Today artificial eyes are constructed using two components. The first is the orbital implant, which is placed at the time of enucleation or evisceration and fills the anophthalmic socket and replaces the lost volume of the natural eye. The second component of the modern artificial eye is the ocular prosthesis, which is what makes the artificial eye appear life-like with iris color and conjunctival vessel markings. It is placed 6-8 weeks after enucleation/evisceration and can be custom-made on an individual patient basis. It is inserted anterior to the orbital implant, just behind the eyelids. A variant of the ocular prosthesis is a very thin hard shell known as a scleral shell which can be worn over a damaged or eviscerated eye. Ocular prosthesis roughly takes the shape of a convex shell and is made of medical grade plastic acrylic. A few ocular prostheses today are made of cryolite glass Ocular prostheses are usually not fabricated for 6-8 weeks following enucleation or evisceration to allow for healing of the socket. During this time, a temporary acrylic conformer is worn to keep the fornices formed and to prevent socket contracture. An ocular prosthesis does not provide vision; this would be a visual prosthesis. Here we will mainly discuss the ocular prosthesis.

The ocular content removing surgeries are mainly enucleation, evisceration and exenteration. The enucleation removes the eyeball by severing the muscles, which are connected to the sclera. The surgeon then cuts the optic nerve and removes the eye from the socket. An implant is then placed into the socket to restore lost volume and to give the artificial eye some movement, and the wound is then closed. Dating back thousands of years, there is evidence that the Egyptians and Sumerians were making artificial eyes and performing enucleations. It was not until the 1500s that enucleations were reported in the medical literature.

With evisceration, the contents of the eyeball are removed. Noyes first reported evisceration of the ocular contents in 1874. In this operation, the surgeon makes an incision around the iris and then removes the contents of the eyeball. A ball made of some inert material such as plastic, glass, or silicone is then placed inside the eyeball, and the wound is closed. At the conclusion of the surgery, the surgeon will place a conformer (a plastic disc) into the socket. The conformer prevents shrinking of the socket and retains adequate pockets for the prosthesis. Conformers are made out of silicone or hard plastic. Orbital exenteration is quite a disfiguring and destructive procedure it implies the removal of the orbital contents including the periorbita and eyelids but when possible, orbital tissue is conserved and eyelid skin and orbicularis muscle are spared. Exenteration surgery is necessary when orbital and periorbital tumors, and occasionally other conditions, that are potentially fatal.

Figure 1: Ocular prosthesis
or relentlessly progressive cannot be treated more effectively in other ways. Cosmetic rehabilitation with reconstructive surgical procedures may not be always possible. Cosmetic rehabilitation with occlusofacial prosthesis and appropriate retentive aids is a good option in these cases.

Various types implants are also used for orbital fracture repair. These fractures are the result of energy transmitted in the form of pressure or through direct mechanical stress to the orbital walls. Therefore, the decision to operate and the timing for surgery rely on clinical and radio-graphical evidence. Approaches to the repair fractures include transconjunctival, subciliary, mid-lower eyelid, infraorbital and, more recently, endoscopic transanal approaches.

History and evolution of ocular prosthesis

Early artificial (Figure 1) eye makers may not have been creating prostheses at all, but rather decorations for religious and aesthetic purposes. In the millennia B.C. the people of Babylon, Jericho, Egypt, China, and the Aegean area all had highly developed arts and beliefs in the afterlife. Radiographs of mummies and tombs have revealed numerous artificial eyes made of silver, gold, rock crystal, lapis lazuli, shell, marble, enamel, or glass. The Aztec and Inca also used artificial eyes for similar reasons. The earliest known evidence of the use of ocular prosthesis is that of a woman found in Shahrl Sokhta, Iran dating back to 2900-2800 BCE. It has a hemispherical form and a diameter of just over 2.5 cm (1 inch). It consists of very light material, probably bitumen paste. The surface of the artificial eye is covered with a thin layer of gold, engraved with a central circle (representing the iris) and gold lines patterned like sun rays. On both sides of the eye are drilled tiny holes, through which a golden thread could hold the eyeball in place. Since microscopic research has shown that the eye socket showed clear imprints of the golden thread, the eyeball must have been worn during her lifetime. In addition to this, an early Hebrew text references a woman who wore an artificial eye made of gold (Yer. Ned. 41c; comp. Yer. Sanh. 13c). Roman and Egyptian priests are known to have produced artificial eyes as early as the fifth century BCE constructed from painted clay attached to cloth and worn outside the socket.

