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Review Article

Osteo-Odonto-Keratoprosthesis (OOKP) for patients with corneal blindness: A review

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Abstract

Anatomically, the cornea is the outermost layer of the eye and is primarily responsible for light refraction which allows for central and peripheral vision. Corneal diseases are among the major causes of global blindness, secondary to cataracts. This paper intends to review Osteo-Odonto Keratoprosthesis (OOKP), which is a two stage procedure whereby dental and buccal tissue is auto-transplanted into eye to serve as a synthetic cornea. Our purpose is to inform readers about the relevant anatomy, two-stage procedure, surgical inter-professionalism, indications, contraindications, complications, long-term functional and anatomical results and patient outcomes of OOKP. The present manuscript was constructed by extensive review of literature of various review articles and case reports and the data was collected from 32 review articles and case reports.

Key words

Cornea, Auto-Transplant, Osteo-Odonto-Keratoprosthesis (OOKP).

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Introduction

The eye is considered as the "Window of our soul"; the cornea is the "Window of the eye". Like the lens of a camera, the cornea is transparent and has a strong focusing power that focuses light rays on the retina. Degeneration, trauma, chemical burn, infection, inflammation and allergy etc. are some of the common conditions that can affect the cornea, resulting in corneal scarring and opacities which results in poor vision for the patient.

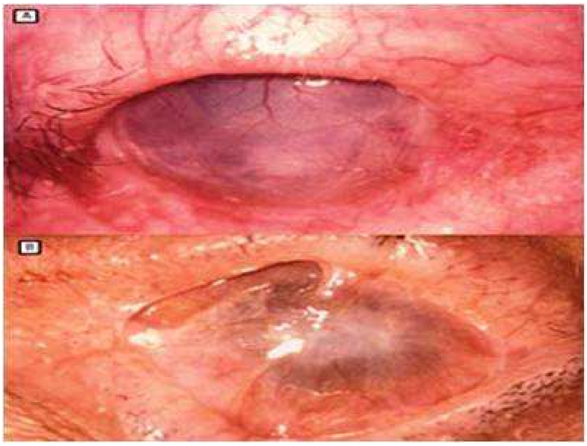
In some situations, medical treatment is enough to clear this cloudiness. However, in certain cases where medical treatment fails, corneal transplantation will be the next step. Yet, in some cases the damage is so severe that corneal transplantation will not work. Common examples include severe chemical burn, severe dry eye with corneal opacity, severe drug allergy (Steven-Johnson Syndrome) and repeated graft rejection, etc. (**Figure - 1**) To provide the patient with useful vision, not only the conventional corneal graft but a wide variety of materials has been tried earlier as artificial corneal implants including metals, ceramics, glass plastics and biological tissues for anchoring skirts, plates or haptics. For the plastic prosthesis to retain in the eye, tissues from the patient's own body are used. The tooth is ideal because it has a hard part to which the cylinder can be fixed and also it resides in the mouth where it co-exists with soft tissues, as in the eye [1-4].

Historical review

Replacing damaged and opaque cornea with an artificial implant or keratoprosthesis dates back, about more than 200 years to Pellier de Quesgsy, a French opthalmologist who proposed implanting a glass plate into opaque cornea. Nussbaum placed the first artificial corneal implant in a human eye, as early as in 1855 [5].

Since then more attempts were made to develop different keratoprosthesis and techniques. Almost all the early implants extruded but the interest in the keratoprosthesis waned the introduction of keratoplasty. Since then many pioneers were involved in developing new keratoprosthesis, but it was Strampelli (1963) who suggested the use of patients own tooth and bone for replacing acrylic implant in the corneal envelope. The tooth and bone would form an autograft picture frame. Initially, the technique did not gain much popularity. It was only after the refinement work of Dr. Gian Carlo Falcinelli in 1980 the technique has gained fame and was named as Rome-Veinna protocol [4-6].

Figure - 1: Pre-operative anterior segment photograph taken from patient with dry eyes due to pemphigoid and chemical burn.



