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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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 (Stensaa and Stensaa, 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 foramen (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). Field brain-machine interface is growing as the
| 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. Elter                | 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          |
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 neuromuscular 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 neuromuscular 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 (Ndez, 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 sustenance 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.

CONCLUSIONS
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.

REFERENCES
Babiloni, F. 2010. From the Analysis of the Brain Images to the Study of Brain Networks Using Functional Connectivity and Multimodal Brain Signals. Brain Topography, 23(2):115–118.

Choudhari, S., Thenmozhi, M. S. 2016. Occurrence and Importance of Posterior Condylar Foramen. Research Journal of Pharmacy and Technology, 9(8):1083–1083.

deCharms, R. C., Blake, D. T., Merzenich, M. M. 1999. A multielectrode implant device for the cerebral cortex. Journal of Neuroscience Methods, 93(1):27–35.

Edell, D. J., Toi, V. V., McNeil, V. M., Clark, L. D. 1992. Factors influencing the biocompatibility of insertable silicon microshafts in cerebral cortex. IEEE Transactions on Biomedical Engineering, 39(6):635–643.

Gilley, P. M., Sharma, A., Dorma, M. F. 2008. Cortical reorganization in children with cochlear implants. Brain Research, 1239:56–65.

Gordon, K. A. 2011. Multiple effects of childhood deafness on cortical activity in children receiving bilateral cochlear implants simultaneously. Clinical neurophysiology: official journal of the International Federation of Clinical Neurophysiology, 122(4):823–833.

Gulino, M. 2019. Tissue response to neural implants: the use of model systems towards new design solutions of implantable microelectrodes. Frontiers in neuroscience, 13.

Hafeez, N., Thenmozhi 2016. Accessory foramen in the middle cranial fossa. Research Journal of Pharmacy and Technology, 9(11):1880–1880.

Hassler, C., Boretius, T., Stieglitz, T. 2011. Polymers for neural implants. Journal of Polymer Science Part B: Polymer Physics, 49(1):18–33.

Hirano, S. 2000. Functional differentiation of the auditory association area in prelingually deaf subjects. Auris Nasus Larynx, 27(4):303–310.

Johnson, J. 2020. Computational identification of MiRNA-7110 from pulmonary arterial hypertension (PAH) ESTs: a new microRNA that links diabetes and PAH. Hypertension research: official journal of the Japanese Society of Hypertension, 43(4):360–362.

Kannan, R., Thenmozhi, M. S. 2016. Morphometric Study of Styloid Process and its Clinical Importance on Eagle’s Syndrome. Research Journal of Pharmacy and Technology, 9(8):1137–1137.

Keerthana, B., Thenmozhi, M. S. 2016. Occurrence of foramen of huschke and its clinical significance. Research Journal of Pharmacy and Technology, 9(11):1835–1835.

Kipke, D. R. 2003. Silicon-substrate intracortical microelectrode arrays for long-term recording of neuronal spike activity in cerebral cortex. IEEE transactions on neural systems and rehabilitation engineering, 11:151–155.

Krishna, R. N., Babu, K. Y. 2016. Estimation of stature from physiognomic facial length and morphological facial length. Research Journal of Pharmacy and Technology, 9(11):2071–2071.

Legris, E. 2018. Cortical reorganization after cochlear implantation for adults with single-sided
deafness. *PloS one*, 13(9):204402–204402.

Levine, S. P. 2000. A direct brain interface based on event-related potentials. *IEEE Engineering in Medicine and Biology Society*, 8(2):180–185.

Mamelle, E., Kechai, N. E., Granger, B., Sterkers, O., Bochot, A., Agnely, F., Ferrary, E., Nguyen, Y. 2017. Effect of a liposomal hyaluronic acid gel loaded with dexamethasone in a guinea pig model after manual or motorized cochlear implantation. *European Archives of Oto-Rhino-Laryngology*, 274(2):729–736.

Maynard, E. M., Fernandez, E., Normann, R. A. 2000. A technique to prevent dural adhesions to chronically implanted microelectrode arrays. *Journal of Neuroscience Methods*, 97(2):93–101.

Menon, A., Thenmozhi, M. S. 2016. Correlation between thyroid function and obesity. *Research Journal of Pharmacy and Technology*, 9(10):1568–1568.

Nandhini, J. S. T., Babu, K. Y., Mohanraj, K. G. 2018. Size, Shape, Prominence and Localization of Gerdy’s Tubercle in Dry Human Tibial Bones. *Research Journal of Pharmacy and Technology*, 11(8):3604–3604.

