the intracortical prosthesis include the Utah and Illianos type processor.

- a) Utah type prosthesis - multiple silicon spikes arranged in a square grid measuring 4.2 x 4.2 mm with a platinum electrode at the tip of each spike
- b) Illianos Intracotical Visual Prosthesis Project - consisting of 152 intracortical microelectrodes, has been implanted in an animal model and the model for human implantation is under discussion.

The advantage of the prosthesis is that it bypasses all diseased visual pathway neurons rostral to the primary visual cortex. There are many disadvantages of this type of prosthesis too.

- i. Various histological changes induced by this prosthesis.
- ii. The organisation of the visual field at the level of the primary cortex is very complicated.
- iii. Prosthesis related complications which causes significant morbidity and mortality in these patients.

**Optic Nerve Prosthesis (Figure – 2)**

An electrode cuff is surgically placed, circumferentially on external surface of Optic Nerve. This was done by Veerart et al. It does not penetrate the Optic nerve sheath. It is based on the principle of retinoptic organisation within the optic nerve. It offers the advantage of representation of the entire visual field on a small area and that it is accessible. However there are many disadvantages like surgical manipulation of this region involves dissection of dura which makes it highly prone for infections.
Retinal Prosthesis (Figure -3)

This is based on the fact that the electrical impulse stimulates remaining intact retinal neurons to elicit visual perceptions. There are two main types of retinal prosthesis – Epiretinal and Subretinal. 5

Epiretinal Prosthesis -

Here the device is implanted into vitreous cavity and attached to the inner retinal surface. Epiretinal implants rely on imaging devices such as a camera and then transform this visual information to patterns of electrical stimulation to excite remaining viable retinal neurons. Humayun et al, developed a device called the Intra retinal Prosthesis (IRP). This prosthesis has two components – External or a wearable component with spectacle, incorporated with a light weight camera, pocket batteries & visual processing unit wherein power and data is sent by a wireless link from external unit to internal portion of the prosthesis. The other component is an Implantable or intraocular component with a reciever stimulating chip & microelectrode array including 16 platinum electrodes. The major advantage of this type of prosthesis is that the wearable portion of electronics allows for easy upgrades without requiring subsequent surgery. It has drawbacks like technical difficulty in holding the device on to the inner retina. 5

Subretinal Prosthesis -

The subretinal approach to the retinal prosthesis involves implanting a microphotodiode array (MPDA) bipolar cell layer and retinal pigment epithelium. This is accomplished surgically either via an intraocular approach through a retinotomy site (ab interno) or a transscleral approach (ab externo). It uses microphotodiodes (solar cells) as a powering mechanism. According to Chow et al, the low level of current delivered by the implant has a therapeutic and neuroprotective effect on the dying photoreceptors. 8 Zrenner et al, have also concluded that a subretinal implant may act as a replacement for lost photoreceptors. 9 However it offers many advantages like closer proximity to rest of the surviving neurons to the visual pathway (i.e; bipolar cell) and therefore less current requirement, also lack of mechanical means of fixation. Limitations are that there is limited subretinal space to place electronics close proximity of the retina to the electronics which would increase the risk of thermal injury to the neurons. 5

The Argus II Epiretinal Prosthesis (Figure – 4)

This belongs to the second generation epiretinal implant designed for the treatment of RP induced blindness. It is an epiretinal stimulating device to improve visual functioning in the visually disabled. The devices are electrically conducting and has potential to be used in patients to detect light or even differentiate various objects. The device contains 16 electrodes, which aids in providing images with better resolution. It received the CE mark of Europe back in 2011. However, the FDA approved it for the treatment of RP in 2013. This is currently in use in United States of America.
The Alpha IMS Prosthesis

Its being manufactured in the Retina Implant AG at Germany.\textsuperscript{10} This is the only retinal prosthesis that has undergone long term testing in humans. In July 2013, it received the CE mark in Europe. Unlike the ARGUS, it does not require an external eyeglass mounted camera. Also, it has a wireless subretinal chip, which moves with the eye, containing 1,500 electrodes, which transform the incoming light into electric signals. After passing via an amplified circuit, these signals will stimulate the remaining intact retinal cells to induce visual perceptions. From the various trials conducted recently, authors have mentioned ALPHA IMS as a “reliable and luminance dependent signal generation”.

CONCLUSION

The advancement of science and technology has enabled the immobile brindley type of prosthesis to be replaced by the portable and hassle free Epiretinal prosthesis. This has been of great advantage especially to the RP and the AMD patients. The micro technology have allowed for the development of high end circuit systems to be placed in the epiretinal or the subretinal spaces. These devices are very similar to the Cochlear Implants, but the visual system is much more complex than the auditory system and hence more challenging. Inspite of these advances, there are several ill effects of these implants. Biocompatibility is one such issue due to the various kinds of chemical, biophysical, and immunological reactions to the implanted materials. Encapsulation of the implant due to fibrosis could lead to miscommunication between the implant and the target tissue. Also, the potential effects of heat generation and transfer of electrical energy have not been completely understood by majority of the investigating groups. Hence continued research is required for other modalities of treatment of RP like drug therapy and gene therapy.
REFERENCES