Patient selection criteria

Patients with bilateral corneal blindness resulting from severe end stage Stevens-Johnson syndrome, Lyell syndrome, ocular cicatricial pemphigoid, chemical or thermal burns, end stage trachoma, severe keratitis, dry eyes, multiple failed grafts and graft-versus-host disease and consequences of perforating injuries may be considered for OOKP surgery. The other causes of dry eye are ectodermal dysplasia, ionizing radiation damage, cicatrizing conjunctivitis from topical medication,

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congenital trigeminal nerve hypoplasia, linear IgA disease and nutritional deficiency. Only those patients who are aware of their severe condition and fully understand the need for major surgical procedure, the risk of severe complications and commit to lifelong follow up. The better eye with poor vision should be rehabilitated [4, 7-11].

Contraindications

Patients who are happy and managing with their level of vision, children under the age of 17 years, eyes that have no perception of light, evidence of phthisis, advanced glaucoma or irreparable retinal detachment should be excluded [10].

Patient assessment

Pre-operative assessment

Multi disciplinary approach is required and patient has to be scrutinized by the team of ophthalmologist, oral surgeons and radiologists who form a surgical team. This evaluation should include the detailed history and etiology for loss of vision [4, 10].

Oral assessment

The oral assessment must take into account both the buccal mucosal graft donor site and a selection of an appropriate tooth to form a dentine/bone lamina [8, 10].

Since a number of patients will need an OOKP due to muco-cutaneous diseases, 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 that severe scarring of the oral mucosa may compromise the successful harvest. Those who smoke should be advised to stop smoking to improve the chance of graft revascularization. Betel nut chewing will compromise tissue quality [4, 8].

Overall oral hygiene is assessed; donor site selected must be absolutely free from any diseases. Buccal mucosa is examined thoroughly to rule out any mucosal lesions like lichen planus, oral submucous fibrosis etc. teeth selected should be free from any periapical disease and must be tested for vitality. The length of the teeth is estimated using panaromic and periapical radiographs. The healthiest and best-positioned tooth with best shape, size and good covering of alveolar bone is selected. The most suitable tooth for modified preparation of the osteodental lamina is the maxillary canine because it has the longest and largest root with the greatest quantity of alveolar bone. Contraindications for using a particular tooth include non-vitality, previous root canal therapy, and inadequate bone investing the root, peri-radicular pathology and close proximity of adjacent teeth. Other single-rooted teeth can be used in the absence of a canine. The choice of upper or lower canine depends on the proximity of the maxillary sinus and the mental foramen. In lower canine harvesting, buccal plate is occasionally thin and the lingual muco-periosteum is difficult to preserve. There is a risk of antrum perforation in case of upper canine. In the majority of patients, an autologous osteodental lamina is used. Occasionally when there is no suitable tooth available or in case of edentulous patients an allogaft is considered [4, 5, 8, 9, 10, 12, 13, 14].

Ophthalmic assessment

Patients are thoroughly assessed for the etiology of vision loss by in detailed history and comprehensive ocular examination [4, 10].

Psychological assessment prior to OOKP surgery

Patients have to understand that they may require multiple procedures and that there is a significant risk of serious complications including loss of the eye. The patient must commit to life-

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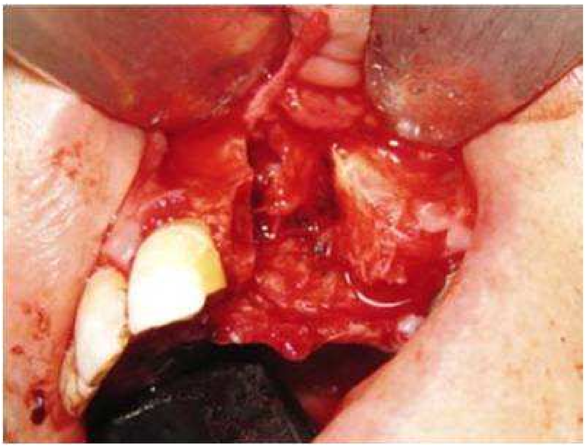
long followup, and not have unreasonable expectations of outcome and cosmesis [10].

