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Osteo-Odonto keratoprosthesis: Tooth for an Eye

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Abstract
Face is the mirror of the mind and the eyes serves as a window to the soul. The sensory system is accountable for providing information to the brain regarding where the body appears in reference to the horizon. Poor vision may lead to loss of balance. Corneal disease is the second most common cause of blindness in the world and occurs in association with a severely damaged corneal and ocular surface. Osteo-Odonto Keratoprosthesis (OOKP) is a surgical procedure to restore vision where the diseased cornea is replaced with an artificial cornea. OOKP consists of autologous tissue derived from tooth and bone that surrounds a central PMMA Optic (Poly Methyl Methacrylate). This review discusses the types, parts, indications, contraindications, surgical techniques and complications of Osteo-Odonto Keratoprosthesis.

Keywords: Osteo-odonto keratoprosthesis, poly methyl methacrylate optic, boston keratoprosthesis

1. Introduction
The eye may be a little part of the proprioception system-the balance system of the body. The most grievous yet, unfortunately, the most commonly occurring loss out of all sensory organs is that of an eye, hence, not until one of them is partially or totally lost, its real value is never fully obliged. Such an adversity may have a prodigious emotional and psychological impact on the patient with loss of function [1].

OOKP procedure includes removal of a tooth from the patient or a donor. After removal, a lamina of tissue cut from the tooth is drilled and the hole is fitted with optics. The lamina is grown in the patient's cheek for a period of 4 months and then is implanted upon the eye. The procedure was pioneered by the Italian Ophthalmic operating surgeon Prof Benedetto Strampelli in the early 1960's. Before Implantation, the osteodental skirt is pre-implanted into the buccal mucosa to allow colonization of fibroblasts to support integration when implanted ocularly. It is one of the most successful Keratoprosthesis as it has a low extrusion rate, due to the excellent integration of the skirt material (Mostly Hydroxyapatite) with the host tissue (Mehta *et al* 2005) [2]. Keratoprosthesis is a surgical operation where an unhealthy membrane is replaced with a synthetic membrane. It is recommended after a person has had a failure of one or more donor corneal transplant. While conventional cornea transplant uses donor tissue for transplant, an artificial cornea is used only in the keratoprosthesis procedure. The surgery is performed to restore vision in patients suffering from severely damaged cornea due to congenital birth defects, infections, injuries and burns. Keratoprosthesis are made of clear plastic with excellent tissue tolerance and optical properties [3].

History
1789 - Pellier de quengsy – Glass lens in silver ring for leukomatous cornea.
1853 - Nussbaum-Collar-Stud glass device consisting of **2** plates sandwiching the cornea and connected by an optical cylinder, 2 with trials in rabbit eyes
1859 - Heusser- First to implant a keratoprosthesis in a human eye; this was retained for three months. Other attempts made in later half of 19th century (Von Hippel 1877, Dimmer 1889, Baker 1889, Van Milliangan 1895, Salzer 1895) but almost all the implants failed and were extruded. The interest in keratoprosthesis declined following the development of successful

Penetrating keratoplasty (PKP) in the first decade of the 20th century.
(The realization that transplanting a human cornea would not be successful in all cases of corneal blindness).
During the Second World War, the incidental discovery of corneal tissue tolerance to plexi-glass fragments from aeroplane canopies suggested a new direction for future research [4].

Types of Keratoprosthesis Include
Boston Keratoprosthesis
Osteo-Odonto Keratoprosthesis
Alpha Cor and Keraklear artificial cornea

Parts of Keratoprosthesis (Boston)

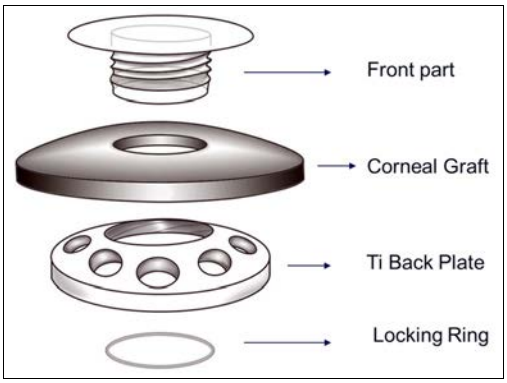


Fig 1: Collar button design

Front plate and Back plate sandwiching a fresh donor site
Titanium locking device is used to secure front and back plates (8.5mm)
Back plate wholes are important to improve corneal nutrition [5]

Principle behind Osteo-Odonto Kertoprosthesis
The osteo-odonto keratoprosthesis (OOKP), like the Boston type 2 Keratoprosthesis, is primarily used for patients with severe dry eye. The concept of the OOKP derived from earlier research shows that, the integration is maximized while immune reactions are minimized through the use of the patient's own tissue, including cartilage, and tibial bone [6]. The basic—ingenious—principle of OOKP is the use of a single rooted tooth and surrounding intact alveolar bone to fashion a plate as a carrier for a PMMA optical cylinder. The optical cylinder is cemented to the dentine, the central part of this ''picture-frame'' OOKP lamina. The dentine itself is coupled to the alveolar bone by the dentoalveolar ligament. The OOKP lamina is fixed by surrounding periosteum to the anterior corneal and scleral surface with sutures but is also covered and thereby protected by a thick buccal mucous membrane graft, which also serves to supply the living bone with nutrients. Therefore, the biologic ''behaviour'' of the implant is quite similar to that of a dental implant [7].

