Development of Microelectronic Visual Implants

Essay
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Abstract

The role of the central visual pathways is to process and integrate visual information that travels to the brain by means of the optic nerves. Although the eye is responsible for transducing patterns of light energy into neuronal signals, it is the brain that is ultimately responsible for visual perception and cognition. Vision at the level of the central nervous system is perhaps the best understood of all the sensory systems, partly because there is a wealth of information on its neuroanatomic and functional organization.

Key Words :

accessory optic system - direct current - Iridium oxide .

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AMD : age related macular degeneration
AOS : accessory optic system
ASR : Artificial Silicon Retina
CNS : central nervous system
DC : direct current
DNA : deoxyribonucleic acid
DTN : dorsal terminal nucleus
EEPs : electrically evoked potentials
EER : Electrical-evoked response
IrOx : Iridium oxide
IRP : intraocular retinal prosthesis
LGN : lateral geniculate nucleus
LTN : lateral terminal nucleus
LVES : low vision enhancement system
MEMS : microelectromechanical systems
MiViP : microsystem based visual prothesis
MPDA : microphotodiode array
MTN : medial terminal nucleus
NOT : nucleus of the optic tract
OCT : optical coherence tomography
OKAN : optokinetic after-nystagmus
OKN : optokinetic nystagmus
PR : photoreceptor layer
RGCs : retinal ganglion cells
RNA : ribonucleic acids
RP : retinitis pigmintisa
RPE : retinal pigment epithelium

SC : superior colliculus

SRS : subretinal space

STS : suprachoroidal transretinal stimulation

TiN : titanium nitride

UV : ultra violet

VI : primary visual cortex

INTRODUCTION AND AIM OF WORK

The improvement and restoration of vision had been goals of science and medicine as far back as 1665, where the English natural philosopher Robert Hooke wrote that; the next care to be taken, in respect to the Senses, was a supplying of their infirmities with instruments, and as it were, the adding of artificial organs to the natural .., and as glasses had highly promoted our seeing, so it is not improbable, but that there may be found many mechanical inventions to improve our other senses of hearing, smelling, tasting, and touching ***(*Weiland and Humsyun*, 2003).***

As scientists began to understand electricity and apply it to living things, this knowledge improved understanding of human body systems and eased human suffering. In the nineteenth century, Galvani and Volterra performed experiments demonstrating that both muscles and the auditory system responded to electrical stimuli. Those reports demonstrated that the human body is an electrical system and that electricity may have therapeutic uses. Electrical stimulation continues to find valid therapeutic applications in the human body. However, therapeutic electrical stimulation to treat disease is not the same as electrical stimulation to replace lost function, and the two should not be confused **(Weiland and Humsyun, *2003).***

Historically, several methods of supplementing remaining functional vision had been pursued via interventions at several points along the visual pathway, including the retina, optic nerve, and occipital cortex. .The concept of electronically stimulating the nervous system to create artificial vision was first introduced in 1929 when Foerster et al observed that electrical stimulation of the visual cortex caused his subject

to detect a spot of light (phosphene). They demonstrated that the spatial psychophysical location of this phosphene depended on the location of the electrical stimulation point over the cortex) **(Foerster *et al, 1929)***.

The First serious effort of establishing an electrical artificial vision system was undertaken in the 1960s by Giles Brindley. Brindley's implantation of an 80-electrode device on to the visual cortex of a blind patient revealed the possibilities of electrical stimulation to restore vision and the barriers to implementation of a suitable device. Brindley pioneering work had influenced all subsequent major efforts in the area of electronic visual prostheses. In the past 50 years, exponential advances in our understanding of electronics, physiology, and medicine have enabled the development of implantable microelectronic systems that overcome the shortcomings of Brindley's large, immobile visual stimulator) **(Brindley, *1965)***.

Such advances had been noted in the fields of electrical engineering, computer sciences, and micromachining technology. For instance, very-large-scale integration microfabrications and microelectromechanical systems (MEMS) technology had contributed to the evolution of the field of visual prostheses by allowing for the creation of both smaller electronics and smaller neural interfaces. These technological advancements, coupled with recent scientific investigations, had transformed the focus of the field from whether it is possible to create visual sensations through electrical stimulation to the more important question of whether this stimulation creates useful vision ***(*Ryan, *2006)***.

Whether useful vision can be rendered via artificial visual prostheses depends on establishing a definition of useful vision that was

based on the minimum number of pixels required for human beings to accomplish activities of daily living. Several researchers had completed psychophysical experiments designed to determine the minimum acceptable resolution for useful vision. Brindley originally suggested that 600 points of stimulation (pixels) would be sufficient for reading ordinary print **(Ryan, *2006)***.

More studies had tested humans with normal visual function by pixelating their vision via a portable phosphene simulator, consisting of a small head-mounted video camera and monitor. Patients then walked through an obstacle course and read pixelated text. In this fashion, it was determined that 625 electrodes implanted in a I-cm2 area near the foveal representation in the visual cortex could produce a phosphene image with a visual acuity of approximately 20/30 and reading rates near 170 words/mm with scrolled text and 100 words/mm with fixed text. Further, a degree of plasticity in the visual system was noted as walking speeds increased fivefold during 3 weeks of training ***(*Cha *et al, 1992)***.