Ryu, S. B., Fried, S. I. 2018. Comparison of responses of visual cortical neurons in the mouse to intracortical and extraocular electric stimulation of the retina. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 2458–2461.

Samuel, A. R., Thenmozhi, M. S. 2015. Study of impaired vision due to Amblyopia. *Research Journal of Pharmacy and Technology*, 8(7):912–912.

Scherf, K. S., Sweeney, J. A., Luna, B. 2006. Brain Basis of Developmental Change in Visuospatial Working Memory. *Journal of Cognitive Neuroscience*, 18(7):1045–1058.

Schwartz, A. B. 2004. Cortical Neural Prosthetics. *Annual Review of Neuroscience*, 27:487–507.

Sekar, D. 2019. Methylation-dependent circulating microRNA 510 in preeclampsia patients. *Hypertension Research*, 42(10):1647–1648.

Seppan, P., Muhammed, I., Mohanraj, K. G., Lakshmanan, G., Premavathy, D., Muthu, S. J., Shimray, K. W., Sathyanathan, S. B. 2018. Therapeutic potential of Mucuna pruriens (Linn.) on ageing induced damage in dorsal nerve of the penis and its implication on erectile function: an experimental study using albino rats. *The Aging Male*, pages 1–14.

Serruya, M. D., Hatsopoulos, N. G., Paninski, L., Fellows, M. R., Donoghue, J. P. 2002. Instant neural control of a movement signal. *Nature*, 416(6877):141–142.

Sriram, N., Thenmozhi, Yuvaraj, S. 2015. Effects of Mobile Phone Radiation on Brain: A questionnaire based study. *Research Journal of Pharmacy and Technology*, 8(7):867–867.

Stensaas, S. S., Stensaas, L. J. 1976. The reaction of the cerebral cortex to chronically implanted plastic needles. *Acta neuropathologica*, 35(3):187–203.

Stensaas, S. S., Stensaas, L. J. 1978. Histopathological evaluation of materials implanted in the cerebral cortex. *Acta Neuropathologica*, 41(2):145–155.

Stropahl, M., Chen, L.-C., Debener, S. 2015. Cortical reorganization in postlingually deaf cochlear implant users: Intra-modal and cross-modal considerations. *Hearing Research*, 343:128–137.

Stropahl, M., Plotz, K., Schönfeld, R., Lenarz, T., Sandmann, P., Vovel, G., Vos, M. D., Debener, S. 2015. Cross-modal reorganization in cochlear implant users: Auditory cortex contributes to visual face processing. *NeuroImage*, 121:159–170.

Subashri, A., Thenmozhi, M. S. 2016. Occipital Emis-sary Foramina in Human Adult Skull and Their Clinical Implications. *Research Journal of Pharmacy and Technology*, 9(6):716–716.

Taylor, D. M., Tillery, S. I. H., Schwartz, A. B. 2002. Direct cortical control of 3D neuroprosthetic devices. *Science*, 296(5574):1829–1832.

Thejeswar, E. P., Thenmozhi, M. S. 2015. Educational Research-iPad System vs Textbook System. *Research Journal of Pharmacy and Technology*, 8(9):1158–1158.

Torppa, R., Salo, E., Makkonen, T., Loimo, H., Pykäläinen, J., Lipsanen, J., Faulkner, A., Huotilainen, M. 2012. Cortical processing of musical sounds in
children with Cochlear Implants. *Clinical Neurophysiology*, 123(10):1966–1979.

Vetter, R. J. 2004. Chronic neural recording using silicon-substrate microelectrode arrays implanted in cerebral cortex. *IEEE transactions on biomedical engineering*, 51(6):896–904.

Wartchow, K. M. 2020. Insulin-producing cells from mesenchymal stromal cells: Protection against cognitive impairment in diabetic rats depends upon implant site. *Life sciences*, 251:117587–117587.

Wellman, S. M. 2018. A materials roadmap to functional neural interface design. *Advanced functional materials*, 28(12):1701269–1701269.

Williams, J. C., Rennaker, R. L., Kipke, D. R. 1999. Long-term neural recording characteristics of wire microelectrode arrays implanted in cerebral cortex. *Brain Research Protocols*, 4(3):303–313.

Won, S. M. 2018. Recent Advances in Materials, Devices, and Systems for Neural Interfaces. *Advanced Materials*, 30(30):1800534–1800534.

Xie, H., Shek, C. H., Wang, Y., Chan, L. L. 2019. Effect of interphase gap duration and stimulus rate on threshold of visual cortical neurons in the rat. *2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pages 1817–1820.