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New Technologies in Eye Surgery – A Challenge for Clinical, Therapeutic, and Eye Surgeons

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Abstract

Eye surgery is always progresses as the same way that the science advances. New emerging technologies such as bio-printing in 3D, developments and mathematical modeling in prototyping lab- on- a chip, visual implants, new biopolymers started to use in eye enucleation, detection of eye biomarkers at the cellular level, bio-sensors and new diagnostic tests should be considered to improve the quality of life of patients after surgery. This chapter provides a review of new and emerging technologies which are already working on global research centers. Emerging and converging technologies are terms used interchangeably to indicate the emergence and convergence of new technologies with demonstrated potential as disruptive technologies. Among them are: nanotechnology, biotechnology, information technology and communication, cognitive science, robotics, and artificial intelligence that have been launched as innovative products that promise to improve the quality of life and vision of patients with ocular compromised or low vision impairment. Some acronyms for these are: NBIC: Nanotechnology, Biotechnology, Information technology and Cognitive science. GNR: Genetics, Nanotechnology and Robotics. GRIN: Genetic, Robotic, Information, and Nanotechnology. BANG: Bits, Atoms, Neurons and Genes. Otherwise, to training ophthalmologist on news techniques, sophisticated simulation machines has been developing around the world.

Keywords: Artificial retina, nanotechnology, visual health, ocular prosthesis, retina

1. Introduction

Eye surgery always progresses the same way as science advances. New emerging technologies such as bio-printing in 3D, mathematical modeling, and developments in prototyping lab-on-a-chip, visual implants, and new biopolymers have started to be used in eye enucleation, the

detection of eye biomarkers at the cellular level, bio-sensors, and new diagnostic tests that are considered to improve the quality of life of patients after surgery.

This chapter provides a review of new and emerging technologies, which are already working in global research centers. The term “emerging technologies” refers to the implementation of new innovative products designed to improve the quality of life. Some acronyms used are:

NBIC: Nanotechnology, Biotechnology, Information technology, and Cognitive science.

GNR: Genetics, Nanotechnology, and Robotics.

GRIN: Genetic, Robotic, Information, and Nanotechnology.

BANG: Bits, Atoms, Neurons, and Genes.

New technologies, such as nanotechnology, artificial intelligence, and genetics among others, have emerged not only to create alternatives to health service, but also to provide alternatives for new ophthalmologists in their surgical practice. There are increasing reviews in literature about the relationship with developments such as new surgical techniques not only for refractive surgery but also for simulation prior to cataract. Retina implants incorporating electronic devices, stem cells, and new inserts for corneal implants are some of the many devices made from biopolymers and electronics that have the promise to be an alternative for visually impaired patients.

Otherwise, as a response to training ophthalmologists on these new techniques, sophisticated simulation devices have been developed around the world [1].

2. Problem statement

Eye surgery has always been characterized by innovation, the introduction of new surgical techniques, and also the inclusion of technology. But being so specialized, this information is not readily disclosed to the targeted patients who directly require these new developments in order to restore their vision or improve the quality of their life. Otherwise, medical students and residents in ophthalmology require an overview of these new developments to plan the training for these new techniques and apply it to patients that have these requirements according to the new protocols, inclusion criteria, and the available technology in the operating room in order to plan new investments for clinical practice and training. Knowing where you are in making this progress, communication and the creation of partnerships between experts are priorities to be able to respond to the patients’ needs.

This chapter intends to update eye surgeons in new biopolymers and innovations for ocular prostheses and visual implants for visual care. In the previous years, there are a lot of innovations such as visual implants, artificial silicon retinas, suprachoroidal transretinal stimulation (STS), and artificial corneas among others, which are changing nowadays due to the new advancements in technology and also due to the development of new biomaterials, new microelectrodes, and several types of neural devices around the world. Now, real “artificial eyes” are not only the craniofacial, maxillofacial, ocular, and orbital prostheses that replaces an absent eye after an enucleation but they are also new materials such as cryolite glass, gel

from cellulose, glass, silicone and porous polyethylene, graphene, dental biopolymers among others that are being implemented as materials for the heart, eye, and other organ implants due to their characteristics to improve good biological compatibility, be more resistant, reduce allergies, and improve durability. These implants are used for the replacement of the orbital content of anophthalmic cavities [2].

The traditional concept of ocular prostheses (ocular, orbital, epithesis, and maxillofacial), visual implants (retinal, optic nerve, cortical, subretinal, epiretinal and cortical), and others of engineering and biomedical sciences have been changing and must be reviewed in the future.

Otherwise, digital cameras, electrodes, and other electronic devices are useful for the visually impaired. In France, there has been some work on retinal implants using nanodiamonds in the artificial retina. This allows converting light signals into electrical signals. In the field of ocular pharmacology, the nanocarrier molecules for the sustained release of drugs and other devices to vitrectomies are some of the significant visual health advancements in the recent years. Additionally, in the field of contact lenses and artificial corneas, biopolymers have been developed for the early detection of keratoconus or systemic diseases. Nanotechnology is emerging as a science applied to the visual industry and medicine, involving a multidisciplinary team that requires new directions in the role and performance of ocular professionals around the world in the near future. The handling of materials and processes at the nanoscale (one billionth of a meter) level, the instrumentality in the accurate detection, and the telerehabilitation intervention using robots of bioelectrical retinal implants nano lenses are just some of the promising developments in the field of eye care. Visual health professionals seek the entry of this science in our curricula, research, and training discipline for innovation and technology based on nanotechnology and robotics. The high costs should not prevent the alliance between university research centers and the private industry in bringing innovation to our population and creating transdisciplinary research lines to improve the quality of life in eye health.

In the recent years, we have reviewed scientific literature regarding publications in surgical techniques of eye surgery. The number of publications on visual implants, artificial corneas, stromal rings, and cross linking has increased in the same manner as the development of new patents did. Also in the recent years, the inclusion of digital imaging systems, visual simulators, and virtual and augmented reality, prior or during the surgeries, have taken place. Some of the ophthalmic surgical procedures mentioned above are useful for improving the life quality of patients. This may pose a challenge to ophthalmic surgeons, but, has improved the quality of life of patients and their rehabilitation. The topics are discussed under the following areas: pre-operative tests, operative surgery, prevention of complications and current and future major advances in eye surgery of importance to surgeons, researchers, physicians, and health personnel.

3. Eye surgery on literature

Global announcements regarding new developments in eye surgery across all fields require a systemic search for there are many institutions and authors contributing to this knowledge.

