Piggyback Lens System in the Management of Keratoconus

Abstract

A review of literature on the use of Piggyback contact lens system in the management of Keratoconus. Factors discussed included the oxygen transmission through the dual lens system, lens material, cost, and rate of contact lenses related complications. One the most important raised questions are: does this lens system fulfill the definite goal in the management of Keratoconus which is best optical correction along which least corneal insult.

Keywords: Contact lenses; Keratoconus; Piggyback

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Abbreviations: PBS: Piggyback System; RGP: Rigid Gas Permeable; SCL: Soft Contact Lens

Introduction

Keratoconus

A bilateral [1,2], non-inflammatory and asymmetric [3,4] corneal degeneration distinguished by bulging of the thinned cornea as a result of localized and gradual corneal thinning mostly in the inferior temporal and central cornea. Other complications include: Bowman's layer rupture, iron accumulation within corneal epithelial basal layer, stromal fibroblast's degradation and reduction in stromal lamellae and keratocytes [5] (Figure 1).

Also, corneas in keratoconus experience reduction in aldehyde dehydrogenase Class 3 and superoxide dismutase enzymes that have leading role in the reactive oxygen processes. This reduction results in oxidative damage due to reactive oxygen accumulation causing cytotoxic deposition of malondialdehyde and peroxynitrites and tissue damage (Figure 2). The increasing level of proteases and other catabolic enzymes as well with decreased levels of proteinase inhibitors such as α2-macroglobulin and α1-antiprotease is accused of participating in stromal regression [5].

Even the tear film in the keratoconic eyes is disturbed with proteases increase and reduction of lactoferrin, lysozyme and IgA [6]. Such anatomical and physiological changes induce progressive changes in the refractive power of the eye, itchiness, and other visual phenomena such as halos, distorted images and monocular diplopia. It affects contact lens tolerance and fitting as well. It is considered the most prevalent primary corneal ectasia with an estimated prevalence of (54/100,000) worldwide [7]. It appears in the second decade of life with no ethnic or gender variation but with a strong genetic connection.

Management of keratoconus depends on the stage of the disease. While spectacles are only effective in very early stages, as the protrusion progresses it wouldn't be effective to rule out the high myopia & irregular astigmatism. Mild and moderate keratoconus stages may benefit from contact lenses use with or without the aid of other surgical solutions such as cross linking and intraocular intacs. Severe cases will need keratoplasty [7]. The aim in management is to reach best possible optical correction with good corneal health and enhance comfort to delay the penetrating keratoplasty surgery.

Although contact lens use have proven to be favorable in managing high refractive changes and delaying the need for surgery, it is very challenging to fit the already sensitive, compromised ectatic cornea with good tolerance and less complications. The challenge arises from the need to provide the patient good visual acuity along with reduced scarring, controlled protrusion and consequently better tolerance [7]. Several contact lens options are available in the market with variable characteristics. One of the choices which will be discussed in this article is the piggyback system (PBS).

Figure 1: The stroma of a normal cornea is distinguished by regular collagen fibers.

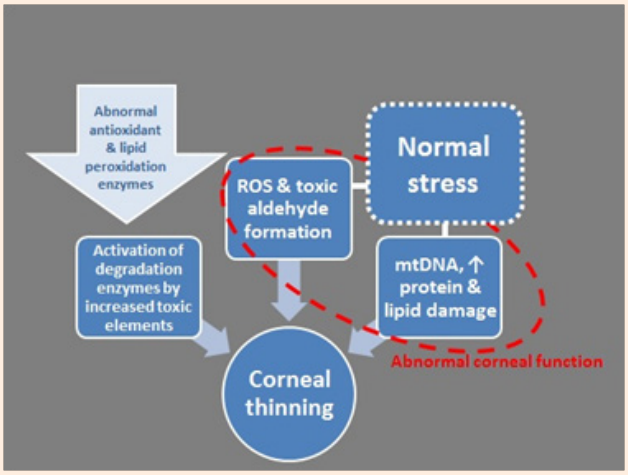

Figure 2: Oxidative damage in Keratoconus.

Properties of the Piggyback system

Piggyback contact lens system (PBS)

Is a combination of a rigid gas permeable (RGP) contact lens (which provides good optical correction especially for irregular astigmatism) and a soft contact lens (a carrier lens that acts as a bandage lens promoting comfort & enhancement of the corneal irregularities) [8]. The use of such combination started in the early seventies as a compromising solution in cases of rigid gas permeable lenses intolerance [9-11].