The skill of the Egyptian artists was so great that they were probably asked to create artificial eyes for human use, especially if the afflicted were royalty. The first insocket artificial eyes were made of gold with coloured enamel, later evolving into the use of glass (thus the name “glass eye”) by the Venetians. Ambrose Paré (1510-1590), a famous French surgeon, was the first to describe the use of artificial eyes to fit an eye socket. These pieces were made of gold and silver, and two types can be distinguished: ekblephara and hypoblephara, intended to be worn in front of or under the eyelids, respectively. A hypoblephara eye was designed to be used above an atrophic eye, as enucleation was not a common practice until the middle of the 1800s. In 1579, the Venetians invented the first prosthesis to be worn behind the eyelids. These artificial eyes were very thin shells of glass, and therefore, did not restore the lost volume of an atrophied or missing eyeball. Because the edges were sharp and uncomfortable, the wearers had to remove the eyes at night in order to get relief from discomfort and to avoid breakage. After the invention of this glass shell prosthesis, there were no significant advances in artificial eyes until the nineteenth century.

As with most things that evolved over time, it is difficult to trace the inventor of the artificial glass eye, but William Shakespeare (1564-1616) knew of its existence: Get three glass eyes; And, like a scurvy politician, seem to see the things thou dost not. (King Lear to the Earl of Gloucester, Act IV, Scene 6).

Enamel prostheses (1820s-1890s) were attractive but were expensive and not very durable. In the early 1800s, The introduction of cryolite glass, made of arsenic oxide and cryolite from sodiumfluoride (Na6A2F12),produced a greyish white colour suitable for a prosthetic eye. German craftsmen are credited with this invention. To make these glass eyes, a tube of glass was heated on one end until the form of a ball was obtained. Various colours of glass were used like paintbrushes to imitate the natural colour of the eye. A German glassblower by the name of Ludwig Muller Uri, who made lifelike eyes for dolls, developed a glass eye for his son. Though it took 20 years to perfect his design, his success forced him to switch occupations to making artificial eyes fulltime.

In 1880, Dutch eye surgeon Hermann Snellen developed the Reform eye design. This design was thicker, hollow glass prosthesis with rounded edges. The increase in thickness restored most of the lost volume of the eye and the rounded edges gave the patient much more comfort. Germany became the centre for manufacturing glass artificial eyes. Several years later in 1884, a glass sphere was implanted for the first time in the scleral cavity (the hollowed out interior of the white of the eyeball) after enucleation to restore lost volume and to give the prosthesis some movement. The sphere implant was subsequently adapted for the enucleated socket as well.

During World War II, the glass eyes from Germany were unavailable, and therefore, the United States had to find an alternate material. In 1943, the U.S. Army dental technicians made the first plastic (acrylic) artificial eye. This material had the advantage of being unbreakable as well as malleable. Though these plastic prosthesis were impression fitted, the back surface was not completely polished, leading to irritation of the eye socket due to a poor fit. An alternative was introduced by German American glass blowers who were learning to make artificial eyes out of plastic using the Reform design. Though this type of artificial
eye was an improvement, there were still problems with a persistent discharge of mucus from the eye socket. The wearers could sleep with the prosthesis in place, but were required to remove it every morning for cleaning. Despite these limitations, demand outpaced what the oculists could handle, and therefore, a few large optical companies began mass producing the 12 most commonly used glass eye shapes. Called stock eyes, they have the disadvantage of not being properly fitted to the individual’s eye socket.

In the late 1960s the modified impression method was developed by American Lee Allen. This method included accurately duplicating the shape of the individual socket, as well as modifying the front surface of the prosthesis to correct eyelid problems. The back surface of the prosthesis must also be properly polished for an optimum fit. This method is widely used today.

Use and evolution orbital implant and material

An English doctor, Phillip Henry Mules, used the implant to restore lost volume and to give the prosthesis some movement. The sphere implant was subsequently adapted for the enucleated socket as well. Many materials such as bone, sponge, fat, and precious metals have been used for implants since then, but 100 years later, the Mules sphere is still used in the majority of cases. Eye sockets with spheres within the scleral cavity following evisceration continue to result in excellent cosmetic results.

