Bionic Eye – A Headway in Maxillofacial Prosthesis.

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Abstract – Rehabilitation of Maxillofacial defects and newer advances made into it day by day has always been of much fascination to specialists. The invention of the AI-powered Bionic eye combines neuroscience with prosthetics. The current review focuses on the history, evolution, advances, and challenges of this concoction. It has undoubtedly brought a change in the viewpoint of prosthodontists and other concerned specialties.

Introduction – "Progress lies not in enhancing what is, but in advancing toward what will be" -Khalil Gibran.

Maxillofacial prosthesis rehabilitation replaces missing structures to restore function and appearance due to facial defects or injuries. Patients experience hereditary diseases, cancer, or trauma that led to maxillofacial abnormalities. Such flaws typically occur because of related aesthetic and psychological problems.[1] A range of options for providing patients with prosthetic restorations during rehabilitation in order to enhance function and appearance is provided by maxillofacial prosthodontics. An attractive and useful maxillofacial prosthesis without the dangers associated with surgery helps individuals feel less anxious and enhances their quality of life[1]. Prosthodontics had exponential growth in the area of diagnostic and treatment planning, materials used, and even prosthesis production as a result of favorable changes in digital dentistry.[2]

The creation of neuroprosthetic devices intended to help people with sensory loss and/or movement disability has been made possible by developments in the fields of microfabrication, microelectronics, material science, wireless technology, and high-speed computer processing power. The fundamental idea behind all neuroprosthetic techniques is that by carefully planning and delivering electrical stimulation to specific nerves or muscles, it may be possible to partially restore an injured organ's or limb's physiological function.[3] One such device is the Bionic eye which not only restores a defect structurally but also functionally. The use of artificial retinal devices and another visual prosthesis, among other things, is an innovative and ground-breaking method of treating severe sight loss. These gadgets have developed to the point where they are starting to help blind people regain some basic vision function in ongoing clinical trials.[4] The first reports of man-made phosphenes were connected to direct cortical stimulation in the past. Since that time, gadgets have been created that aim at numerous points along the visual pathway, not just limiting to outer appearance. According to where they work along the visual pathway, these devices can be divided into cortical, subcortical, optic nerve, and retinal prostheses.[4] According to the WHO, it is estimated that globally about 253 million people live with vision impairment, including about 36 million of those who are reported to be amaurotic and 217 million with various vision impairments.[5] Bionic eye for such people can turn a boon to live a normal life. Besides its advantages to patients, this discovery has given a different standpoint in the field of maxillofacial rehabilitation. This review focuses on the history of the prosthesis, Conceptual views from different authors, future scope and challenges.

History - Roman and Egyptian priests are known to have created painted clay fake eyes that were fastened to fabric and worn outside the socket. A wide range of materials, including gold, rock crystal, shell, and coloured stones, have been used to make artificial eyes. Famous French surgeon Ambrose Pare (1510–1590) described fitting artificial eyes into eye sockets. Since enucleation was not a regular practice until the middle of the 1800s, a hypoblephara eye (Figure 1) was created to be used atop an atrophic eye. Later, Pare created porcelain and glass-based prosthetic eyes.[6] The original in-socket prosthetic eyes were constructed of gold with coloured enamel and later switched to glass (thus the term "glass eye"). After the Latin War, Greeks in Dalmatia were the first to use glass eyes. Later in the 16th century, information from Greece made its way to Venice. These were ungainly, awkward, and delicate, and the Venetians were the only ones who knew how to make them until the end of the 18th century, when Parisians took over as the industry's hub. The focus changed once more, this time to Germany because to their superior glass blowing methods. Ludwig Muller-Uri, a German glassblower, is credited for creating fine artificial glass eye.[6]