To perform this review, keywords were used: Eye surgery and refractive surgery, eye surgery and visual implants, eye surgery and retinal implants, glaucoma eye surgery, and cataract eye surgery. The resources used were Medline and Scopus criteria for the inclusion of surgical techniques (1990-2014). In this review, it has been noted that many institutions have increased ophthalmology publications in these areas and in recent years, advancements in electronic chips to the retina and visual and retinal implants are growing considerably.

Many eye care research institutes supported by the government and universities from all continents have been working for decades on innovations for eye surgery across all fields (cataract, refractive surgery, stromal rings, and retinal implants), which has been progressing in different countries as evidenced by scientific literature.

Scientific publications related to refractive surgery around the world and the institutes that have most published reports on refractive surgery can be seen in the chart below. Scopus analysis can be useful creating partnerships between researchers in the same field. See Figure 1 [3].

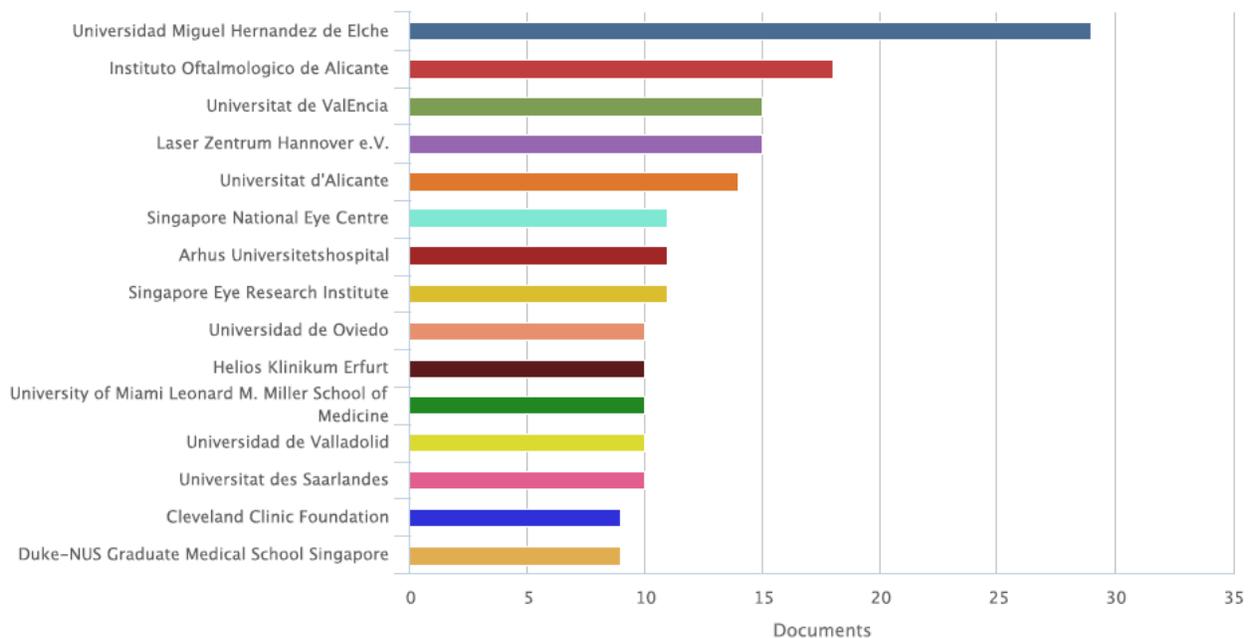


Figure 1. Publications of refractive surgery from Ophthalmology Institutes and Universities around the World from the last decades. Copyright 2015. Elsevier B.V. All right reserved. Scopus is a registered trademark of Elsevier B.V.

Literature reviews on retinal implants, which previously seemed like science fiction, has become a research field not only in ophthalmology and medicine, but also in electronic engineering and nanotechnology. Therefore, these researches should not only make journals specialize in medicine, but the revisions should also include nanotechnology and engineering to make it more accurate. In Figure 2, reports regarding retinal implants that were made by principal countries have been proven evident.

Institutions and universities are making major breakthroughs in the field of retinal implants for more than two decades. In fact, some already have several patents, prototypes, and

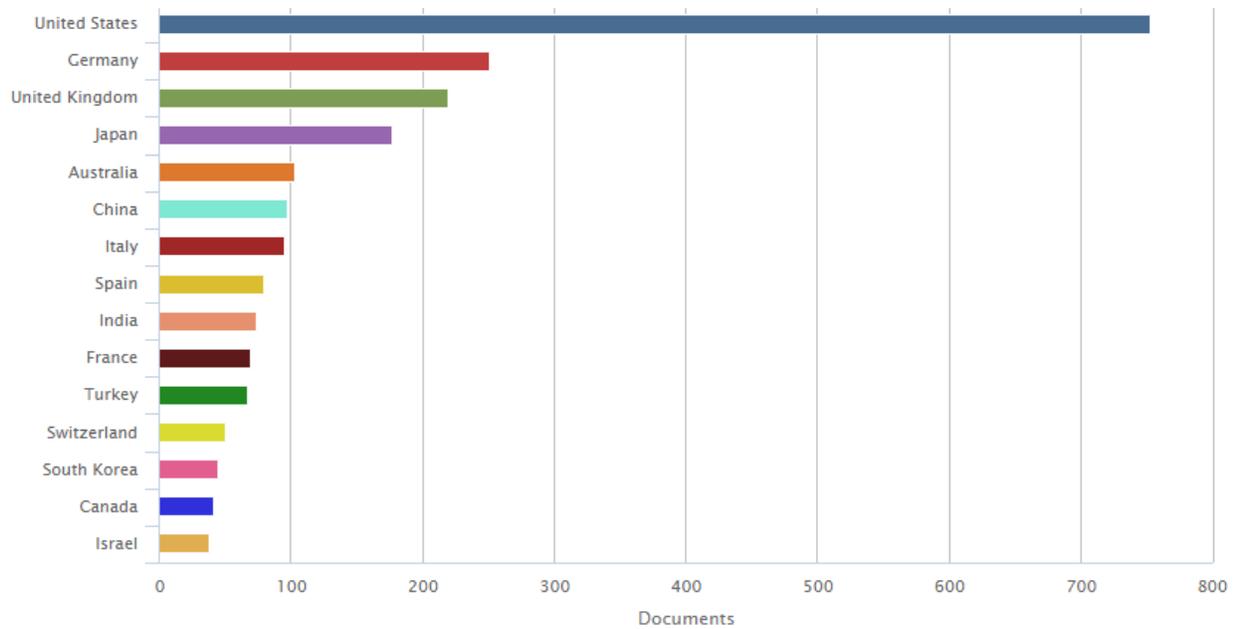


Figure 2. Publications in retinal implants in different countries. Copyright 2015. Elsevier B.V. All right reserved. Scopus is a registered trademark of Elsevier B.V.

experimental models in animals. There is already evidence in humans, which provides a promising future for people with retinitis pigmentosa, which a few years ago would have been considered impossible. See Figure 3 [3].