Back these days lens materials used were of lower oxygen permeability and piggyback system was strongly related to corneal hypoxia [12] since two lenses act as a double barrier hindering oxygen transmission. Several advantages helped keeping this dual lens combination in action such as: the reduced corneal oedema, enhanced comfort, the more stabilization and cone protection. Fortunately, as new lens materials with higher oxygen permeability are used, complications are retracting and more success and comfort is obtained. This is valuable if we considered that 83% of the penetrating keratoplasty was determined due to lack of contact lens tolerance [13]. However, as with other contact lenses designed for keratoconus, problems of training the patient to properly handle and care of the lens and the relatively high cost still persist.

Regardless of the fact that it is used on already compromised corneas which will add to the complications such as: hypoxia that will lead eventually to corneal vascularization and oedema; piggyback system is considered one of the ideal lens choices for patients who couldn't reach optimum optical performance with soft contact lens and can't tolerate rigid gas permables [8,13]. Benefits are the protection from corneal trauma and scarring, eliminating the mechanical friction induced by the rigid gas permeable lens on the corneal surface, promoting epithelial healing after surgeries and optimal correction for irregular astigmatism [8,13,14]. In addition, piggyback system trial can be of less expense for a patient already fitted with a rigid gas permeable lens since all he needs is a fit of an additional soft contact lens but this tactic might reduce the independent movement of the rigid gas permeable lens over the soft contact lens.

Fitting technique and lens choice

The soft contact lens (SCL) is fit with good centration then a rigid gas permeable lens is fitted on the flatter K whereas confirming that both lenses move freely and independently with blinking to ensure adequate oxygen transmission to the interface of the rigid gas permeable - soft contact lens. For more convenient application the practitioner can prescribe a disposable soft contact lens [13,14] yet this approach might highly increase the cost on the patient. They might recommend the use of one solution for both lenses however the solution should be carefully chosen because of the tendency of silicone hydrogel lenses to absorb preservative and emit them later during wearing time.

The trick in fitting is the balance between the need to fit a more positive soft contact lens to enable good rigid gas permeable lens centration (due to more convex surface) [15] & a less positive soft contact lens (less lens thickness) to improve oxygen transmission that is reduced by the use of two lenses on top of each other [13,14]. The contribution of the soft contact lens in the refractive error correction is trivial so, a low powered plus lens might be prescribed to ensure good centration of the rigid gas permeable. An adequate peripheral clearance is important to increase comfort and consequently tolerance, however it is not that easy in keratoconic eyes where the displaced corneal apex can add to the burden [16]. Also, shorter base curve soft lenses might be more suitable to manage the very steep cone.

Another consideration in lens choice is the fact that edge furrows are more probable with lenses with high elastic modulus; such flutting is responsible for less lens tolerance due to ocular surface disruptions and discomfort while other mechanical insults are less probable with such lenses [16]. Those lower elasticity lenses have the benefit of promoting ease of handling and ruling out of corneal irregularities [17]. It goes without saying that the use of higher DK/t value lenses is an obligation to promote sufficient oxygen transmission through lens material keeping in mind that the higher the DK/t and elasticity level the more frequent the need for lens replacement.

The dual lens combination and oxygen

The amount of oxygen reaching the corneal epithelium is a crucial factor in reducing complications induced by contact lens wear. In chronic conditions that requires specially designed lenses, long wearing time and involves other deteriorating aspects compromising corneal health; the need for adequate supply of oxygen transmission increases. In single contact lens use, oxygen supply is provided to the cornea by diffusion through lens material (the higher DK/t the more oxygen transmissibility) and by tear pump under the contact lens while blinking. As for the piggyback system, another factor adds which is the oxygen transition to the rigid–soft interface during blinking and the role of both lenses' DK/t is magnified.

