ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF RESEARCH IN PHARMACEUTICAL SCIENCES

Published by JK Welfare & Pharmascope Foundation   Journal Home Page: https://ijrps.com

Cortical Implants in Cerebrum - A Review

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Article History:

Received on: 23 Jul 2020
Revised on: 12 Sep 2020
Accepted on: 23 Sep 2020

Keywords:

Cortical implants,
neuroprosthetics,
Biocompatible materials,
Brain interface

ABSTRACT

The cortical implant is neuroprosthetic which is a direct bridging link to the cerebral cortex of the brain. It provides stimulation and has different benefits depending upon the type of design and the placement of the implant. It is a typical cortical with a microelectrode array, a small device that transmits or receives the neural signal. Its main goal is to replace the neural circuitry in the brain that no longer functions properly. It has a wide variety of potential uses from restoring vision to helping patients who suffer from dementia. These implants are placed on the prefrontal cortex. Prefrontal Cortex is helpful in restoring the attention that helps in decision making. These implants act as a replacement that replaces the damaged tissues in the cortex. This review was done based on the articles obtained from various platforms like PubMed, PubMed Central and Google Scholar. They were collected with a restriction on a time basis from 2000 - 2020. The inclusion criteria were original research papers. In vitro, studied among various conditions and articles that contain pros and cons. Exclusion criteria came into account for review articles, retracted articles and articles of other languages. All the articles are selected based on cortical implants in the cerebrum. Cortical implants are placed to replace the neural circuitry in the brain that no longer functions properly. It helps patients with neurological disorders. It helps patients who have difficulty in complex sensory and neural functions. The biggest advantage of neuroprosthesis is that it is directly interfaced with the cortex.

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ISSN: 0975-7538
DOI: https://doi.org/10.26452/ijrps.v11iSPL3.3355

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INTRODUCTION

The cortical implant is neuroprosthetic which is a direct bridging link to the cerebral cortex of the brain. It provides stimulation and has different benefits depending upon the type of design and the placement of the implant. It is a typical cortical with a microelectrode array, a small device that transmits or receives the neural signal. Its main goal is to replace the neural circuitry in the brain that no longer functions properly. It has a wide variety of potential uses from restoring vision to helping patients who suffer from dementia. Vision is restored when the visual cortex is directly stimulated. Recent studies show that there has been a development in developing an effective auditory prosthesis that directly interfaces the auditory cortex. Whereas, some implants are designed to improve the cognitive function. These implants are placed on the prefrontal cortex. Prefrontal Cortex is helpful in restoring the attention that helps in decision making. The cerebrum is the largest part of the brain. The cortical implant is responsible for the integration of complex sensory and neural functions which helps in the initiation and coordination of voluntary activity. Brain implants technology and records voltage signals during cognitive tasks (deCharms *et al.*, 1999). These implants have the biggest advantages of being directly interfaced with the cortex. These implants act as a replacement that replaces the damaged tissues in the cortex. Biomimicry is an alternate pathway for signals.

There is some previous research. It is important to record the histopathological evaluations of the materials that are used to implant in the cerebral cortex (Stensaas and Stensaas, 1978). Usage of silicon as a substrate in the microelectrode arrays in the cerebral cortex for chronic neural reading and the histological analysis of tissue (Vetter, 2004). Characteristics of microelectrode arrays that have been implanted in the cerebral cortex for long term recording (Williams *et al.*, 1999). The biocompatibility of neural implants and insertable microelectrode arrays were studied (Edell *et al.*, 1992). The tissues were more reactive when silicon was used as a biocompatible material, but relatively severe reactions had been anticipated. The neural interface of cortical vision prosthesis is a place where the stimulation of a large number of cortical neurons takes place (Normann, 1999). It provides proof of concept for the cortically based artificial vision. There have been recent advances in the materials and system devices that are used for the neural interface (Won, 2018). It provides a long-lived optical or electrical interface to the neural systems that play a critical role in the neuroscience research in the development of non-pharmacological treatments in case of neurological disorders. These advances were established as a foundation of architecture in the optical or electrical neural interface for the future that is blurring of the lines between the biotic and the abiotic systems for the progression in neuroscience research for the welfare of the human being.