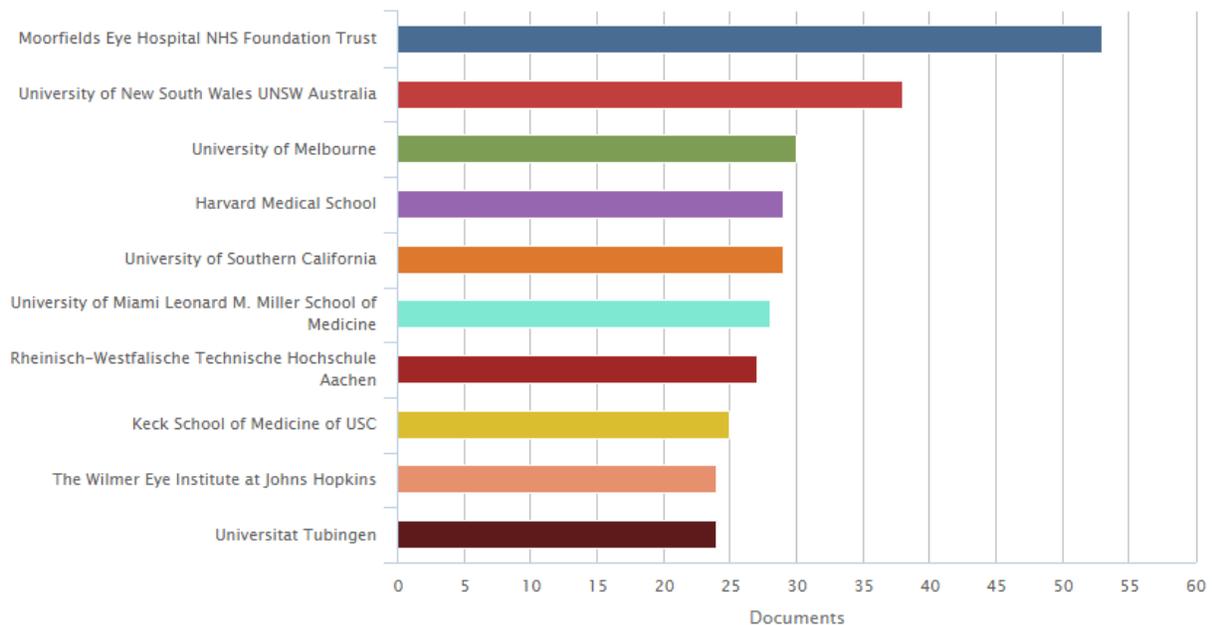


Figure 3. Top Publications in retinal implants for institutes and Universities around the World. Copyright 2015. Elsevier B.V. All right reserved. Scopus is a registered trademark of Elsevier B.V.

4. Types of eye surgery

Today, the classification of eye surgery can be summarized in Figure 4.

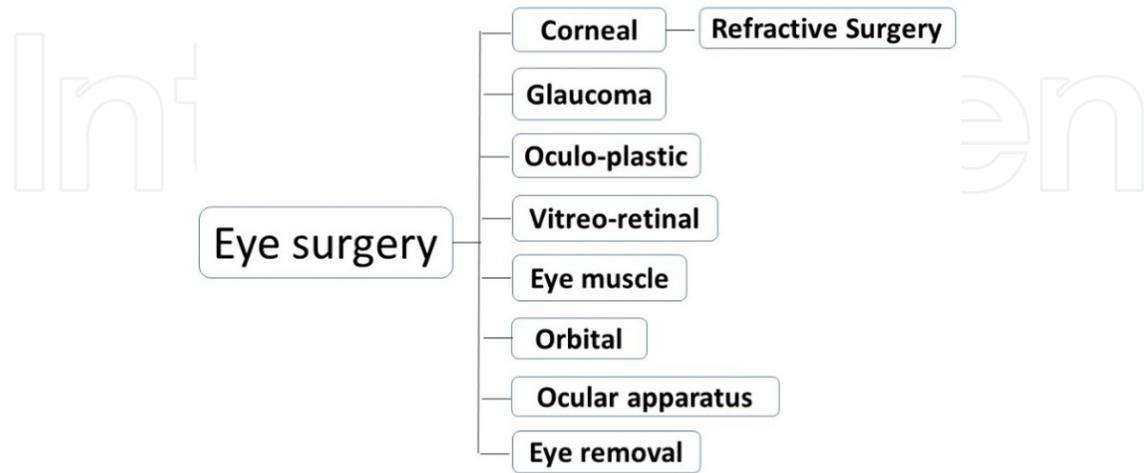


Figure 4. Classification of the types of eye surgery.

5. Ocular surgical techniques

In the surgery of myopia, astigmatism, and presbyopia, several techniques have improved since the 80s (See figure 5). And recently, a stromal ring technique has been introduced for keratoconus. Due to the shortage of donors for corneas, the stem cell culture and the development of new biopolymers has increased until the creation of several artificial corneas.

6. Corneal surgery

The corneal transplant surgery is useful in the removal and replacement of damaged corneas, replacing it with a clear donor cornea (corneal grafting) in its entirety (penetrating keratoplasty) or in part (lamellar keratoplasty). Another surgical technique is the deep anterior lamellar keratoplasty (remotion of the anterior layers of the central cornea) if the replacement includes posterior cells: endothelia, stroma and Descemets cells (DSEK) or Descemets/endothelium (DMEK).

