

DERLEME

Current methods in the treatment of keratoconus

Keratokonüs tedavisinde güncel yöntemler

Alime Güneş

Department of Ophthalmology, Süleyman Demirel University Faculty of Medicine, Isparta, Turkey.

Abstract

Keratoconus is a bilateral, asymmetrical, non-inflammatory, and progressive thinning disease of the cornea. The etiology and pathogenesis of the disease are not known exactly. However, significant advances have been achieved in the treatment of keratoconus in the recent years. In the past, penetrating keratoplasty was the only treatment option in advanced keratoconus. Nowadays, therapeutic advances for keratoconus have been provided various treatment options in different stages of the disease and opportunity to stop the progression of the disease, to rehabilitate vision, or to achieve both. This review analyzes the current methods in the treatment of keratoconus, such as new contact lens designs, corneal collagen cross-linking, intracorneal rings, deep anterior lamellar keratoplasty, conductive keratoplasty, intraocular refractive lenses, photorefractive keratectomy, and combinations of these.

**Keywords:** Keratoconus, Contact lenses, Collagen cross-linking, Intracorneal rings, Lameller keratoplasty.

Introduction

Keratoconus (KC) is a bilateral, asymmetrical, non-inflammatory, progressive thinning disease of the cornea and leads to corneal protrusion, progressive irregular astigmatism, corneal fibrosis and visual deterioration. Generally KC begins during puberty, progresses with variable amounts and stabilized in third or fourth decade of life (1).

Generally, the first symptom is progressive decrease of vision, despite the use of glasses or contact lenses. Computerized corneal topography provide detailed mapping of the cornea and these devices are quite beneficial in early diagnosis and monitoring of KC.

Although, numerous studies have investigated the changes in KC, the etiology and pathogenesis of the disease are not known exactly. It is considered that KC is likely to be a multifactorial, multigenic disorder and environmental factors probably play an important role in the development of the disease.

**Yazışma Adresi/Corresponding:** Alime Güneş  
Department of Ophthalmology, Süleyman Demirel University Faculty of Medicine,  
Isparta, Turkey  
Tel: +90 (505) 482 83 45  
E-mail: dralimesefer@hotmail.com

Özet

Keratokonüs, korneanın bilateral, asimetric, enflamatuvar olmayan ve ilerleyici incelme ile seyreden bir hastalıdır. Hastalığın etyolojisi ve patogenezi tam olarak bilinmemektedir. Ancak, son yıllarda keratokonüs tedavisinde önemli gelişmeler elde edilmiştir. Geçmişte, ilerlemiş keratokonüs- ta penetran keratoplasti tek tedavi seçeneği idi. Günümüzde, keratokonüs için tedavi edici gelişmeler hastalığın farklı aşamalarında çeşitli tedavi seçenekleri sağlamaktadır ve hastalığın ilerlemesini durdurmak, vizyon rehabilitasyonu veya her ikisini birden elde etme fırsatı vermektedir. Bu derleme, keratokonüs tedavisinde yeni kontakt lens modelleri, korneal kollajen çapraz bağ, kornea içi halkalar, derin ön lameller keratoplasti, konduktiv keratoplasti, göz içi refraktif lensler, fotorefraktif keratektomi ve bu yöntemlerin kombinasyonu gibi güncel yöntemleri analiz etmektedir.

**Anahtar Kelimeler:** Keratokonüs, Kontakt lensler, Kollajen kross-linking, Kornea içi halkalar, Lameller keratoplasti.

The aims of management of KC are to halt progression of the disease, improve refractive error and aberrations, and correct ectasia. In early stages of KC, the refractive error can be managed by spectacle and soft contact lenses. As the disease progresses, further treatments could be necessary.

In the past, penetrating keratoplasty (PK) was the only treatment option in patients with poor visual acuity with contact lenses or contact lens intolerance and advanced KC with corneal opacities. Nowadays, therapeutic advances for KC have been provided various treatment options in different stages of the disease.

This review analyzes the current methods in the treatment of KC, such as new contact lens designs, corneal collagen cross-linking (CXL), intracorneal ring segment (ICRS), deep anterior lamellar keratoplasty (DALK), conductive keratoplasty (CK), intraocular refractive lenses, photorefractive keratectomy (PRK), and combinations of these.

