Retinal Prosthesis: An Innovative Technology for Treating Blindness

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Diseases of the retina, such as retinitis pigmentosa (RP) and age-related macular degeneration (AMD), are major causes of blindness in the industrialized world. There are 25 million people across the globe, including 6 million in the United States alone, or who are severely visually impaired, due to RP and AMD. By 2020, this figure is expected to double, creating a virtual vision-loss epidemic. [1]Photoreceptors degenerate in both diseases, however, ganglion cells and other neurons remain functional in these patients. Currently, very few treatments are available for both diseases. Many studies to treat these diseases are performed, which include gene therapy, transplantation of stem cells, neurotrophic factors, and retinal prosthesis.

How Does Retinal Prosthesis Work?

Normal vision starts with light stimulation of retinal photoreceptors (rods and cones). These cells convert light stimulation to electric impulses, which are sent to the optic nerve and the visual cortex of the brain. If photoreceptors degenerate, the visual input is cut off and patients cannot see even though most of their visual pathway remains functional. Retinal prostheses bypass the degenerated photoreceptors. They are designed to accept light stimulation and convert it to electric signals to stimulate the remaining retinal cells and generate image perception in the visual cortex.

History

Experiments using electrical stimulation of the retina to study its function were performed more than 50 years ago and the first reports on retinal stimulation related to a possible treatment were published more than 30 years ago.[2,3] In 1996, Dr. Humayun performed acute human stimulation test at John Hopkins.[4] In 2002, Dr. Rizzo and his colleagues performed acute human retinal stimulation test.[5,6] They generated visual phosphene with electrical stimulation on blind patients during acute human trial, which proved promising. Now there are more than 30 retinal prostheses projects in the whole world, including the United States, Germany, Japan, Ireland, Australia, Korea, China, Belguim and Switzerland with more and more researchers are interested in this field.

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Various research groups are developing either an epi- or sub-retinal prosthesis as a potential form of therapy for RP and AMD. Acute and chronic implantation of both types of prostheses has been performed in animals and humans. Until now, the projects that have been conducted using human clinical trials include one project in Chicago (Optobionics),[7] one project in Southern California (Second Sight) and,[4,8-11] two projects in Germany (Intelligent Medical Implants AG and Retinal Implant AG).[12,13]

Clinical Trials

Drs. Alan Chow and Vincent Chow have developed an artificial silicon retina (ASR) microchip (Chicago, Optobionics). Their microchip is 2-mm-diameter, which contains 5000 microelectrode-tipped microphotodiodes and is powered by incident light. Dr. Alan Chow implanted their device into the subretinal space of 6 RP patients' eyes with standard vitreoretinal surgery technique. Their implant requires no externally-worn devices. During follow-up that ranged from 6 to 18 months, no significant safety-related adverse effects were observed. Subjective improvement include improved perception of brightness, contrast, color, movement, shape, resolution, and visual field size.[7]

All other devices have external structure to provide power and image signals. Dr. Mark Humayun performed 6 human implantations (Southern California, Second Sight). The prosthesis had 4 x 4 array of platinum electrodes tacked to the epiretinal surface. The prosthesis was wirelessly controlled by a computer or by a head-worn video camera. The array came out from the eye and went underneath the skin to the temporal bone behind the ear of the patients. Another part can be attached to this part to provide signal and images. The subjects were able to see perceptions of light (spots), detect motion, recognize simple shapes, spatially resolve individual electrodes and, discriminate and identify oriented patterns.[9,11] More recently, Second Sight Medical began a trial of its second generation, 60 electrode implant. The company has implanted 60-electrode array Argus II Retinal Prosthesis System into two blind patients in the UK.

In Germany (Intelligent Medical Implants AG) 6 patients with RP were implanted with an active subretinal implant via a transchoroidal surgical approach. The cable-bound implant consisted of two separate entities on the subretinal tip of a polyimide foil: a 4 X 4 electrode array for direct (light-independent) stimulation (DS) and a microphotodiode-array (MPDA) with 1500 light-sensitive elements. Study duration was 4-5 weeks. Four subjects had pattern recognition via direct electrical stimulation and two patients reported visual perceptions through the MPDA. The retina of 1 patient after >30 yrs of blindness did not respond to electrical stimulation within the safety limit.[12,13]

Challenges

Visual prosthetics is being developed as a potentially valuable aide for individuals with visual loss. Although 4 groups have already advanced into human testing, we anticipate several problems ahead. 1. How can these devices help blind people navigate through unfamiliar environment and live more independently? 2. Can these devices remain functional and stable in the human eye for many years?