The first account of placing an implant in the socket, following enucleation, was in 1841. In 1885, Mules was the first physician to report the use of an orbital implant, a glass sphere, after an enucleation. Implants have been made of many different materials, shapes, and types throughout the years. Implant Types magnets, gold, silver, glass, silicone, cartilage, bone, fat, cork, titanium mesh, acrylics, wool, rubber, catgut, peat, agar, polyethylene, hydroxyapatite.

There are many different types of implants, classification ranging from shape (Spherical vs egg (oval) shaped), stock vs custom, porous vs nonporous, specific chemical makeup, and the presence of a peg or motility post. The most basic simplification can be to divide implant types into two main groups: nonintegrated (non—porous) and integrated (porous).

Nonintegrated implants

Nonintegrated implants contain no unique apparatus for attachments to the extraocular muscles and do not allow ingrowth of organic tissue into their inorganic substance. Such implants have no direct attachment to the ocular prosthesis. Usually, these implants are covered with a material that permits fixation of the extraocular recti muscles, such as donor sclera or polyester gauze which improves implant motility, but does not allow for direct mechanical coupling between the implant and the artificial eye. Nonintegrated implants include the acrylic (PMMA), glass, and silicone spheres. PMMA is a transparent thermoplastic, has a good degree of compatibility with human tissue, much more so than glass. Although various materials have been used to make nonintegrated implants in the past, polymethyl methacrylate (PMMA) is one of the implants of choice.

Integrated implants

The porous nature of integrated implants allows fibrovascular ingrowth throughout the implant and thus also insertion of pegs or posts. Because of direct mechanical coupling it improve artificial eye motility. Attempts have been made to develop so called ‘integrated implants’ that are directly connected to the artificial eye. Historically, implants that directly attached to the prosthesis were unsuccessful because of chronic inflammation or infection arising from the exposed nonporous implant material. Then came quasi-integrated implants with a specially designed anterior surface that allegedly better transferred implant motility to the artificial eye through the closed conjunctiva and Tenon’s capsule. Porous enucleation implants currently are fabricated from a variety of materials including natural and synthetic.

Hydroxyapatite (Figure 2a)

In 1985 Dr. Arthur Perry (San Diego, CA) began to study sea coral as an ocular implant. Hydroxyapatite implants are spherical and made in a variety of sizes and different materials (Coralline/Synthetic/ Chinese). In 1989 implant made from hydroxyapatite received Food and Drug Administration approval. This material allows fibrovascular ingrowth throughout the implant and permits insertion of a coupling device (PEG) with reduced risk of inflammation or infection associated with earlier types of exposed integrated implants. One main disadvantage of HA is that it needs to be covered with exogenous material, such as sclera, polyethylene terephthalate, or vicryl mesh.

Bioceramic (Figure 2b)

Bioceramic prosthetics are made of aluminium oxide (Al₂O₃). It has been used for more than 35 years in the orthopedic and dental fields. It has low friction, durability, stability, and inertness. Aluminium oxide ocular implants can be obtained in spherical and non-spherical (egg shaped) shapes and in different sizes for use in the anophthalmic socket. The bioceramic implant is available in spherical and egg shaped models for use in the anophthalmic socket. It received US Food and Drug Administration approval in April 2000. Aluminium oxide has previously been shown to be more biocompatible than HA in cell culture studies and has been suggested as the standard reference material when biocompatibility studies are required to investigate new products. The rate of exposure previously associated with the bioceramic implant less than most reports on the HA or porous polyethylene implant.
Porous Polyethylene (Figure 2 c,d)

Porous polyethylene enucleation implants have been used since at least 1989. It is available in dozens of prefabricated spherical and non-spherical shapes and in different sizes or plain blocks for individualized intraoperative customizing. It is firm but malleable and allows direct suturing of muscles. Additionally, smooth surface is less abrasive and irritating also becomes vascularized, allowing placement of a titanium motility post that joins the implant to the prosthesis. The PP implant does not require to be covered. Newer porous polyethylene orbital Implants are Conical orbital implant (COI) and multipurpose conical orbital implant (MCOI). The COI has unique design elements that have been incorporated into an overall conical shape, including a flat anterior surface, superior projection and preformed channels for the rectus muscles. 50 Vicryl suture needles can be passed with slight difficulty straight through the implant to be tied on the anterior surface. In addition, this implant features a slightly recessed slot for the superior rectus and a protrusion to fill the superior fornix. The newest model is the multipurpose conical orbital implant, which was designed to address the issues of the postoperative anophthalmic orbit being at risk for the development of socket abnormalities including enophthalmos, retraction of the upper eyelid, deepening of the superior sulcus, backward tilt of the prosthesis, and stretching of the lower eyelid. The conical shape of the multipurpose conical porous polyethylene orbital implant (MCOI) (Porex Medical) more closely matches the anatomic shape of the orbit than a spherical implant. Allows for a more complete and natural replacement of the lost orbital volume. This shape reduces the risk of superior sulcus deformity and puts more volume within the muscle cone. Muscles can be placed at any location the surgeon desires with these implants. This is advantageous for cases of damaged or lost muscles after trauma and the remaining
Ocular Malignancies