Studies simulating electrodes placed over the entire macula rather than a foveal pixelization had assessed the ability of subjects to recognize faces through a pixelated square grid. Parameters included grid size (10 x 10 to 32 x 32 dots), dot size, gap width, dot dropout rate, and gray-scale resolution. The subjects achieved highly significant facial recognition accuracies in both high- and low-contrast tests with marked learning effect documented. These results suggested that reliable facial recognition was possible even with crude visual prostheses, and possibly makes the task of engineering the implant easier as it would require fewer data/stimulation channels **(Cha *et al, 1992)***.

The ability of subjects to read using a pixelated visual simulator had been evaluated in a separate cohort which demonstrated that most subjects were able to read fonts as small as 36 point (with all at 57 point) using a 16 x 16 pixel array ***(* Thompson *et al, 2003).***

AIM OF WORK

To evaluate the efficiency and safety of microelectronic visual implants .in diseases that potentially benefit from the application of retinal implants as: hereditary pigmentary degenerations (retinitis pigmentosa) and acquired macular diseases as age related macular degeneration.

ANATOMY OF THE RETINA

The retina

The retina includes all structures that are derived from the optic vesicle (The sensory layers of the retina (pars optica retinae), the pigmented epithelium of the retina), as well as the epithelial linings of the ciliary body (pars retinae ciliaris) and of the iris (pars retinae iridis). The retina has two main components: a sensory layer and a pigmented layer that are derived from the inner and outer layers of the optic vesicle, respectively. They are attached loosely to each other by the extracellular matrix that fills the space between the apical villi of the pigment epithelium and the outer segments of the photoreceptors as well as the interphotoreceptor space ***(Fig.1-1), (*Bron *et al,1997)***.

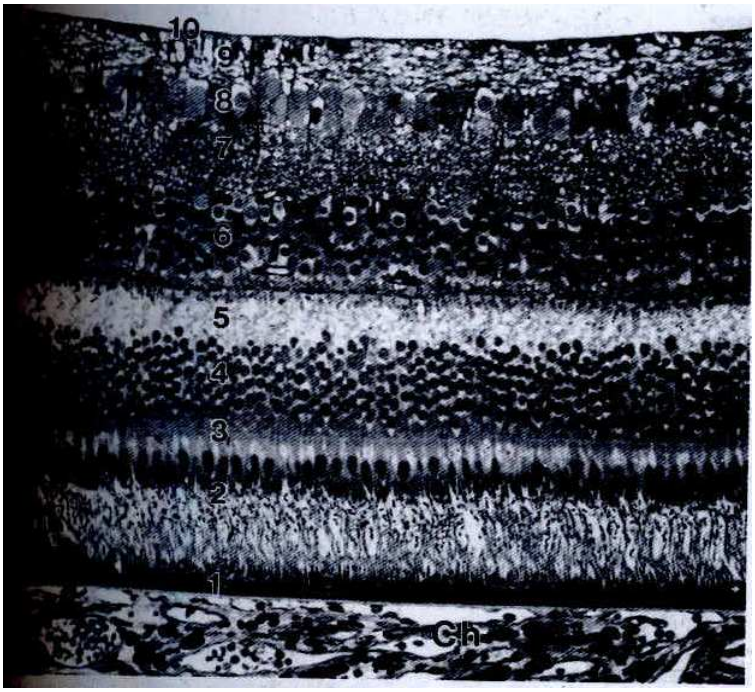

Fig.(1-1) Morphological organization of the retina-transverse section showing layers of the retina***(Bron et al, 1997)***.

Topography of the retina

The retina proper is a thin, delicate layer of nervous tissue that has a surface area of about 266 mm^2. The major landmarks of the retina are the optic disc, the retinal blood vessels, the area centralis with the fovea and foveola, the peripheral retina (which includes the equator) and the ora serrata. The retina is thickest near the optic disc, where it measures 0.56 mm. It becomes thinner towards the periphery, the thickness reducing to 0.18 mm at the equator and to 0.1 mm at the ora serrata ***(*Ogden, *1989).***

The optic disc

In the normal human eye, the optic disc is a circular to slightly oval structure that measures approximately 1.5 mm in diameter. Centrally, it contains a depression which is known as the physiological cup; however, the size and shape of this excavation depends on several factors such as the course of the optic nerve through its canal, the amounts of glial and connective tissues, the remnants of the hyaloid vessels and the anatomical arrangement of the retinal and choroidal vessels **(Bron *et al,1997)***.

The area centralis

The area centralis or central retina is divisible into the fovea and foveola, with a parafoveal and a perifoveal ring around the fovea. This region of the retina, located in the posterior fundus temporal to the optic disc, is demarcated approximately by the upper and lower arcuate and temporal retinal vessels and has an elliptical shape horizontally. With an average diameter of about 5.5 mm, the area centralis corresponds to approximately 15° of the visual field and it is adapted for accurate diurnal vision and colour discrimination ***(*Tripathi and Tripathi, *1984).***