German neurologist Foerster discovered in 1929 that electrical stimulation of the occipital pole resulted in phosphenes, proving the functional capacity of the visual cortex despite years of neglect. Electronic prosthetic devices were created because to an Australian inventor named Graham Tassicker's 1956 patent. Consistent phosphenes were demonstrated by Brindley and Dobelle's tests in the 1960s and 1970s, while Uematsu's work in the 1990s resulted in the miniaturisation of cortical stimulation devices. Numerous clinical trials and research were conducted as a result of advancements in biomaterials, microfabrication, electronics, and retinal surgery. Two retinal prosthesis systems with clearly demonstrated functional vision are currently undergoing extensive clinical studies.[4] Many blind individuals have already undergone bionic eye trials created in the United States successfully.[1]

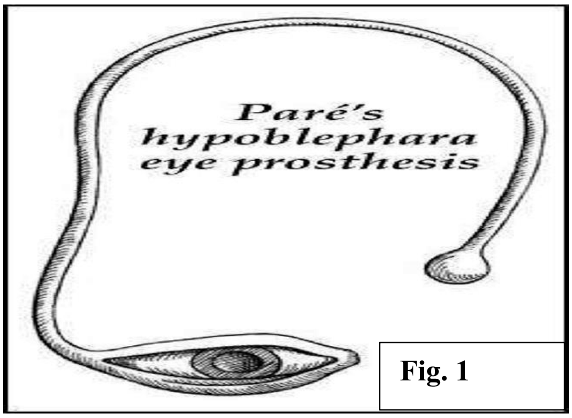

Fig. 1

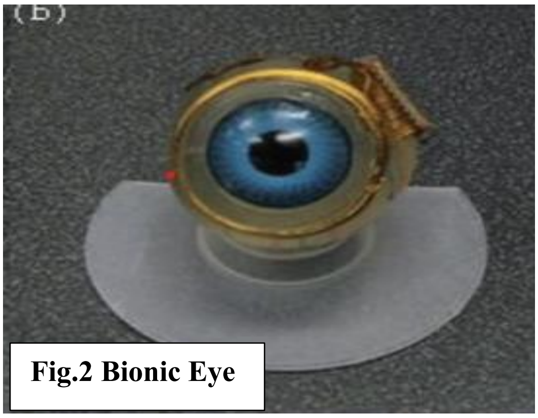

Fig.2 Bionic Eye

Conceptual overview and Advances

A prosthesis should also artificially replace the function of damaged neuronal elements along the visual pathway[3]. They conceptualized the incorporation of Typical microelectrical stimulation which involves tiny microelectrodes to evoke the perception of organized light patterns, resulting in the subjective sensation of discrete points of light called "phosphenes." Geometrical visual precepts can be generated by delivering appropriate multisite patterns, allowing for the perception of visual images. This approach is an oversimplification, as visual prostheses are designed to address spatial detail, rather than focusing on colour, motion, and form.

Two retinal-based approaches are being explored, with subretinal implant placement in degenerated photoreceptors and epiretinal implant or prostheses like Argus I and Argus II attachment to inner retinal surface, close to ganglion cell side.[3][4] Clinical trials at the Doheny Retina Institute in 2002 showed improvements in object detection, counting, object discrimination, and movement direction with the Argus I retinal prosthesis system. The US Food and Drug Administration approved the second-generation system in 2007, demonstrating improved motion detection, mobility, and object distinction. Subjects successfully navigated doors and correctly identified letters in closed set tests with the system on, demonstrating sight restoration as a learning process.[4] Rizzo and Wyatt, who co-founded Boston Retinal Implant Project, created an epiretinal prosthesis that underwent immediate clinical trials. However, due to inconsistent results, BRIP has abandoned the epiretinal implant and is currently working on a subretinal implant.[8]