Boston keratoprosthesis is a synthetic cornea used since 2008 (Boston KPro), which was developed for the Massachusetts Eye and Ear Infirmary. The AlphaCor, a device that contains a peripheral skirt and a transparent central region, is another artificial cornea. The parts connect interpenetrating polymer network made from poly-2-hydroxyethylmethacrylate (pHEMA). Another model is the osteo-odonto-keratoprosthesis, wherein a lamina of the patient's tooth

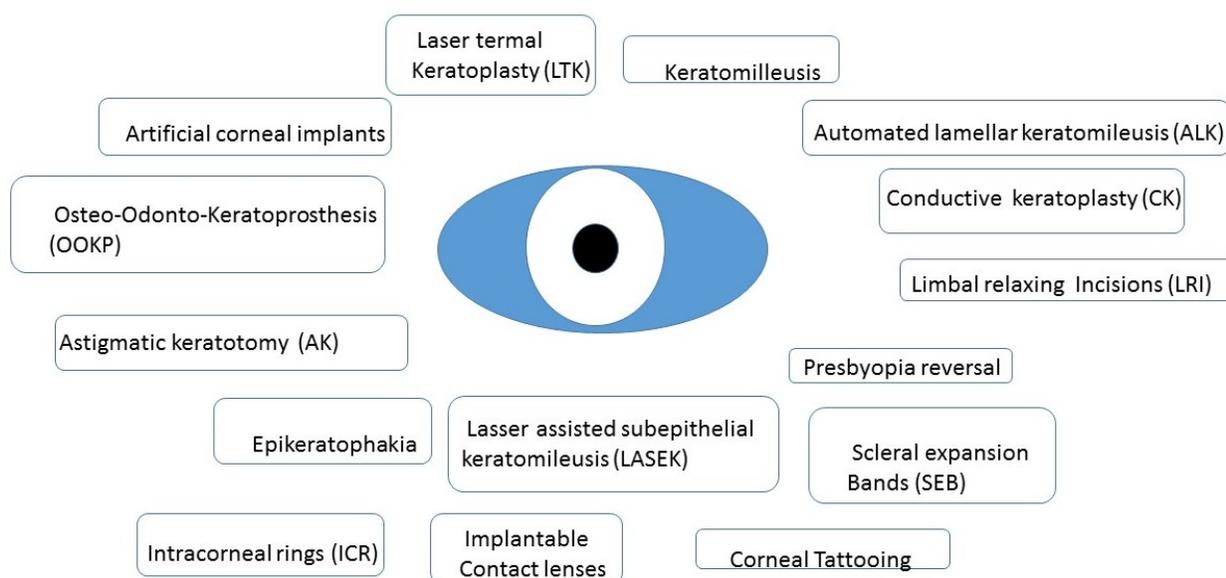


Figure 5. Corneal surgery techniques.

is implanted into the eye using an artificial lens. The porous graphite/PVA hydrogel composite as the skirt of artificial cornea, in the experimental model shows the interconnective porous network. The mechanical properties and water content are similar to nature donor cornea. Water content is another crucial characteristic of hydrogel used as a material for artificial cornea because it will influence the biocompatibility of hydrogel. Experimental studies developed in rabbits *in vivo* shows that the hydrogel nanocomposite implants of Zn NP were well tolerated in over 3 weeks of study, with no evidence of wound leakage, infection, inflammation, or neovascularization [4].

Corneal cross-linking is a technique used for the treatment of keratoconus. It increases the corneal rigidity by photo polymerization of the stromal collagen fibers with UV light for less than 30 minutes. The standard cross-linking technique, also called Dresden protocol (CXL), requires the removal of the central 9 nm of the corneal epithelium layer followed by 30 minutes of riboflavin administration [5].

In order to make a predictive value pair wing refractive surgery and have a more accurate and useful value for refractive surgery and the stromal rings for keratoconus, sophisticated software have been developed to help surgeons take more precise models before the surgery. Some of them are provided by manufacturers and others have been developed based on sophisticated mathematical models, which are very useful in cases of keratoconus or corneal astigmatism [6].

Nomograms are incisions within the cornea without the need to break the epithelium or Bowman's, thus avoiding the risk of wound problems and possible overcorrections during refractive surgery. Recently, specialized software products can help surgeons on the different procedures. Some of them are IBRA, Intacs®, and Nomograms (useful for ICRS in keratoconus by the use of a ring base on the type of the cone) [7, 8, 9]. In presbyopia surgery, an optical

device as thin as a contact lens is inserted into the cornea to reshape the front surface of the eye in order to improve vision. Corneal inlays are used to improve near vision and reduce the need for reading glasses. This device can be combined with LASIK for nearsightedness, farsightedness, and/or astigmatism.

This procedure is less invasive than phakic IOL (intraocular lenses placed deeper in the eye). So, with the corneal inlays for vision correction, eye surgeons may sometimes be able to avoid complications associated with procedures, such as LASIK and PRK, because no corneal tissue is removed. The Kamra Corneal Inlay, previously called ACI 7000, for presbyopia is now in clinical trials. The device is inserted in a thin flap in the center of the cornea. The flap is then replaced over the inlay to hold it in place in a process of 15 minutes [10].

Its innovation holds a promise to replace reading glasses with good near vision in the near future. The characteristics of Kamra are described as follows: 3.8 millimeters in diameter, 10 microns thick, made of an opaque biocompatible polymer (Kynar), and a thermoplastic material that softens in heat and hardens in cooler conditions.

Corneal inlays and onlays are also called keratophakia. They are implants placed in the corneal stroma for the correction of presbyopia. The procedure is done under topical anesthesia and the implant is done monocularly in the non-dominant eye as a stromal pocket or under the flaps created by the microkeratome or by the femtosecond laser. See Figure 6.

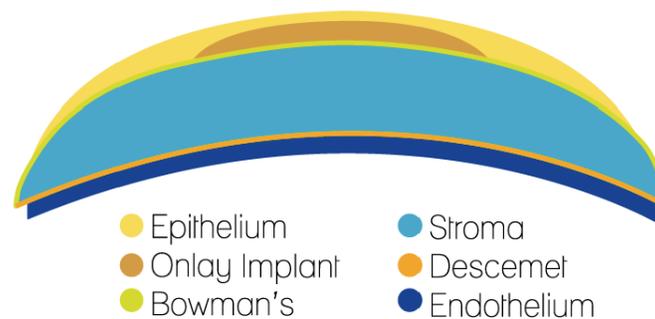


Figure 6. Position of the corneal onlay implants.

Other innovations for these techniques have been developed for researchers in Mexico, who are working on Raindrop near Vision Inlay (ReVision Optics) with some variation on diameters, thickness, and biomaterials.

This inlay is placed in the cornea under a LASIK-style flap. When in position, the inlay changes the curvature of the cornea so the front of the eye acts much like a multifocal contact lens. The other alternative is the Flexivue Microlens (Presbia Cooperatief U.A., Amsterdam), which uses a laser and creates a tiny pocket just below the eye's surface. Currently, it requires developing the instrument to insert the microlens in the pocket that is sealed to hold the lens, and a hydrophilic polymer is irrigated during surgery with a highly moisturizing substance. The synthetic intraocular lens replaces the natural lens during cataract surgery. Its characteristics are as follows: 3 mm in diameter and 20 microns thick at the edges [11].