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**Contact Lenses:** Nowadays many contact lens options are available for the treatment of KC. In early stages, soft or soft toric contact lenses may be sufficient for providing clear vision. The soft contact lenses may have advantageous, e.g. better comfort, longer contact lens wearing time, lower complications rate and lower cost (2, 3). As the disease progresses, special contact lenses are required to provide better vision.

Rigid gas permeable (RGP) contact lenses are the most commonly used treatment method for KC that they provide perfect vision by creating a regular optical surface (4). However, RGP lenses are frequently difficult to apply and uncomfortable which can cause to contact lens intolerance (5, 6).

Rose K lens (Menicon Co. , Ltd, Nagoya, Japan) with multiple curves has shown excellent visual rehabilitation and better comfort than other RGP designs (6, 7). When the cone is a central nipple cone, a Rose K lens can be selected (8). The success rate of Rose K contact lens in KC was reported to be more than 90% (6-10).

Intralimbal lenses can be used for large cones or oval cones. The large diameter of these lenses helps in improving the lens centration and also reduces the movements of the lens, but patients may find it difficult to handle lenses of large diameters (11).

Piggyback contact lens (PBCL) systems which is another option, involves fitting a soft lens underneath a RGP lens. The indications are lens stabilization and comfort, improving comfort, and adding protection to the cone. Though PBCL can improve vision and comfort, the disadvantages include lens displacement and loss, giant papillary conjunctivitis, the difficulty in the care regimen of handling and maintaining two lenses and low oxygen transmission that can cause hypoxia and corneal vascularization (2, 12).

The new design hybrid lenses have a rigid lens in the centre and a soft skirt in the periphery. The indications are RGP intolerance, poor lens centering and reduced wearing time with the RGP (2, 13). These lenses can be used for any stages of KC. The complications are giant papillary conjunctivitis, hypoxia related changes such as vascularisation and central corneal clouding, infection and discomfort (13, 14).

Scleral lenses can be used for very advanced cases with large, decentered cones, or all other contact lenses fail to improve the vision (15). Advantages of scleral lenses include the ability to completely clear the corneal surface, provide good centration, and stabilize visual acuity. Disadvantages are worse tear exchange and increased difficulty with respect to application and removal (2).

As shown there are many different kinds of contact lenses for patients with KC, it is important to select the most suitable lens for an individual patient.

**Corneal collagen crosslinking:** In the recent years, CXL has been commonly used as a treatment option for patients with progressive KC. The goals of the CXL procedure are to increase the mechanical and biomechanical stability of the cornea, halt or slow the progression of the disease, and avoid or delay keratoplasty. In 1997, Spoerl et al. first tested the effects of combination of riboflavin (vitamin B2), and ultraviolet A (UVA) (370 nm) on cornea and reported an increase in corneal rigidity (16). This was followed by the Wollensak et al. and they reported that KC stopped progressing in all eyes, and in 70% of the eyes a regression in keratometric and refractive values had been observed in 22 progressing KC patients (17). Together with this study, Wollensak et al. described the standard CXL treatment protocol, include 30 minutes UVA illumination of 3 mW/cm<sup>2</sup> irradiance with 370 nm light to the cornea was performed after 30 minutes riboflavin instillation of the cornea (17). Previous studies reported safety and efficacy of CXL (18-20). Caporossi et al. examined the effect of CXL on 44 progressive KC eyes and they reported that all eyes treated showed KC stability; 65% of the fellow eyes showed a mean progression of 1.5 diopters in corneal power during the first 24 months of follow-up (18). Goldich et al. analyzed three-year results after CXL and reported stable visual acuity, stable corneal thickness, and stable corneal biomechanical parameters during this time (20).

Schumacher et al. described accelerated CXL which is shorten the duration of the procedure (21). In this procedure, a higher-intensity light used for a shorter period of time; an irradiance of 10 mW/cm<sup>2</sup> for a duration of 9 min was shown to have similar rigidity results. Numerous comparative studies reported equivalence of the conventional and the accelerated CXL method in efficacy and safety (21-23).

Nowadays, studies about CXL is still continues. Indications are evolving, and different protocols are being developed and tested.

**Intracorneal ring segments:** Intracorneal ring segments (ICRS) are made of inert material such as polymethyl methacrylate and acrylic polymers. They are inserted into the corneal stroma using channels created mechanically or by femtosecond laser. With the result that corneal arc length is shortened and the central cornea is flattened, thus, irregularities of the cornea improves, refractive error and the mean keratometry are reduced and visual acuity is improved (24-29).