Ideal keratoprosthesis
Device should be able to surpass the natural cornea by having an improved optical quality, with decreased aberrations and a specifiable power. It should have excellent bio integration and should provide resistance against infection and last the life-time of the patient. It should replicate some of the qualities of the cornea such as drug penetration and allowing intraocular pressure measurement [8].

Guidelines for OOKP surgery
Indications
Patients with bilateral tissue layer visual defect ensuing from severe end-stage Stevens-Johnson syndrome, ocular cicatrical pemphigoid, chemical burns, trachoma, dry eyes or multiple transplantation failure [7].

Indications for Type 1 Keratoprosthesis
With improved outcomes, the indications for Type 1 Keratoprosthesis have been expanding over the past decade. However, it is best to categorize these based on prognostic hierarchy since eyes with guarded prognosis have an increased risk to develop complications.

Good prognosis
1. Multiple failed grafts
2. Aniridia
3. Herpetic keratitis
4. Silicon oil-filled eyes.

Guarded prognosis
1. Pediatric corneal conditions
2. Chemical injuries.

Very guarded prognosis
1. Underlying immune conditions such as Stevens–Johnson syndrome (SJS)/ocular cicatricial pemphigoid (OCP)
2. Severe chemical injuries with severe forniceal shortening and lid abnormalities.

Indications for Type 2 keratoprosthesis
Based on the long-term anatomical and functional outcomes, the choice of keratoprosthesis in severe end-stage ocular surface disorders is preferably the MOOKP (Modified OOKP). In case of the patient being unsuitable for the same, the other Type 2 keratoprosthesis are chosen for the following:
1. Stevens-Johnson Syndrome
2. OCP/mucous membrane pemphigoid
3. Severe chemical injuries
4. Severely keratinized surface [9]

Relative contraindications
Mentally unstable patients (may be boggled or confused by the surgery)
Unreasonable expectation of outcome and cosmesis
Unable to commit to life-long follow-up
Defective light perception (which may signify late stage Glaucoma) etc.
Children under the age of 17 years
Irreparable retinal detachment should be excluded [10].

Pre-operative examination
Multidisciplinary approach is required and patient has to be scrutinized by the team of ophthalmologist, oral surgeons and radiologist who form a surgical team. The evaluation should include the detailed history and aetiology for loss of vision.
The conjunctiva and cornea are examined and evidence of stem cell failure, metaplasia or dysplasia is noted. Thinning of the cornea and evidence of previous corneal perforation, iris adhesion and degree of vascularization should be noted. If visible, the depth of the anterior chamber is noted. The intraocular pressure is determined digitally and a record is made as to whether the eye is phakic, pseudophakic or aphakic. A scan ultra-biometry and B scan ultrasonography

are used to measure the axial length, exclude pre-phthisis, confirming the lens status, exclusion of retinal detachment and with detection of gross glaucomatous cupping. Pre-operative examination should involve an assessment of the general medical and psychological status of the patient. The patient should be absolutely familiar of the procedures and risks. Tear production can be measured with Schirmer testing and goblet cell and meibomian gland function evaluated to assess all three layers of the tear film.

Limbal stem cell function is critical and often compromised in patients with Steven-Johnson syndrome, Aniridia, Chemical burns and ocular cicatricial pemphigoid [11].

Oral Assessment

The buccal mucosal graft donor site and a selection of an appropriate tooth to form a dentin/bone lamina should be assessed [12].

Dental Assessment

The procedure involves obtaining a tooth and its associated alveolar bone for making a "Lamina". An healthy tooth (Root) with the simplest form and size usually the canines (upper/lower canine) with required amount of covering alveolar bone is selected. The surrounding anatomy is assessed to avoid possible complications and to reduce the cosmetic effect to a minimum. Adequate space needed between the teeth to harvest the tooth without damage to its neighbour.

The overall oral health with particular reference to oral hygiene and periodontal bone loss must be assessed (Gingival disease with no bone loss can be easily reversed)

Clinical assessment of bone loss can be useful but radiographs are essential [13]

Tooth

Tooth assessment depends on clinical examination but mainly on radiological assessment using Orthopantomograph (OPG), intra-oral peri-apical radiographs (IOPAR) and CT scans. In the absence of a canine single-rooted teeth can be used.