Procedure

Surgical technique

Stage - 1: OOKP surgery is usually carried out in two stages second surgical procedure is carried out at the time ineterval of two to four months of time. During 1st stage a canine tooth is extracted with the entire root and a portion of the jawbone and wound site is covered (**Figure - 2a, 2b**). The coronal half of the tooth is sectioned and the remaining root, along with the bone and tissue are shaped into a cube that is referred to as osteo-odonto alveolar lamina. A hole is prepared in the centre of OOAL to fit a small clear plastic optical cylinder that is sealed with the help of dental cement (**Figure - 3**). This optical cylinder becomes a media to receive the light ray that is focused on the retina. The dental lamina is inserted through a slit below the lower eyelid of non-operating eye. Superficial keratectomy is then performed and replacing it with a full thickness bucal mucosal graft. Once harvested, the fat from the graft is removed and the graft is sutured to the sclera thus creating a new ocular surface.

Figure - 2a: Extraction of tooth with alveolar bone.



If the eye is very dry, or there is a risk of the mucus membrane graft rejection, it is better to perform stage 1 in two steps.

Step 1a: The mucous membrane graft harvesting is done first.

Step 1b: Only after the graft is very well established, OOKP lamina is prepared.

Figure - 2b: Covering of harvested wound site.

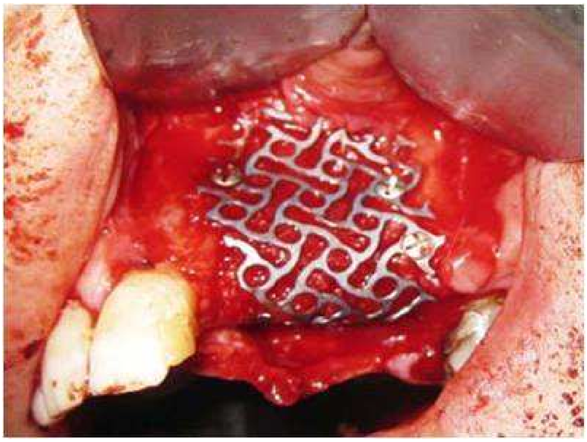
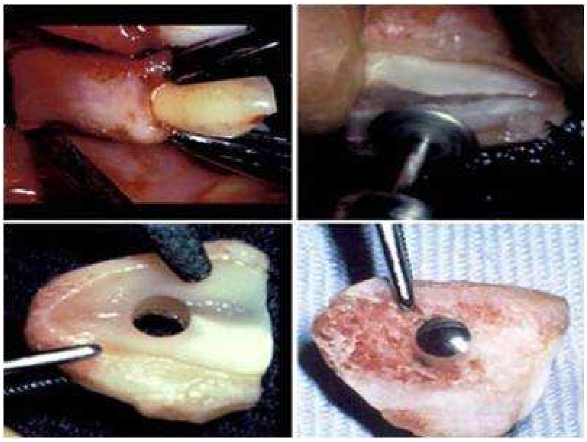


Figure - 3: Preparation of Osteo Odonto Kerato Prosthesis.



Stage - 2: Stage 2 starts with the retrieval and inspection of buried lamina for adequate size. The surgeons now proceed, to prepare the eye for receiving the implant. The buccal mucosal graft is lifted and corneal trephination (5mm in diameter) is created for the central opening in the eye. Iridodialysis and lens extraction is followed by vitrectomy to create the space for new implant. The keratoprosthesis is placed into the opening, which serves as a strong biological

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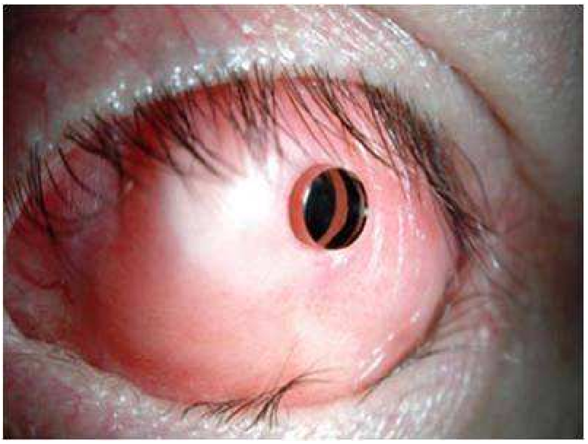
skirt for securing the prosthesis in position by sutures.