As mentioned before, the reduction in aldehyde dehydrogenase Class 3 and superoxide dismutase enzymes – apparent in keratoconus cornea- results in reactive oxygen accumulation

which adds to the challenge [5]. Tsubota et al. [18] compared the oxygen pressure under two piggyback lens combination on rabbit's cornea. One with a rigid gas permeable and a high DK/L soft contact lens, the other a PMMA with a low DK/t soft lens. They stated that oxygen tension under a piggyback combination of PMMA contact lens (34±14) is about one third of the oxygen under a piggyback combination of rigid gas permeable lens (95±14). On the contrary, an in vitro study by López-Alemany et al. [8] suggested that a piggyback system lenses with PMMA have no oxygen under the lens in static condition. Although their measurements are excluding the effect of tear exchange in the dynamic conditions, the information itself emphasizes the importance of lens material effect on oxygen transmissibility and the potential improvement in piggyback system performance by the appropriate lens selection. They concluded that combining the highest DK/L values for both soft and rigid contact lenses guarantees a sufficient oxygen supply to the cornea.

They suggested that the use of a daily disposable soft contact lens with Tisilfocon A rigid gas preambles would promote the ease of handling and spare the patient the burden of disinfection and care of two lenses but would increase the expense while the use of silicone hydrogel and medium- DK rigid gas preambles had similar DK/Lapp value [8]. So, the choice of lens combination can be adjusted to suit the patient's needs and financial capabilities with maintaining adequate oxygen transmission. However, lens permeability is not the only factor affecting the combination potency. Lens thickness, design, fit to cornea and tear exchange during blinking are of high value even though oxygen transmission through rigid gas preambles to the rigid gas permeable–soft lens interface is of the most validity.

Oxygen uptake measurements Florkey et al. [19] taken on human subjects wearing various single soft contact lenses, single rigid gas preambles, and combinations of piggybacked lenses revealed that the highest oxygen uptake on soft contact lens was Acuvue 2.94 times and the highest oxygen uptake on hard contact lens was PMMA 5.0 times. Several piggyback systems provided various levels of oxygen to the cornea by transmission through the lens material. For example, Acuvue & PMMA provided the highest increase in oxygen uptake of 5.0 times the normal open eye uptake whilst pure vision & Fluoroperm151 provided the lowest increase in oxygen uptake 1.54 times. There were no significant differences between dynamic & static conditions in piggyback system. Apparently, the oxygen uptake reduces as lens's oxygen transmissibility increases and oxygen uptake is affected by the same factors influencing oxygen transmissibility. Utilizing these information we can infer that oxygen transmissibility can be increased with proper lens combination selection which will help eliminate hypoxia and corneal vascularization. Resultantly, more comfort, tolerance and penetrating keratoplasty can be further postponed.

Clinical aspects of the Piggyback system

Piggyback lens system in the action: One successful trial of piggyback system was when Randleman et al. [20] prescribed a dual lens system for a patient with a history of severe alkali injury and repeat bilateral penetrating keratoplasty. Although this patient suffered from severe dry eye and chronic ocular surface disruption, he accepted the piggyback system well with good visual acuity and no insult to the graft or adverse reactions. O'Donnell et al. [15] described in details the fitting of a piggyback system for a keratoconus patient who was wearing a Soft Perm contact lenses for seven years before the arise of discomfort and hyperemia. The switch to piggyback system eliminated those complications.

Melia et al. [17] described a successful use of a piggyback system for 27 months with minimal complications after rigid gas permeable and Hybrid lens rejection. They claimed that the fit of flatter rigid gas permeable in a piggyback system have an orthokeratology influence controlling early keratoconus, such a flat fit is not applicable in classic rigid gas permeable fitting for keratoconus due to the strong relation to corneal scarring [21]. This suggested advantage can be beneficial smoothing corneal irregularities of other causes.

Later, Smith & Carre [22] all discussed the fit of a high DK/t Paflufocon B (58) rigid gas permeable lens on a pure vision disposable soft contact lens in a piggyback system that was well tolerated by an advanced stage keratoconus patient having implanted Intacs. The disposable soft contact lens was easily replaced to compensate for the fluctuations in refractive error. This approach helped delaying penetrating keratoplasty and was of additional value because the soft contact lens adjusted for the altered corneal shape by both the keratoconus and the Intacs where a flat mid-periphery contrasts with the central protrusion apex. It also acted as a bandage lens enhancing corneal epithelial health and eliminated the rubbing between the rigid gas permeable lens and the flattened inferior mid-periphery.