7. 3D Models for training and surgery

7.1. Glaucoma

Some helpful preoperative aids recently included for prior surgery are the 3D models. These must be used to investigate the pressure drop on the localization of the main resistance to aqueous egress during iridectomy or trabeculectomy surgery. Some of these are the modeling of the eye drainage using the computational fluid dynamics (CFD) and the eye drainage system devices (GDD). To provide a 3D CFD prototype of the eye, the basis is the anatomy of a real human eye. Some models are based on stacks of microphotographs from human eye slides from which digital processing of the images of the eye structure and 3D reconstruction of the model are performed. The simulations of the distribution of pressure and the flow velocity in the model of a healthy eye bring results comparable to physiology references. Mimicking glaucoma conditions, most likely the real eye, led to an increase of the IOP from normal range, which went down to lower values after a filtering procedure. With this, a computer assisted design (CAD) model of the device is inserted in the 3D eye through the DC and the trabecular meshwork of the anterior chamber angle, parallel to the plane of the iris [12].

7.2. Cataract surgery

A simulation, very similar to the real environment, has been implemented, so the training for the surgeon is more secure. It is also in real-time as a virtual simulator with a control position tracking in a stereoscopic display mounted on a head, with a video, audio, and haptic interface in virtual reality. A real environment has been simulated that is created electronically in a controlled and protected environment where the surgeon can learn, practice, and improve their skills for surgery in a safe environment [13].

SensAble Phantom Omni TM is equipped with a device that controls virtual surgical instruments and feeds the skills of the surgeon, allowing six degrees of freedom tracking, three of which are important in human-machine interface for simulation. A haptic interface is designed to identify the types of surgical operations, such as cutting, grasping, pushing, emulsion, and calculated reaction force, and allows modeling the deformation of the mesh fabric, such as an eye model. The cyanoacrylate polymerizes as soon as it touches something like water and aqueous or saline solution. Fibrin glue is also another sealant that is also used for pterygium with conjunctival auto-grafts and secures amniotic membrane tissue in pterygium surgery. Sealants made of polyethylene glycol hydrogel are used for sealing corneal incisions and implantation in the IOL [14].

8. 3D Bioprinting

3D printing, better known as bioprinting, has been widely accepted in the health industry. This was initially developed to print 3D process designs in the gastronomy industry. Later on, it has become one alternative medicine for organ replacement. Printing with organs like heart,

liver, kidney, replacement hip bones, and maxillofacial trachea has become an alternative in association with research on stem cells to regenerate tissue. Eye level attempts have been cast for 3D modeling and future impressions of the eyeball for cosmetic purposes in people requiring ocular prostheses turned what was previously artisanal towards a more precise subsequent enucleation process. This improves the aesthetic value and lowers the probability of infection that occurs in these tissues due to poor hygiene because there is no need to frequently remove it for cleaning purposes [15].

This process consists of the printing, layer by layer, on a 3D printer using stable biological materials applied in tissue engineering. Very few materials, which fulfill the requirements for bioprinting as well as provide adequate properties for cell encapsulation during and after the printing process, are available. Some of the materials that are similar to the contact lens hydrogel composite or include alginate and gelatin precursors were tuned with different concentrations of hydroxyapatite (HA) and were characterized in terms of rheology, which is the swelling behavior and mechanical properties used to assess the versatility of the system properties [16].

9. Development on visual implants

The LIS-CEA laboratory in France has been studying retinal implants from nanomaterials and nanodiamonds. By means of the implementation of memristors and digital technology, electronic devices that respond to Moore's Law (processing speed, memory capacity, and number of pixels) inspired the creation of cardiac pacemakers and created an intelligent flash. This concept was introduced by Leon O. Chua and was developed as a model of neural networks, the biomimetic model of the retina, where they expected to even send 3D signals. [17].

A project was undertaken wherein other technologies using silicon microchips as a "wafer" to create a biological and electronic device in the form of functional circuits that interact with live cells and shows a promise for the present and future cells. The construction of the small three-dimensional models of the human organs can be used to treat and replace costly and time-consuming animal studies that currently hamper the development of drugs. Furthermore, these micro-electromechanical systems (MEMS) allow testing in cell cultures without using a full tissue. A lab-on-a-chip enables the replication of tissue samples [18].

FDA approved a project of more than 15 years which comprised an interdisciplinary group of researchers. The retinal prosthesis was created: Second Sight Argus II, with funding from the National Eye Institute. It consists of a camera that captures images via implanted electrodes that stimulate cells in the retina, producing a light on the patient's visual field. This camera mounted on a pair of eyeglasses wirelessly (with 60 electrodes and hoping to increase it to 1500), has an array of microelectrodes and is mounted on a miniature camera on a pair of glasses that act as a sensitive photodiode light. The camcorder captures a portion of the visual field and transmits the information to the VPU. The device is already being used in patients with retinitis pigmentosa [19].

Traditionally, the aesthetics of the manufacturing and fitting of ocular prostheses are acceptable and responds efficiently in improving the patient’s confidence and physical and psychological well-being, therefore, helps to improve their social acceptance and quality of life. Recently, the introduction of visual implants is a different alternative designed to transmit electronical signals from the retina to the brain. According to the surgical technique and position, they are inserted or transplanted into the body and tend to be used as a therapeutic instrument for visual rehabilitation. The artificial stimulation to the visual pathway allows the brain to recognize the electric signal as light. New electronical materials useful for the fabrication of these devices have been developed in the recent years. An ocular prosthesis helps the patient psychologically and improves confidence, but doesn’t have a visual function. Different techniques are available to fabricate a custom ocular prosthesis. In contrast, visual implants are currently being developed as an innovation to restore nerve impulses between the eyeball and the cerebral cortex, linking transdisciplinary efforts, electronic engineers, and ophthalmologists worldwide working to develop the bionic eye. The researchers are focused to allow and improve the perception of spots of light and high contrast edges by means of the devices’ stimulator as electrodes or optogenetics transducers.

See Figure 6 [20].