Finally the buccal mucosal graft is sutured over the implant and trephined in the centre to allow the anterior aspect of the optical cylinder to protrude (**Figure - 4**). This will allow the light to enter the optical cylinder and then the buccal graft is sutured back onto the sclera. The patient should be able to see within two-three weeks time. Immediate post operative-care entails symptom relief including corticosteroids and antibiotic prophylaxis. Follow up is life-long with ophthalmologist. One month after surgery, a cosmetic prosthesis covering the external ocular surface can be given. Main outcome measures to be considered are visual acuity, field of vision, anatomical integrity and stability and complications related or unrelated to the OOKP technique [4, 8, 9, 10, 15-20].

Figure - 4: Post operative picture of Eye with OOKP showing optical cylinder and buccal mucosal graft.



Complications and their management

Surgeons as well as the ophthalmologists, who have treated the patients with OOKP surgery, should be well aware of potential complications, as early identification and appropriate treatment can enhance Kpro survival [4, 5, 11, 12, 21].

Ocular complications that are commonly encountered include perforation of cornea, ocular surface inflammation, buccal mucosal membrane thinning and ulcertaions, globe perforations and glaucoma. Continuation of primary disease process may result in shallow fornices, upper and lower lid cicatricial entropion and wide palpebral fissures. A study by Liu et al showed that main factor resulting in anatomical failure was OOKP lamina resorption. When the implant is in subcutaneous pouch it may lead to absorption of dentine, bone infection or loosening of cylinder; if they do the implant should be explanted and treated prior to continuation of the procedure [4, 5, 11, 12, 21].

Oral complications followed by extraction may lead to trismus resulting from submucosal scar formation, oro maxillary fistula, buccal mucous membrane infection, palatal or lingual bone fracture. Poor healing may lead to exposure of roots of adjacent teeth; this can be avoided by using sharp blades and careful technique. Excessive force or overheating of drill during complicated extractions can break the dentine and damage the dentoalveolar ligment and render it useless as a lamina for optical cylinder. Other complications of extraction may include oronasal perforation, damage to mental nerve leading to lip paresthesia during extraction of mandibular canines and cosmetic defect when the tooth in the anterior segment of jaw is extracted [4, 21].

Systemic complications that may occur include complications related to local and general anesthesia and immunosuppression because of corticosteroid administration [22].

Discussion

Ever since the first performance of OOKP surgery, the technique has been practiced for over past 40 years. OOKP surgery has been

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performed with minor modifications to the technique in at least 8 specialized centers around the world [10, 29].

The OOKP remains keratoprosthesis of choice for the end stage corneal blindness not amenable to penetrating keratoplasty. It is particularly resilient to the hostile environment such as dry keratinized eye resulting from steven Johnson syndrome, ocular cicatricial pemphigoid, trachoma and chemical injuries [4].

Nail (onycho-keratoprosthesis) can be used instead of a tooth but it has the disadvantage that if it is taken from the nail root, it is liable to grow in the eye [4]. Casay, et al. used a chondro-keratoprosthesis, a piece of cartilage removed from the 8th costal cartilage and has reported their best results till date. Some surgeons found tibial bone i.e. temprano- keratoprosthesis (TKP) as a better option. Viitala R, et al. have tried synthetic analogue (bioceramics) instead of OOKP and found that at normal physiologic pH the degradation of bioceramics was equivalent to tooth and bone. However at pH of 6.5 to 5 associated with infectious and inflamed tissue, the degradation rate of bio ceramics was much higher when compared to bone and teeth [4].

The functional results seen in the patients who have undergone OOKP surgery confirmed the overall statistical trends observed for the anatomical outcome because post-operative best-corrected visual acuity found in general, is acceptably good and stable over the years. The innovation introduced to the original OOKP procedure may make the present surgical approaches less prone to fatal complications (endothalmitis and prosthesis extrusion) and more likely to achieve better functional outcome when compared with either the original technique or other proposed approaches. We recognize that this procedure routinely requires the extraction of at least 1 of the patient's teeth, which has disadvantage of scarifying a strong and healthy tooth along with considerable amount of healthy bone. However, the findings of numerous studies provide evidence of a long-term stability of prosthesis with a level of visual rehabilitation that is currently unattainable with other keratoprosthesis techniques [9].