muscles are transposed to improve postoperative motility. And in anticipation of future peg placement there is a 6 mm diameter flattened surface, which eliminates the need to shave a flat anterior surface prior to peg placement. Both implants (COI and MCOI) are composed of interconnecting channels that allow in growth of host connective tissue. Complete implant vascularization reduces the risk of infection, extrusion, and other complications associated with nonintegrated implants. And both implants produce superior motility and postoperative cosmesis.

Use and evolution oculofacial prosthesis

Oculofacial prosthesis needed after exenteration surgery. Exenteration was described by German physician Bartisch in 1583 cited by Goldberg et al1. Frezzotti et al reviewed the history of exenteration, attributed the first description to Gooch in 1767. Artificial facial parts found on Egyptian mummies long time ago. Ancient Chinese known to have made facial restoration. Polymethyl methacrylate and silicon most commonly used materials for oculofacial prosthesis. Various methods of auxiliary retention for facial prostheses have been described2 they include eye patches (Figure 3a), prosthesis fastened to spectacle frame (Figure 3b), extensions from the denture (Figure 3c), magnets (Figure 3d), adhesives and osseointegrated implants. Modern prosthetic replacements are secured with adhesives.

Use and evolution orbital floor repair implants

As such, there exists a great deal of literature evaluating reconstruction of this region, describing orbital fracture repair with a considerable variety of materials that are autogenic, allogenic or alloplastic in nature.
Evolution: Ocular Implants and Prosthesis

**Biologic Materials**

**Autografts**

Autografts were the first major class of materials used in the reconstruction of orbital floor defects. Commonly used autologous materials are bone and cartilage. In 1908, Mauclaire first described the use of the iliac bone graft for calvarial reconstruction. Kappis and Ballin later used rib grafts. These continued as popular grafts for most of the 20th century, until Marchac and Tessier introduced the use of both full and split thickness calvarial bone grafts for orbital fracture reconstruction. For decades, bone grafting donor sites have grown to encompass the ilium, rib, antral bone, mandible, maxilla, and calvarium. Autologous bone grafts remain the “gold standard” for orbital floor reconstruction. They provide rigidity and molding capacity, vascularity, biocompatibility, and minimal immune reactivity. Autologous cartilage grafts have a favorable application in orbital floor reconstruction owing to ease of access, malleability, and reliable support without evidence of resorption. They are still used for small orbital floor fractures.

**Allografts**

The allogenic materials that have been used are human dura mater, lyophilized cartilage, banked bone, fascia lata and heterogenic bovine bone graft. Lyophilized dura mater, obtained in 1 of 3 forms: human, animal, or alloplastic. Eventually, they are replaced with endogenous collagenous connective tissue. Allografts are associated with an increased risk of disease transmission from donor to patient. The use of demineralized human bone (DHB) implants remains unsettled. Demineralized human bones are available as biocompatible resorbable sheets.

**Xenografts**

In the late 1980s, Webster proposed the use of lyophilized porcine dermis. He found this material to be suitable for orbital floor repair. This has recently been supported by Morax et al in a series of 20 patients. Material was found to be safe with no evidence of biologic incompatibility, inflammation, or infection. A more commonly applied xenograft is an absorbable gelatin film (Gelfilm). It is manufactured from denatured porcine collagen. It is available in a thickness of 0.075 mm. Resorption occurs within 2 to 3 months after implantation. Gelfilm is appropriate for small linear fractures less than 5 mm.