The choice of upper or lower canine depends on the proximity of the maxillary sinus in the upper and the proximity of the mental foramen in the lower. The lower canine harvesting is straight forwarded but the buccal plate is occasionally a little thin and the lingual muco-periosteum is more difficult to preserve. The upper canine occasionally gives too much bone palatally and there is the risk of violation of the antrum but technically the harvesting is easier. The patient must be given full information at this stage to give adequate consent. The patient's regular dental practitioner should be informed at this stage so that preparation to replace the missing tooth may be made; also the oral hygiene and periodontal condition can be optimized pre-operatively [14].

Buccal mucosa assessment

OOKP due to muco-cutaneous disease, the oral mucosa may be damaged. The extent of damage has never been such to affect the harvesting of a graft, but this must be borne in mind and severe scarring of the oral membrane could compromise the triple-crown harvest. Smokers and betel nut chewers interfere in the chance of graft revascularization. Compromising the tissue quality. Hence they should be advised to stop smoking and improve their dental cleanliness and oral health. For edentulous patients, related or unrelated tooth donors may be considered and screened as required [8]. OOKP patients are observed to be presenting with damaged mucosa. The extent of damage has never been such to affect the harvesting of a graft [14].

Psychological assessment

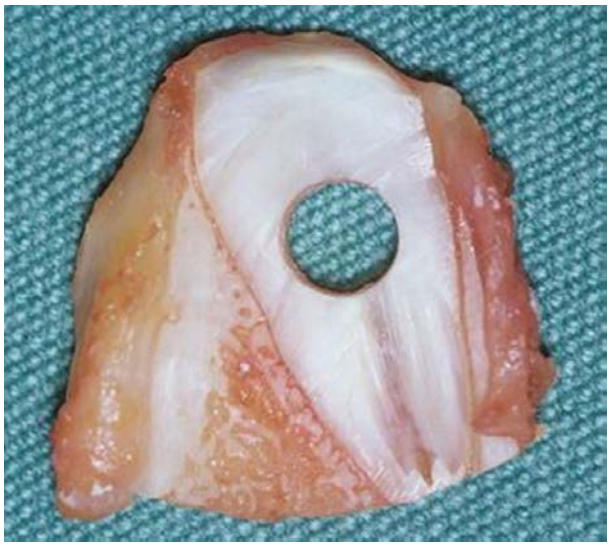
Patients are thoroughly investigated for their psychological and general health by the multidisciplinary team. Patients are educated about the OOPK surgery and provided with printed leaflets. Surgery is generally offered to patients with bilateral poor vision. The eye with an honest visual potential is sometimes chosen. Subsequent visits are planned to help the patients to arrive at a decision. The family members, patient carer's and tooth donors are also consulted. Once a decision is made for the surgery, they are referred to the anaesthetist for assessment. Patients have to understand that they may require multiple procedures and that there is significant risk of serious complications including loss of eye. Patient must commit to lifelong follow-up and not have unreasonable expectations of outcome and cosmesis [12].

Surgical procedure

Stage 1

Full thickness Mucous Membrane graft is harvested from the buccal mucosa. Graft is sutured over damaged cornea at insertion of 4 recti muscles and sclera in four quadrants with 3-o vicryl suture material. The extent of graft should be extended from upper to lower fornix and measures around 3-4 cm in diameter. It has stem cells, high proliferating capacity and adapted to high bacterial load.

Followed by preparation of the osteodental acrylic lamina (ODAL). A single firm tooth, preferably the upper canine is chosen for preparation of the lamina. The tooth with the surrounding alveolar bone is extracted. Then sliced sagitally and central hole is drilled. Customized PMMA optical cylinder is cemented. ODAL is then placed in the subcutaneous pouch in the orbito-zygomtic area for next 3 months to develop vascularization of connective tissue.



Stage 2

This is performed 3 months after stage 1. The graft is dissected off from the subcutaneous pouch and examined for its integrity. The central cornea is trephined according to the posterior diameter of the cylinder. The graft is placed with the cylinder centred over the corneal trephination and sutured. The mucous membrane graft is finally reflected back on the lamina with a central trephination through which the anterior cylinder protrudes out.

Complications

Complications of OOKP surgery may include oral, ocular and systemic complications if the patient is on immune suppressants. An artificial corneal device bridges the nonsterile ocular surface with the sterile anterior chamber. There is a high risk of rapid invasion of bacterial pathogens into the corneal stroma where the artificial cornea device is situated [15].

Complications during stage I

Globe perforation, Post-operatively - Lamina and Mucous membrane infection [16] Lamina resorption [17].