According to the study of Shim S et al 2020[6], Every artificial vision system requires an image sensor to convert optical patterns into electrical impulses, much way the retina's photoreceptors do. Utilising an external camera mounted on glasses is one method of image acquisition that is frequently employed. This camera is put on a pair of spectacles, which records live video, modifies it into stimulation data, and then transcutaneously sends the modulated data to an external visual prosthesis. The glasses-mounted camera has the advantage of producing complex images in a range of sizes, colours, and formats that are simple to process. However, because its motions are invariably synchronized with those of the head rather than the eye, it lacks the ability to concentrate on objects in accordance with natural eye movements. To implement this focusing function, the glasses-mounted camera, therefore, requires complicated hardware and software. Additionally, patients may experience some difficulty from glasses, which can also make it challenging to perform some common activities like taking a shower or swimming. A micro-photodiode array (MPDA) implanted in the subretinal area is a different technique. The MPDA may provide electrical impulses that are directly converted from incident light since it is often integrated with stimulation circuits to function as a visual prosthesis on its own. The MPDA implanted in the eye can track objects and eye movements and does not require wearing devices like glasses, in contrast to the glasses-mounted camera. However, the MPDA produces incomplete images without the full camera structure, which may just have light intensity. Even if there are enough photodiodes, the spatial resolution of stimulation would be constrained by electric crosstalk because the MDPA targets a narrow field of neurons under the retina. This is because the MPDA needs to be integrated with stimulation circuits, which limits the number of photodiodes in one array spatially and results in low image resolution. A new image acquisition strategy for artificial vision employing an active intraocular prosthesis (AIP), in conjunction with visual cortex stimulation, to get around the shortcomings of both the glass-mounted camera and the MPDA is done by Shim S et al[6].

The use of optic nerve prosthesis whose primary advantage is the consolidation of the entire perimetry into a small area. Special spiral cuff electrodes are attached to an optic nerve implant to allow signals from a camera to be sent through the optic nerve and produce visual stimulations. This kind of implant was created by Veraart et al., who tested it on blind individuals and saw encouraging results. By establishing impulse parameters and allowing the bionic eye to work with the optic nerve, the use of such a wrap cuff enables the bionic eye to generate numerous phosphenes. Patients who evaluated those prostheses were able to function]and bar orientations; some patients could even read big optotype.[9],[10]

Future scope –

When the number of human clinical trials increases and patients continue to use these visual neuroprosthetic devices on a regular basis. We now shift our focus from merely providing proof of concept to establishing the reality that an implanted patient's quality of life can be improved by a bionic eye on a more long-term basis.[3] To enhance 3D display systems, some researchers use the bionic compound eye structure (BCES), which functions as a microlens array.[11] When creating the artificial retina, 1T1M (one-transistor-one-memristor) visual sensors were employed. One memristor and one MOSFET were used to build a photoreceptor cell and ganglion cell.[11] Artificial photoreceptors from the 1T1M generation are a novel form of structure in the retina that can simultaneously integrate spike and analogue signals. The signal's ability to travel deeper along the optic tract was shown to be problematic, the researchers found.[11] Optogenetics has the potential to bypass the limitations of electrical stimulation in blind animal models. Dedicated ion channels controlled by endogenous receptors may offer a synergistic effect. Yagi T. has applied multiple neurons to microelectromechanical arrays, while 3D printers can restore damaged retinal cells. Organic photodiodes (OPD) can perceive light and express it as photovoltaic pixels and can be incorporated in such prostheses.[12][13][14]

Challenges –

There is a definite need for updated, standardized evaluations of device efficacy that can be calculated in a way that is scientific. able to be tested and verified. The selection criteria for prospective candidates must also be obvious. Not only would this make it simpler to compare the results of different design efforts, but it would also help determine and assess patients' visual requirements and needs in light of what a visual prosthesis may ultimately provide. Certainly, as the technical challenges will get solved, the quality of prostheses would improve largely.[3]

A deeper knowledge of how the brain adjusts to losing vision and how the remaining senses interpret information in the visually impaired for a neuroprosthetic maxillofacial device to enable meaningful vision-restored visual input must be modulated properly in the brain.

Learning to the patient is very important and a multidisciplinary approach and collaboration with different specializations is one of the major challenges faced.

Conclusion –

It is not wrong to say that with every step further impossible is made possible. The implementation's results are on par with human results although the application is not possible in every case.[7] This Bionic eye prosthesis is a radical and ground-breaking method for giving these people their vision back restoring aesthetics too.[4] It is going to live its footprints and give a different perspective to field of maxillofacial prosthetics. This invention has given dentists a distinct visionary to expand their horizons.

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