Over the past years various research done by our team was on osteology (Choudhari and Thenmozhi, 2016), foramina in middle cranial fossa (Hafeez and Thenmozhi, 2016), styloid process (Kannan and Thenmozhi, 2016), foramen of Huschke (Keerthana and Thenmozhi, 2016), foramen meningo-orbitale (Pratha and Thenmozhi, 2016), girdy's tubercle (Nandhini *et al.*, 2018), Occipital emissary formanen (Subashri and Thenmozhi, 2016), stature estimation (Krishna and Babu, 2016), radiation effects of mobile phone (Sriram *et al.*, 2015), use of i-pads in education (Thejeswar and Thenmozhi, 2015), on micro RNA (Johnson, 2020), microRNA especially on preeclampsia patients (Sekar, 2019), animal studies (Seppan *et al.*, 2018), and in few other fields like thyroid function (Menon and Thenmozhi, 2016), and amblyopia (Samuel and Thenmozhi, 2015). There was not much work done on cortical implants; hence the aim of the present review is to elaborate about the importance to replace the neural circuitry in the brain that no longer functions properly. It helps the patients who have neurological disorders and to those who have difficulty in complex sensory and neural functions. Cortical implants are the visual implants for optics. Auditory implants are for hearing. Cognitive implants are for attention and decision making—brain-computer interface. The biggest advantage of neuroprosthesis is that it is directly interfaced with the cortex. It is a replacement that is done to the damaged tissues in the cortex.

Methodology

This review was done based on the articles obtained from Various platforms like PubMed, PubMed Central and Google scholar. They were collected with a restriction on a time basis from 1970 - 2020. The inclusion was original research papers, in vitro studied among various conditions and articles that contain pros and cons. Exclusion criteria came into account for review articles, retracted articles and articles of other languages. All the articles were selected based on Cortical Implants in Cerebrum.

They are determined by article title, abstract and complete article. When article holder websites were analyzed on the topic of Cortical Implants in Cerebrum, more than 2000 articles and based articles were found, when it was shortlisted based on the inclusion and exclusion criteria, the number of articles was lowered to 130 articles. When the timeline and other factors were quoted, only 31 articles came into play. This article is reviewed from the 31 articles collected. Quality of articles used was assessed using a quality assessment tool and graded as strong, moderate and weak (Table 1).

Implant materials

Silicon is suitable for long term recording of the cerebral cortex and acts as an effective platform technology for the foundation of the neural interface in humans (Vetter, 2004). Polymers are common material that acts as both substrate and insulation material for metals and interconnection of wires in the electrode sites (Hassler *et al.*, 2011). Advances in the neurotechnologies that revolutionized scientific treatment help in the prevention of a variety of neurological disorders (Wellman, 2018).

Table 1: Quality of study for articles used in review

S.No	Author	Year	Type of study	Key points	Quality of study
1	David T. Blake	1999	Research	Implant technology and records signals	Moderate
2	Suzanne S Stensaas	1978	Research	Histopathological evaluations	Moderate
3	R. J. Vetter	2004	Research	Chronic neural reading	Strong
4	Robert L. Rennaker	1999	Research	Characteristics of micro electrode array	Moderate
5	D. J. Edell	1992	Case study	biocompatibility	Moderate
6	Richard A. Normann	1999	Case study	Neural interface	Moderate
7	Sang Min Won	2018	Case study	Recent advances	Moderate
8	Tim Boretius	2010	Research	Polymers as common material	Moderate
9	James R. Eler	2018	Research	neurotechnologies	Strong
10	M. Gulino	2019	Case study	Field brain machine interface	Moderate
11	Justin C. Williams	2000	Case study	Working span	Strong
12	Taylor. D	2002	Research	Control of implants	Strong
13	Paninski. L	2002	Research	Control movement	Moderate
14	Andrew B. Schwartz	2004	Research	Extraction of algorithms	Moderate
15	Normann. R. A	1996	Research	Ultra intra cortical electrode array	Moderate
16	Fernandez. E	2000	Research	Relative movements	Strong
17	Gary Keib	2001	Case study	Cellular synaptic elements	Strong
18	Rousche PJ	2001	Research	Advanced neuroprosthetic systems	Moderate
19	Rohde MM	2000	Research	Direct brain interface	Strong

Field brain-machine interface is growing as the most important source of progress in neuroscience research (Gulino, 2019). Needles made up of plastic araldite were implanted in the cerebral cortex that changes indwelling when inserted in a foreign body (Stensaas and Stensaas, 1976). Cobalt, a toxic material, has extensive changes in the zones of connective tissue, astrocytes indicate that materials that are tolerated by the brain are used in the fabrication of neuroprosthetic devices (Stensaas and Stensaas, 1978).

Biocompatibility

The model system has various advances in the biocompatibility of neural implants for the development of the cortical component in the neural implant's working span (Kipke, 2003).