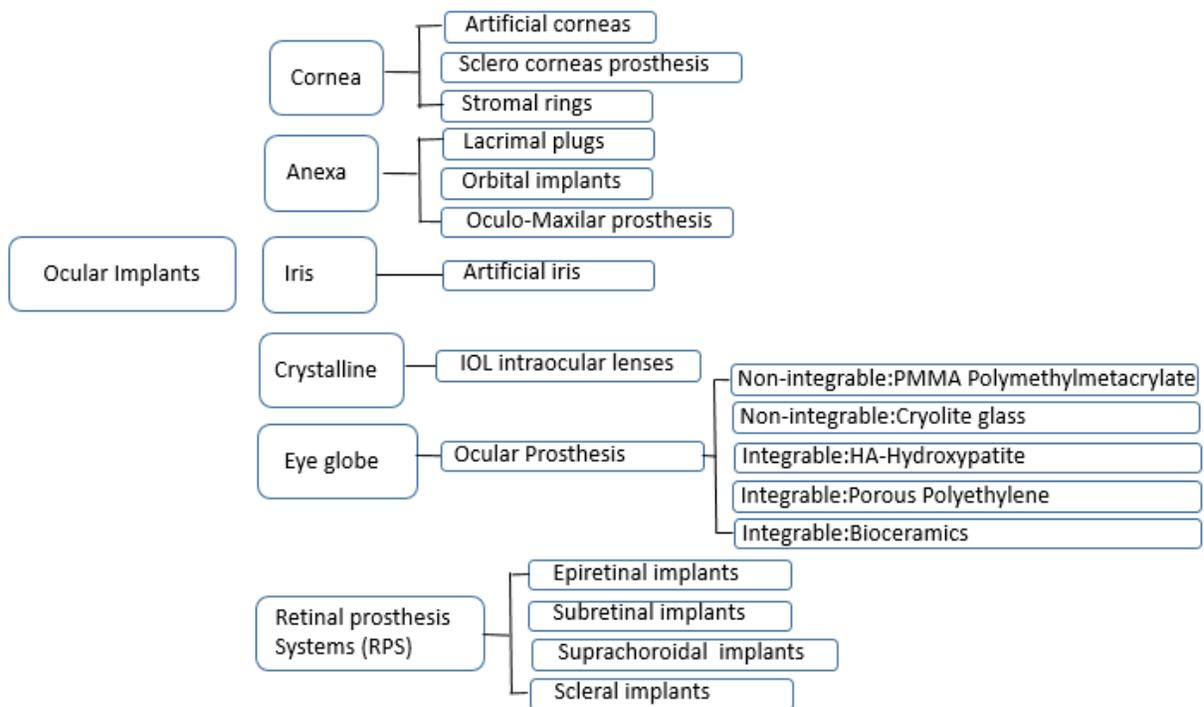


Figure 7. Classification of Ocular implants. Durán, P. Diaz, M, Plaza, J. Journal of ocular diseases and therapeutics. 2 N. 1, 2014.

Ocular prostheses were made and are still fabricated in inert and non-integrable materials, such as polymethylmetacrylate (PMMA) and cryolite glass. But these days, integrable materials for anophthalmic cavities, such as a gel from cellulose produced by *Zoogloea* sp.

porous polyethylene dental biomaterial composites and graphene among others, are implemented as materials for the heart, eye and other organs implants due to their characteristics in improving biological compatibility to be more resistant, to reduce allergies, and improve durability. The future development of the ocular prostheses is focused on the impression of digital measurements, 3D modeling software, and the digital impression of the iris [21].

Many implants are being studied around the world. Some patents and other humans have been implanted to help in visual rehabilitation. Some of these examples are divided into two categories according to design or operations principles, some use an external camera and image processing drive implanted electrodes. Another example is the use of 1500 small units in microphotodiode arrays (MPA by Retina Implant AG) and Stanford retinal prosthesis. Some required external energy to drive the stimulators, while others are wireless. The Stanford array projects a high intensity infrared image on the implanted photocells and generates a sufficient current to excite the secondary neurons. In addition, the classification must be made according to the implant site e.g., in the inner retinal (epiretinal) or outer (subretinal) retinal surface; if the implant is inserted below the choroid plexus (suprachoroidal) or if the implantation take place outside the sclera (episcleral) [22, 23, 24].

Before the production of visual implants, many studies should be performed to verify the noise pattern, the extraction processing of the temporal space, monitoring to check the quality of the image, the spatial resolution, the circuit architecture, and advanced intelligent functions.

The future smart 3D image sensor architectures will most probably consist of a sensor layer at the top and various processing layers below. Each layer will be organized into locally connected cellular arrays with additional global communication/operation mechanisms. Layers will be vertically interconnected using bi-directional parallel channels implemented by through-silicon-vias (TSVs). Images at different scales and abstract information about salient points and features will be transmitted top-down across the stack, while commands will be transmitted bottom-up to support adaptation.

10. Optical Coherence Tomography (OCT) in surgery

The OCT has revolutionized the clinical management of ophthalmic diseases and promises to be of great help in the surgical rooms. The Prospective Intraoperative and Perioperative Ophthalmic Imaging with Optical Coherence Tomography (PIONEER), a single site multi-surgeon prospective is incorporating the OCT to the surgical room because of feasibility, safety, and utility. This study is performed by the Cleveland Clinic. The variables including past ocular history, procedure type, preoperative diagnosis, techniques, and number of imaging sessions are recorded one day before surgery. The structured study follow-up is done after the surgery [25].

The protocol managing for them is next. Disease-specific or procedure-specific imaging protocols (eg. scan type, pattern, density, size, orientation) were outlined for anterior and posterior segment applications. Anterior segment imaging included a 12mm³, 12mm volu-

metric cube scan at 0 degree orientation. Posterior segment imaging included a 10 mm³, 10 mm volumetric cube with 100 B-scans per volume at both 0 and 90 degrees, a 5 - 3 10mm volumetric cube with 7 B-scans per frame for averaging, a total of 175 B-scans per volume at both 0 and 90 degrees, and a 10 mm radial scan with 100 B-scans per volume. The surgeons were provided with guidance for surgical milestones to consider for imaging (e.g., pre-incision, following membrane peeling, following graft placement), but the specific imaging sessions were at the surgeon's discretion. When possible in vitreoretinal cases, scan sequences were obtained in the operating room prior to any surgical manipulation of the area of interest. Following various surgical milestones, scan sequences were performed to allow for comparative data and change analysis. A "scan" was defined as a single set of images. A "scan session" was defined as a series of scans obtained during a single pause during surgery. Typically, multiple scan sessions were often performed during the surgical procedures. A specific surgical procedure (e.g., Membrane peeling, lamellar keratoplasty) intraoperative OCT feedback form was included as part of the study protocol. This form included questions regarding the impact of the intraoperative OCT on surgical decision making and on how intraoperative OCT may have impacted the understanding of the surgical disease of interest. OCT provides rapid testing that reduces costs, time, and enhances quality care for surgeons and patients [26].

11. Further research

Future research of new innovations in visual implants improves existing research for best results. The early implementation of refractive surgery and cataract surgery is recalled, however, it is important that the increase of that research is conducted in global scientific communities where you can monitor patients and have access to people with visual impairment that requires the surgery. High costs should be borne by health systems, according to the laws of each country, so that they can be taken advantage by the patients who need them. Some of the challenges that are presented in eye health are the cost of the technology transfer, more high-level training in surgical procedures, and the establishment of protocols according to the clinical findings. Just as eye surgery has been the pioneer in the world among many technological advancements, it becomes a possible reality in the near future to restore vision for visual rehabilitation and to provide a better quality of life for visually impaired patients.