**Manufactured Materials (Resorbable and Nonresorbable)**

**Absorbable**

Absorbable polymers have been widely used for more than 30 years in many fields of surgical practice. In the 1990s,
these materials were introduced to craniomaxillofacial surgery. They offer more control and predictable absorption kinetics than those of biologic grafts. In addition, such polymers can be easily tailored to obtain an implant of the desired size and shape. The use of resorbable materials spares operative time and allows for primary reconstruction while avoiding potential donor-site morbidity. Absorbable polymer implants do not necessarily require rigid fixation. They may be applied in large quantities for large volume displacement of orbital content. Theoretically, the role of resorbable materials is to provide temporary support.

Gelatin film: Gelatin film is manufactured from denatured collagen. In an animal model compared with silicone sheets for orbital repair. It demonstrated decreased implant migration, less inflammatory response and improved healing compared with silicone sheets.

Polyglycolic acid: Biodegradable polyglycolic acid (PGA) is another option as an implant material. This implants should not be used for larger defects.

Polydioxanone: Polydioxanone is a synthetic biodegradable polymer. It is currently used as suture material that resorbs approximately six months following implantation.

Nonresorbable

As an alloplastic Titanium (Figure 4a) material for orbital floor repair began in the early 1990s. It has been used for the repair of large orbital floor defects and correction of globe malposition. The process of shaping and cutting this material very challenging. Advantages of titanium mesh plates include availability, bio-compatibility, ease of intraoperative contouring, and rigid fixation. Irregular edges of the mesh may catch prolapsed orbital fat. Placement of the mesh deep within the orbital cone is relatively difficult. Custom-made titanium implants using computer-assisted designs have enabled surgeons to achieve optimal reconstruction in areas of limited visibility and protection of vital structures. Porous polyethylene is available in sheets of various sizes and thicknesses (0.4Y1.5 mm). Open pore structure allows vascularity along with soft tissue and bony ingrowth. Interconnected, omni-directional pore structure promotes native tissue in-growth for enhanced biocompatibility. Implants may be contoured with surgical scissors in the sterile field to fit the individual needs of each patient. Barrier™ surface option present to prevent tissue in-growth when desired. Medpor Titan (Figure 4b) implants with embedded titanium mesh are available providing strength, shape retention when bent, and flexibility for various surgical procedures. In the early 1970s, Hench et al discovered that certain glass compositions bond chemically to bone. Bioactive glass is a synthetic material available as large blocks or small granules. This material is osteoconductive, bacteriostatic, and rigid. It allows their use for repairing orbital floor fractures. Rigid fixation is not required. Lipshutz and Ardizone in 1963, introduced silicone sheets to orbital floor fractures repair. It is a polymer of variable chain length, cross-linked by glucose molecules. Other materials like Nylon, Teflon, Seprafilm are also introduced for fracture repair.

Advances

Improvements will continue in the ocular prosthesis, several developments have already occurred in recent years.

Artificial prosthesis and pupil

All efforts and investments to improve the appearance of artificial eye are neutralized by the immobility of the pupil. A prosthesis with two different size pupils which can be changed back and forth by the wearer was invented in the early 1980s. In the same period, a soft contact lens with a large black pupil was developed that simply lays on the cornea of the artificial eye. One solution to this problem has been demonstrated recently. There is a requirement in ophthalmology for a prosthetic iris that is self accommodating, to improve the quality of life of patients who have lost an eye. To addresses this need by exploring a solution on the basis of the LC displays. The proposed solution is to use a small LCD, positioned over an iris image, in which ring shaped pixels will appear black or transparent depending on the ambient light, to simulate the dynamic pupil3.
Cosmetic prostheses as an alternative to clear conformers

Early cosmetic improvement seems to be important in the emotional rehabilitation of the patient following the loss of an eye. Ocular prostheses are usually not fabricated for 6-8 weeks following enucleation or evisceration to allow for healing of the socket. During this time, a temporary acrylic conformer is worn to keep the fornices formed and to prevent socket contracture. Standard conformers are clear and do not resemble a natural eye, in addition, they are often too large or too small. There are so-called cosmetic conformers available that come in a variety of sizes, iris colors, and scleral colors\textsuperscript{4,5}.

Future

Ongoing research going to make artificial eye that can provide sight as well. Though it may take several more years before prosthesis will both look and see just like a natural eye. There are researches going on for developing an artificial eye that will be connected either to the optical nerve or directly to the visual cortex. This eye consists of a rubbery lens that can change focus, a high precision colour processing system, and microscopic photoreceptors that sense the presence of objects and pick up motion.

Reference