Control of cortical implant prosthesis

3D movement neuroprosthetic devices are controlled by the activity of cortical neurons through the usage of algorithms that are used to decode the movement in real-time (Taylor *et al.*, 2002). Electrode array for human use is a neurally based control movement that is feasible for paralysed humans (Serruya *et al.*, 2002). Control of prosthesis through cortical signals three elements in the chronic microelectrode arrays for the extraction of algorithms in the prosthetic effectors (Schwartz, 2004).

Microelectrode arrays

Ultra intracortical electrode array is a combination of a large number of electrodes that is suited for parallel processing mechanism in the cortex (Fernandez *et al.*, 2014)—minimizing the relative movements in the neural tissues to embrace the capacity of the microelectrode array (Maynard *et al.*, 2000). Multi-site unit recordings in the cerebral cortex awake animals in the period of time (Williams *et al.*, 1999).

Neuro cortex in the human brain has cellular, synaptic elements that are arranged in layers (Scherf *et al.*, 2006).

Advanced neuroprosthetics systems improve the quality of life of deaf, blind and paralysed populations (Rousche *et al.*, 2001; Johnson, 2020).

Interface

Cases considered for appropriate operation act as a direct brain interface (Levine, 2000). Adequate recognition provides an effective engagement in the new communication of motor disabilities (Babiloni, 2010). Brain modulates cortical responses that are prescribed by operant conditioning rules (Kipke, 2003).

Cochlear implant

Central auditory pathways are limited in age groups and implantation occurs with benefits. These are a limited number of implantations in congenitally deaf children (Gilley *et al.*, 2008). Neurocognitive processing for the auditory input and the type of changes that are adequately processed in cochlear implants in children (Torppa *et al.*, 2012). Childhood deafness seeks to restore the normal development function and cerebral auditory function (Gordon, 2011). Post lingually deafened subjects having a hearing of speech through the cochlear implants that had increased activation in both the temporal and frontal cortices (Hirano, 2000). Prospective longitudinal designs can track dynamics in the cortical plasticity before and after implantation (Stropahl *et al.*, 2017). Residual takeover persists after adaptation in cochlear implants, need not be necessarily maladaptive (Stropahl *et al.*, 2015). Effects in place of stimulation, cortical auditory evoked potentials in the speech performance in the cochlear implant listeners (Mamelle *et al.*, 2017). After cochlear implantation, speech understanding has been improved and speech and noise were spatially separated (Legris, 2018).

Research on rats

Insulin-producing cells and mesenchymal stroma cells are protective against cognitive impairment in the implant site of diabetic rats (Wartchow, 2020). Stimulation threshold has an efficient design in retinal and visual and cortical implants in rats (Xie *et al.*, 2019). The response of visual cortical neurons in the mouse, intraocular and extraocular are stimulated by electrical signals in the retina (Ryu and Fried, 2018). The results indicate a therapeutic activity towards the sustainment of the penile erection within the presence of an extract in aged rats (Seppan *et al.*, 2018).

Future Research

Diabetes mellitus is a public health problem and can cause long term damage in the brain that results in cognitive impairment (Wartchow, 2020).

RESULTS AND DISCUSSION

Silicon material is used for long term recording of the cerebral cortex. This technology lays a foundation for the neural interface in humans. Needles made up of plastic araldite that are implanted in cerebral cortex indwells when inserted in a foreign body. Cobalt which is a toxic metal that leads to extensive changes in the connective tissue and astrocytes indicates the materials that are tolerated by the brain and help in the fabrication of neuroprosthetics devices (Stensaas and Stensaas, 1978; Kipke, 2003).

Childhood deafness seeks restoration in the normal development function of cerebral auditory function. Prospective differs from longitudinal design and could track dynamics and cortical plasticity before and after implantation. Residual takeover persists after adaptations and cochlear implants are need not be necessarily maladaptive (Maynard *et al.*, 2000; Gordon, 2011; Stropahl *et al.*, 2015).

The limitation of the review is this study is the intramural cortical microstimulation that evokes a behavioural response, penetrating into the Utah intracortical electrode array.

The future scope of the cortical implant is that the insulin-producing cells and mesenchymal stroma cells are protective against cognitive impairment in the implant site of diabetic rats.

CONCLUSION

From this review, it can be concluded that cortical implants are placed to replace the neural circuitry in the brain that no longer functions properly. It helps patients with neurological disorders. It helps patients who have difficulty in complex sensory and neural functions. Visual implants are for optics. Auditory implants are for hearing. Cognitive implants are for attention and decision making. The biggest advantage of neuroprosthetics is that it is directly interfaced with the cortex. Lots of improvements are expected to happen in the near future in this field which could greatly benefit patients suffering from various diseases.

Funding Support

The authors declare that there is no funding support for this study.

Conflict of Interest

The authors reported the conflict of interest while performing this study to be nil.

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