Likewise, due to the interaction of the new sciences, ophthalmologists around the world should have comprehensive training from his clinical practice in various branches of medicine, biomedical engineering and electronics, and nanotechnology. Team groups with different point of views must be formed to answer the needs of patients, such as applying science to the clinic, establishing protocols to prevent errors, and improve processes in eye surgery and thus, optimizing costs, human resources and effectiveness for patients. All these innovations must be reimbursed by health insurance systems around the world.

So that these advancements reach patients, there should be access to global insurance to cover the population that needs them. Germany and the United States are already doing this. However, in underdeveloped countries, this possibility does not even exist and is yet to be built.

The truth is that in the near future, these new surgeries may have results that help reduce blindness, improve the coverage and quality of life for patients with myopia, astigmatism, presbyopia, cataracts, and retinitis pigmentosa among others. The inclusion of contact lenses has always been considered as one of the most important innovations for mankind. But this technology is linked to new projects and has developed new biopolymers. The challenge for innovators and surgeons in the next decades is the immersion with electronic chips. The accuracy of current studies is required and must be taken advantage by the academic community for the scientific needs and reading of the general population.

Another important area in future work on education to transfer this technology and provide updates with experts and developers for the patients' safety, must be worked in partnership with the different industries and academia.

12. Conclusion

Eye surgery is not only considered a pioneer in the world by technological advancements, but evidence also shows that it has been and will continue to be important to combat blindness in the world. Among the most significant advancements are visual implants, artificial corneas, new biopolymers, and the inclusion of nanotechnology in operating rooms where other major global challenges will come from.

The challenge of new visual innovation includes multiple fields that must continue to be improved for these new global developments in refractive surgery, ocular prosthesis, and visual implants. In order to make these advancements accessible to patients, it is required to improve the transfer of technology and improve the training of surgeons around the world. The following points must also be taken into consideration:

1. Eye surgery research: strengthening global researchers' mobility and internships among researchers of visual health-electronical engineering groups around the world to be training in transdisciplinary teams about the new surgical technique and developments in electronic engineering and their applications to visual health. It must include developments for other healthcare artifacts.
2. Financial resources: search financial resources from government and public and private entities to develop new technology transfer policies.
3. Database creation for target population in visual implants or visual rehabilitation: the creation of a global database of possible patients that can benefit from these innovations should be a priority in each country and will make us plan for monitoring, check the progress in new implanted patients, verify the recovery rates, and design a project of the improvement thereof.
4. Challenge for Institutional Review Boards (IRB committees) of academic institutions: The Institutional Review
5. Boards of universities around the world should construct and share global protocols about new technology surgery: to take care of the visual implants, fill up the informed consent

in the use of these new innovations, provide mechanisms for timely and appropriate communication to users, investors, and inventors, and report the cost - benefits of these new alternatives.

6. **Marketing:** The other challenge is the distribution channels. A highly qualified medical and rehabilitation staff is required after the implantation: a team of psychological support, visual rehabilitators, and low vision experts around the world. Most importantly, family support is key for a successful visual recovery. In the case of ocular prosthesis, the personal cleaning regime requires periodic professional care. Some authors have proposed the three phase model according to the discharge associated with prosthetic eye wear. In the initial period, the freshly polished prosthesis set the homeostasis in the first phase as surface deposits are removed is more comfortable and safer. However, you can make an increased likelihood of harm when continued wear, that's the reason to think in recovers such as nanofilms or new biopolymer can reduce the deposits another way is the traditional surface polish. There is not too much published literature about maintenance care of visual prosthesis, electrodes and microarrays.

The new research for eye surgery is focused on the development of artificial organs, ocular prosthesis, and the inclusion of new biomaterials as graphene or nanocoatings against biofilm and microorganisms. This creates digitalized prototypes and is customized for each patient, using new technology and working with 3D printing organs. Some advancements have been developed in the United Kingdom, in partnership with Fripp Design and Research and Manchester Metropolitan University, using the Spectrum Z-Corp 510 3D printer. The main reason for inclusion of graphene as an ocular biomaterial is because this material serves as a photovoltaic semiconductor, which is unlike the metal or silicon-based materials used until now for such biotechnological interfaces. The graphene is soft, light, flexible and highly biocompatible. Naturally, new biomaterials and neuro-implants is the challenge for visual care for sensitivity to visible light. It uses photovoltaic material and does not require an external electrical source to function.

Nomenclature

AK: Astigmatic Keratoplasty

ALK: Automated lamellar keratomileusis

BANG: Bits, Atoms, Neurons, and Genes.

CK: Conductive keratoplasty

GNR: Genetics, Nanotechnology and Robotics.

GRIN: Genetic, Robotic, Information, and Nanotechnology.

ICR: Intracorneal rings.

LRI: Limbal relaxing keratoplasty

LTK: Laser thermal keratoplasty

NBIC: Nanotechnology, Biotechnology, Information technology and Cognitive science.

OOKP: Osteo-Odonto-Keratoprosthesis

LASEK: Laser assisted subepithelial keratomileusis

OCT: Optical Coherence Tomography

PIONEER: Prospective Intraoperative and Perioperative Ophthalmic Imaging With Optical Coherence Tomography

SEB: scleral expansion bands

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References

- [1] Durán, P. Are nanotechnology and robotics alternatives for therapeutic and theragnostic ophthalmic applications technologies for eye care services. *Journal of ocular diseases and therapeutics*. Savvy Science. Pg 24 – 32. DOI: <http://dx.doi.org/10.12974/2309-6136.2013.01.01.6> Download at: <http://savvysciencepublisher.com/downloads/jodtv1n1a6/>.
- [2] Bainoa, F. Pereroa, F., Ferrarisa, S., Miola, M. Balagnaa, C., Vernéa, E. Chiara Vitale-Brovaronea, Coggiolac, A. Dolcinoc, D., Ferrarisa, M. Biomaterials for orbital implants and ocular prostheses: Overview and future prospects. *Acta Biomaterialia*. Volume 10, Issue 3, March 2014, Pages 1064–1087. <http://dx.doi.org/10.1016/j.actbio.2013.12.014>.