Complications during stage II

Vitreous Haemorrhage

Choroidal and Retinal detachment

Post-operatively – vision may be limited by a pre-existing condition such as Glaucoma or Macular disease, resorption of the lamina, fistula formation and extrusion of the optical cylinder.

Reducing the incidence of complications requires accurate surgery and meticulous follow-up. Trophic changes of the buccal membrane may occur after either stage 1 or 2 leading to erosions and this can be related to a bony spur on the optical lamina. In these cases the treatment is that the flap is lifted and any eroded bone removed with smoothing.

Covering the mucosa with alternative tissue like sclerotic coat or skin isn't adviced.

Retroprosthetic membrane formation is rare with OOKP surgery unlike other keratoprosthesis because of the removal of the iris and lens and through anterior vitrectomy. If the membrane develops it should be removed by YAG optical laser capsulotomy or via a Pars plana approach. Fong *et al*., advocate a baseline morphological assessment of the OOKP using laser beam pictogram or multidetector CT. After the OOKP has been established, the dimensions are outlined radiologically, and then regularly monitored with clinical assessment to identify cases at risk of optic extrusion and consequent endophthalmitis [18]

Buccal mucosa harvest site

The graft harvest bed is left to granulate. This usually takes place rapidly and is complete at 2 or 4 wks. Occasionally there is excess of scarring, resulting in limitation of mouth opening requiring mouth opening exercises and massage of the scar, otherwise this can easily be dealt with by incision of the scar band.

Alveolar Graft Harvest Site

The complications are due to poor healing at the site resulting in exposure of roots of adjacent teeth and damage to adjacent anatomy. The area's most at risk are the roots of adjacent teeth and maxillary sinus. The dental injury are often avoided by use of fine blades and careful technique. The damage to the maxillary sinus can be avoided by not making apical cut too high but if the root of the donor tooth is very close to the maxillary sinus this combination is unavoidable. Breach of the maxillary sinus can be closed by advancement of surrounding mucosa. If the oroantral fistula remains patent, Obturators will be needed to prevent nasal reflux until formal closure can be carried out.

Ocular complications [19]

Oculoplastic complications associated with OOKP surgery includes fornical and tarsal conjunctival cicatrisation, associated with ocular surface inflammation and primary disease process. As a result, patient may have shallow fornices, upper or lower lid cicatrical entropion and wide palpebral apertures.

Glaucoma

Single most serious complication leading to irreversible loss of vision.

Chronic low grade inflammation, progressive angle closure, anterior displacement of iris have been implicated. Topical treatment is effective in patients with Boston type 1 keratoprosthesis. Systemic treatment can be used with Boston type 2 and MOOKP (Modified keratoprosthesis). Tube shunts and cyclophoto coagulation have been successfully used with all types of keratoprosthesis. Caiazza *et al*. reported the association of early and recurrent bacterial infections due to Staphylococcus epidermidis extensive laminar resorption [20].

Retinal Detachment [21]

Early detection and treatment of a retinal detachment is essential. Patients may have symptoms such as a sudden onset of floaters, flashing lights or a shadow across the vision. Detachments may be decreased by fundoscopy or with B-scan ultrasonography.

Modified Osteo-Odonto keratoprosthesis (MOOKP)

The OOKP was initially introduced by Strampelli in 1963. Later Modified OOKP by Falcinelli and Coll. It uses the patient's own complex body part and surrounding alveolar bone to support a centrally cemented optical cylinder. Multi staged procedure, treatment in mouth and eye. Strampelli's OOK offers three advantages over the alloplastic prostheses:

(1) Permanent fixation of an acrylic lens;

(2) Insertion of the mucosal epithelium onto the alveolar dental ligament;

(3) Long-term retention of the prosthesis due to its complete biological compatibility as far as other pathological conditions does not occur [22].

Indications to the MOOKP

Bilateral blindness in case of Stevens-Johnson Syndrome Ocular surface disease is a common manifestation of SJS and TEN [23] Ocular cicatrical pemphigoid

Lyell syndrome

Acquired epidermolysis bullosa

Trachoma

Chemical injury

Physical injury

Loss of the lids (eg: Crouzon disease)

Vascularized corneas with complete vegetative cell loss and waterlessness following alternative causes Aniridia with severe tissue layer changes. Multiple failed penetrating keratoplasty. Corneal failure after vitrectomy with silicone oil filling that cannot be removed safely.

Contraindications

Absent light perception

Edentulous patient

Age <17 years

Patients with severe post segment pathologies

Mentally unstable patients

No light perception in candidate eye

Advanced glaucoma or severe optic nerve damage (relative contraindication)

Irreparable retinal detachment

Evidence of phthisis
Unrealistic expectations [24]

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