Sengor et al. [13] tried the fit of piggyback system on 29 keratoconic eyes ranging from mild to severe stages for limited time- 3 to 12 months- before going back to wear rigid Rose K brand lenses (aspheric or multi curve posterior surface lens designs). They concluded that use of piggyback system increased tolerance of rigid gas permeable lenses because of decreased sensitivity during its use and epithelial erosions healing. Also, 89.7% of the patients had improved visual acuity compared to rigid gas permeable lenses alone. Rigid gas permeable lenses alone were rejected in three eyes (10%) who continued to wear piggyback lens combination. All previously inspected trials are supported by the fact that the piggyback system have wide range of parameters and requires no additional experience in fitting.

Piggyback system and other contact lenses options

Forister et al. [23] estimated the rate of contact lens related complications among rigid gas permeable, soft contact lens, and piggyback system wearers. Compared to soft contact lenses, giant papillary conjunctivitis and neovascularization were less in piggyback wearer than soft contact lens wearer which can be explained by the fact that piggyback lens wearers tend to have more frequent visits to the clinic and less extended wear time reinforcing the role of good follow up in complications' elimination. On the contrary, diffuse and localized superficial punctate keratitis were higher in piggyback lens system wearers probably due to the fact that it is applied on already compromised corneas or because of the less tear exchange. On the other hand, comparing piggyback system to hard contact lenses revealed relatively similar results of diffuse and localized superficial punctate keratitis occurrence while hard contact lenses contributed to less giant papillary conjunctivitis and neovascularization. Unfortunately, no other

studies are available regarding the complication rates among piggyback contact lens wearers. Regarding optical performance the piggyback system have similar performance to that of rigid gas permeable and better than those of soft contact lens.

Comparison of piggyback contact lens system with ClearKone hybrid lenses- hybrid lens comprises a rigid center of high oxygen permeability and a skirt of soft contact lens material of low oxygen permeability- revealed no significant differences after analyzed bulbar conjunctival impression cytology, tear interleukin-6 (IL-6), tear interleukin-8 (IL-8) levels and confocal microscopic changes of the cornea before and 6 months after wearing contact lenses [24]. Drawbacks of the ClearKone lenses include the limited range of parameters and the difficulty obtaining a successful fit on the highly irregular cornea.

Scleral contact lenses are another option that has the benefit of apex clearance i.e. the lens touches the eye on the sclera only sparing the conic cornea leading to minimal scar risk. However, skills of handling and use are hard to master and time consuming. There is a high risk of prompting hypoxia even with new Scleral lenses with higher DK/L and thinner central thickness [25].

Table 1 One major problem of contact lens wear in general- including piggybacked lenses- is hypoxia, neovascularization, and oedema which can be avoided by prescribing lenses with higher oxygen permeability that doesn't induce vascular response [26]. Also, diffuse and localized superficial punctate keratitis and giant papillary conjunctivitis is more prevalent among piggyback contact lens users [24]. These complications can be reduced by good follow up and frequent visits to the clinic. Difficulties of centration are frequent in very steep/ highly irregular corneas, to overcome this problem a custom made soft contact lens is used with a recess to place the rigid lens within.

Table 1: Obstacles facing the piggyback system.

Hypoxia
Neovascularization
Oedema
Punctate Keratitis
GPC
Handling & Care
Displacement & Loss
Self Awareness

Another problem is the inconveniency of handling and cleaning two lenses that would tire the patient and might not be applicable if he has a dynamic life style. However, with training the time spent can be much reduced. Other aspects are the high cost, the frequent need for soft lens replacement due to furrows and deposits. Many of keratoconus patients are not highly motivated to try contact lens settlements especially those designs that is apparent due to increased self awareness. This barrier rises in the piggyback contact lenses situation because most practitioners try them after failing with other contact lens types when the patient is depressed from the frequent need for new solutions to overcome the progressive condition. Patient education has a major role to eliminate those problems, increase patient's compliance and consequently enhance the outcomes.

Conclusion

As a conclusion, the use of the piggyback system in earlier stages of keratoconus along with frequent checkups and monitoring might provide the patient better chance to delay the penetrating keratoplasty along with cone apex protection, good optical performance and suggested control to the protrusion progression. However, it is still used as a lens choice compensatory of rigid gas permeable rejection where the use of such lenses violates the integrity of the cornea and in such cases where the soft contact lenses are incapable of providing adequate refractive error correction. This approach adds to the obstacles facing these lens combination.

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