- [3] Scopus database. Elsevier. Analyzer. Consult date. January 2015.
- [4] Zhang Q., Su Q., Chan-Park M.B. et al. Development of high refractive ZnS/PVP/PDMAA hydrogel nanocomposites for artificial cornea implants. *Acta Biomaterialia* 10 (2014) 1167–1176.
- [5] Romppainen, T.; Bachmann, L. M.; Kaufmann, C.; Kniestedt, C.; Mrochen, M.; Thiel, M. A. (1 December 2007). "Effect of Riboflavin-UVA Induced Collagen Cross-linking on Intraocular Pressure Measurement". *Investigative Ophthalmology & Visual Science*. pp. 5494–5498. doi:10.1167/iovs.06-1479.
- [6] Pine, K., Sloan, B., Jacobs, R. A proposed model of the response of the anophthalmic socket to prosthetic eyewear and its application to the management of mucoid discharge. Department of Optometry and Vision Science, New Zealand National Eye Centre, The University of Auckland, New Zealand. *Medical Hypotheses* - August 2013 (Vol. 81, Issue 2, Pages 300-305, DOI: 10.1016/j.mehy.2013.04.024).
- [7] Shetty, R. D'Souza, S. et al. Decision making nomogram for intrastromal corneal ring segments in keratoconus. *Indian J Ophthalmol* 2014. Jan 4; 62(1): 23–28. doi: 10.4103/0301-4738.126170.
- [8] Gortzak, R., Willem Jan. et al. Advanced personalized nomogram for myopic laser surgery: First 100 eyes. http://www.retina.nl/downloads/jaarcijfers_november_2008.pdf. Consulted on January 5 2014.
- [9] IBRA Software. <https://www.zubisoft.com/http/overview.php>. Consulted on January 5 2014.
- [10] Güell J., Arrada O. Intracorneal Inlays – Special Focus on the Raindrop Ophthalmic Review, 2014;7(2):123–30 <http://www.touchophthalmology.com/articles/intracorneal-inlays-special-focus-raindrop-0>. Consulted January 2015.
- [11] Presbia Flexivue Microlens procedure. <http://presbia.com/surgery/index.php>. Consulted January 2015.
- [12] Villamarin, A., Roy, S., H. Reda et al. 3D simulation of the aqueous flow in the human eye. *Medical Engineering & Physics* 34 (2012) 1462– 1470. DOI: <http://dx.doi.org/10.1016/j.medengphy.2012.02.007>.
- [13] Kiang Ch., Sundaraja, K., Sulaiman, N. Virtual reality simulator for phacoemulsification cataract surgery education and training. *Procedia Computer Science* 18 (2013) 742 – 748.
- [14] Agarwal A, Jacob S, Kumar DA, Narasimhan S. Handshake technique for glued intrascleral haptic fixation of a posterior chamber intraocular lens. *J Cataract Refract Surg*. 2013; 39:3:317-22: http://www.reviewofophthalmology.com/content/d/technology_update/c/49801/#sthash.qGdheAxS.dpuf

- [15] Artopoulou, I. Montgomery, P. Wesley, JP. Lemon, J. Digital imaging in the fabrication of ocular prostheses *The Journal of Prosthetic Dentistry, Volume 95, Issue 4, April 2006, Pages 327-330*. <http://dx.doi.org/10.1016/j.prosdent.2006.01.018>.
- [16] Conesse, M. Bioprinting: A further step to effective regenerative medicine and Tissue Engineering. <http://omicsgroup.org/journals/bioprinting-a-further-step-to-effective-regenerative-medicine-and-tissue-engineering-2169-0111.1000e112.pdf>. Consulted January 2015.
- [17] Bengonzo P. Diamond to Retina Artificial Micro-Interface Structures. In France 2010; pp. 1-10. Available on <http://cordis.europa.eu/documents/documentlibrary/123542961EN6.pdf>. (Accessed March 2013).
- [18] Bhisitkul RB, Keller CG. Development of Microelectromechanical Systems (MEMS) forceps for intraocular surgery. *Br J Ophthalmol* 2005; 89 (12): 1586-8. <http://dx.doi.org/10.1136/bjo.2005.075853>.
- [19] Da Cruz L, Coley BF, Dorn J, Merlini F, Filley E, Christopher P, et al. The Argus II epiretinal prosthesis system allows letter and word reading and long-term function in patients with profound vision loss. *Br. J Ophthalmol* 2013;97(5): 632- 6. <http://dx.doi.org/10.1136/bjophthalmol-2012-301525>.
- [20] Durán, P. Cáceres, M. Plaza, J. A Review in Innovation in Ocular Prostheses and Visual Implants: New Biomaterials and Neuro-Implants is the Challenge for the Visual Care. *Journal of ocular diseases and therapeutics*. DOI:0020 <http://dx.doi.org/10.12974/2309-6136.2014.02.01.3> Download at <http://savvysciencepublisher.com/downloads/jodtv2n1a3/>.
- [21] Cordeiro-Barbosa Francisco de Assis, Aguiar José Lamartine de Andrade, Lira Mariana Montenegro de Melo, Pontes Filho Nicodemos Teles de, Bernardino-Araújo Sidcley. Use of a gel biopolymer for the treatment of eviscerated eyes: experimental model in rabbits. *Arq. Bras. Oftalmol.* [serial on the Internet]. 2012. Aug [cited 2013 Dec 26] ; 75(4): 267-272. Available from: <http://dx.doi.org/10.1590/S0004-27492012000400010>
- [22] Chen J, Patil S, Seal S, McGinnis JF. Rare earth nanoparticles prevent retinal degeneration induced by intracellular peroxides. *Nature Nanotechnology*. 2006 Nov;1(2): 142-50.
- [23] Chow, A.Y. Chow, V.Y. Artificial retina device with stimulating and ground return electrodes disposed on opposite sides of the neuroretina and method of attachment. <https://www.google.de/patents/US8306626>. 2012.
- [24] Ehlers JP, Tao YK, Farsiu S, Maldonado R, Izatt JA, Toth CA. Integration of a spectral domain optical coherence tomography system into a surgical microscope for intraoperative imaging. *Invest Ophthalmol Vis Sci*. 2011 May 16;52(6):3153-9. doi: 10.1167/iops.10-6720.

- [25] Ehlers, J. Dupps, W. et al. The Prospective Intraoperative and Perioperative Ophthalmic Imaging with Optical Coherence Tomography (PIONEER) Study: 2-Year Results. *Am J Ophthalmol.* 2014 Nov;158(5):999-1007. doi: 10.1016/j.ajo.2014.07.034. Epub 2014 Jul 29.
- [26] Tao YK, Srivastava SK, Ehlers JP. Microscope-integrated intraoperative OCT with electrically tunable focus and heads-up display for imaging of ophthalmic surgical maneuvers. *Biomed Opt Express* 2014; 5(6):1877–1885. doi: 10.1364/BOE.5.001877

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