References

1. Humayun MS, Freda R, Fine I, et al. Implanted Intraocular Retinal Prosthesis in Six Blind Subjects. *Invest Ophthalmol Vis Sci.* 2005;46(Suppl. S): E-Abstract 1144.
2. Dawson WW, Radtke ND. The electrical stimulation of the retina by indwelling electrodes. *Invest Ophthalmol Vis Sci.* 1977;16(3):249-252.
3. Wolff JG, Delacour J, Carpenter RH, Brindley GS. The patterns seen when alternating electric current is passed through the eye. *Q J Exp Psychol.* 1968;20:1-10.
4. Humayun MS, de Juan E Jr, Dagnelie G, et al. Visual perception elicited by electrical stimulation of retina in blind humans. *Arch Ophthalmol.* 1996;114(1):40-46.
5. Rizzo JF 3rd, Wyatt J, Loewenstein J, Kelly S, Shire D. Perceptual efficacy of electrical stimulation of human retina with a microelectrode array during short-term surgical trials. *Invest Ophthalmol Vis Sci*. 2003;44(12):5362-5369.
6. Rizzo JF 3rd, Wyatt J, Loewenstein J, Kelly S, Shire D. Methods and perceptual thresholds for short-term electrical stimulation of human retina with microelectrode arrays. *Invest Ophthalmol Vis Sci.* 2003;44(12):5355-5361.
7. Chow AY, Chow VY, Packo KH, et al. The artificial silicon retina microchip for the treatment of vision loss from retinitis pigmentosa. *Arch Ophthalmol*, 2004. 122(4):460-469.
8. Humayun MS, Freda R, Fine I, et al. Implanted Intraocular Retinal Prosthesis in Six Blind Subjects. *Invest Ophthalmol Vis Sci.* 2005;46(Suppl. S): E-Abstract 1144.
9. Yanai D, Weiland JD, Mahadevappa M, Greenberg RJ, Fine I, Humayun MS. Visual performance using a retinal prosthesis in three subjects with retinitis pigmentosa. *Am J Ophthalmol.* 2007;143(5):820-827.
10. Humayun MS, de Juan E Jr, Weiland JD, et al. Pattern electrical stimulation of the human retina. *Vision Res*. 1999;39(15):2569-2576.
11. Humayun MS, Weiland JD, Fujii GY, et al. Visual perception in a blind subject with a chronic microelectronic retinal prosthesis. *Vision Res*. 2003;43(24):2573-2581.
12. Gekeler F, Sachs H, Szurman P, et al. Surgical Procedure for Subretinal Implants With External Connections: The Extra-Ocular Surgery in Eight Patients. *Invest Ophthalmol Vis Sci.* 2008;49(5):E-Abstract 4049.
13. Gekeler F, Sachs H, Szurman P, et al. Fluorescein Angiographic Findings in Blind Patients Treated by an Active Subretinal Implant. *Invest Ophthalmol Vis Sci.* 2007;48(5): E-Abstract 2567.

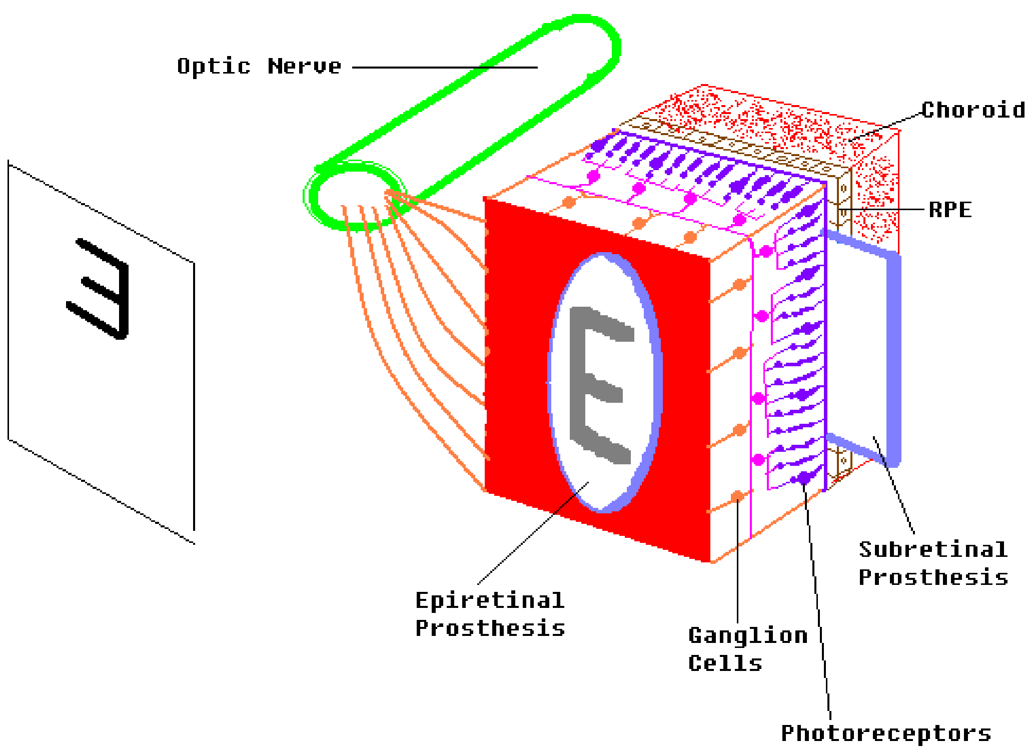

Figure 1. Epiretinal Prosthesis and Subretinal Prosthesis.