In reviewing the efficacy of OOKP procedures the success of surgery is found to be dedicated to the material used for implants by most of the authors [9].

The superiority of OOKP over other (biointegrated and biocompatible Kpro) approaches has been proved and supported by various clinical and histological studies as reported by G. Falcinelli, et al in 2005 [9]. The efficacy of these implants is mainly due to its uniqueness of the living material, that composes the keratoprosthesis i.e. the tooth along with the alveolar bone with its ligament and small periosteum which are all covered by the autologous oral mucous membrane, that provides a long term support to the optical component of Kpro with the lowest risk of infection and extrusion. Indeed, in various clinical studies post operative complications are less frequently reported with OOKP than as compared with other biologically compatible or biointegrated haptic implants [9].

Donald, et al. performed OOKP surgery on 15 patients, with a mean follow-up of 19.1 months. Eleven patients (73.3%) attained a stable best spectacle-corrected visual acuity of at least 20/40 or better, whereas 9 (60%) attained stable 20/20 vision. Four patients achieved a visual potential ranging from 20/100 to counting fingers vision [20].

Michael, et al. yielded wonderful results in his 10-year follow up study. Statistically significant far better results were obtained with use of OOKP against the use of osteokeratoprosthesis

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in terms of anatomic and functional survival as well as visual acuity [13]. Fong, et al. used electron beam tomography (EBT) in imaging of OOKP to identify early bone and dentine loss. They concluded that it is important to monitor regularly the dimensions and stability of the OOKP lamina, as it will help detect cases that are at risk of extrusion of the optical cylinder and consequent endophthalmitis. They also found out that EBT have excellent resolution and speed and recommend regular scanning of the lamina in all patients [23].

Hille, et al. have implanted a total of 35KPs, 29 with biologoic haptic (25 OOKP and 4 TKPs) and 6 KPs with biocompatible haptic. There was no significant difference between the various types of KPs concerning the best postoperative visual acuity. During long-term follow up, only 1 of the KPs with biologic haptic (TKP) was lost compared with 4 out of 6 KPs with biocompatible haptic ($P<0.0001$). Thus they concluded that OOKP leads to the best results in the long-term follow up [24].

Percorella I, et al. biopsied the junction between the osteodental acrylic lamina and surrounding modified oral mucosa in 7 patients and were examined by light microscopy. Six of the 7 corresponded microscopically to conjunctiva. Typical oral mucosa could still be observed overlying the osteodental acrylic lamina. Thus they concluded that the production of local regulatory factors is a possible explanation for the survival of oral mucosa over the osteodental acrylic lamina, whereas their absence in distant areas may have induced the oral mucosa to trans differentiate into a conjunctival-type lining. Alternatively, conjunctival regrowth from forniceal stem cells should be taken into consideration [25].

Percorella I, et al. demonstrated elastic and precursor fibers and distribution of collagen type I to VI in bone and dental tissue which were exposed to the ocular surface [26].

Ricci R, et al. showed that preservation of the alveolar-dental ligament plays a definitive role in the maintenance of the prosthesis. If this tissue undergoes necrosis, the implanted material is eventually lost. However, when no such event occurs the OOK is well preserved and well tolerated even 20 years after implantation [27]. Although the complications of OOKP can vary in severity, majority of patients have stable implants. Because OOKPs have been shown to improve and maintain visual acuity, this procedure is an innovative alternative for managing end stage ocular surface diseases after failed PKPs. The procedure still remains technically difficult, requires special training and healthy dentine and buccal tissues. Current research is being done for creating synthetic analogues to substitute the dental lamina and as well as accurately measuring intraocular pressures (to diagnose Glaucoma) in post-transplant patients [28, 29, 30].

Conclusion

The future of OOKP is promising, as the literature and scientific interest is increasing. Modern OOKP surgery still has many barriers to becoming universally accepted because of the required technical and surgical expertise, but it does provide hope for restoring vision in refractory corneal blindness. The creativity of using a tooth as an eye implant should hope to inspire future inter professional approaches to ophthalmic practice to provide the best care for patients.

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