The eligibility criteria for the ICRS include clear central cornea without scarring, minimum 350 µm corneal thickness at the thinnest point, maximum keratometry value is under 60 diopters (D), and refractive error is under -6 D (24, 28). ICRS implantation provides significantly better results in patients with a severe form of the disease and a notable loss of visual acuity can be expected in patients with a milder form of KC (29). Major complications include infection, corneal haze, erosion, melting, corneal perforation, neovascularization, and loss of visual acuity (24-27).

The ICRS surgery is a minimally invasive and reliable method, but the duration of the effects of ICRS is still unknown.

**Penetrating keratoplasty:** The indication criteria for keratoplasty in KC patients are contact lens intolerance or inability to wear contact lenses, poor visual acuity with contact lenses, and corneal scar. For quite a few years, PK has been used for visual rehabilitation in KC and KC is amongst the best indications for doing a PK with long-term graft survival rates (30-32). Thus, PK is still important for the treatment of KC.

**Deep anterior lamellar keratoplasty:** In the recent years, DALK has emerged as an alternative to PK for KC. In this procedure, up to the Descemet's membrane (DM) are removed, host endothelium is preserved. This can be performed either by manual dissection or by a "big bubble" technique, which uses an air bubble to dissect the plane between corneal stroma and the DM (33, 34). Intraoperative online optical coherence tomography can use for visualisation of injection needle placement and with assessment of bare Descemet's membrane as well as interface fluid during the DALK surgery (35).

DALK has the advantages of essentially being an extraocular procedure and retaining the host endothelium, thereby obviating the risk of endothelial graft rejection and probably improving graft survival. Disadvantages are difficulty of the surgical technique, prolonged operation time, complications in the graft-host surface, high-order and tilt aberration, and more postoperative myopia than PK (33-40).

Complications are intraoperative DM perforation, which may necessitate conversion to PK, postoperative DM detachment, and interface haze (38). DALK is equivalent to PK in terms of refractive error, and more advantageous for preservation of endothelial cell density (40).

In summary, DALK should be attempted as the standard surgery procedure when keratoplasty is required in KC.

**Conductive keratoplasty:** Conductive keratoplasty is a new method to reshape corneal configuration using radiofrequency energy (41, 42). In this procedure, thermal spots placed on the mid-peripheral cornea which increases the curvature of

the central cornea, inducing myopic shift. Usually this procedure used for the correction of hyperopia or presbyopia. Previous studies reported results of CK in patients with KC (43, 44). In KC, CK spots are applied selectively to flat axis for steepen, thus astigmatism is reduced. Also, CK guided by topography (45). Patients with nonprogressive advanced KC with a clear visual axis and contact lens intolerance are ideal candidates for CK, but the corrective effect is temporary (44).

**Intraocular refractive lenses:** The aim of intraocular refractive lenses is to correct the high refractive error in KC. The patients should have a clear cornea, stable refraction, sufficient anterior chamber depth, and shouldn't have anterior segment pathology except KC and glaucoma (28). Disadvantages include the risk of endothelial damage and difficulties with intraocular lens power calculations due to low repeatability of keratometric measurements (43).

Anterior chamber (angle-supported and iris-supported) and posterior chamber localized types are available. Intraocular refractive lens surgery results in eyes with KC are very successful. Large amounts of spherical error (up to -22.00 D) can successfully be corrected, as well as highly significant improvement in visual acuity. Cylindrical correction is good at lower levels of astigmatism but limited in high degree cylindrical error. Complications include halos and glare in low light, endothelial cell loss, cataract formation, dislocation of the intraocular lens and pigment dispersion (47-54).

In summary, intraocular refractive lenses provide successful results in the treatment of stable mild KC with low irregular astigmatism, a clear central cornea and relatively good pre-operative spectacle corrected visual acuity.

**Photorefractive keratectomy:** Recently, there has been an interest in PRK for refractive error correction in KC. It is thought that, PRK could influence the anterior corneal layers and block the pathological process, stimulating regenerative processes and preventing progression of KC (55).

Chelala et al. reported good outcomes of PRK in KC eyes, with excellent uncorrected visual acuity and predictable refractive outcome in a majority of eyes (56).

However, close follow-up of patients is needed to detect any progression of the disease.

**Combined procedures:** Each of these procedures has advantages and disadvantages, no one treatment offering the perfect solution for the correction of vision. Thus, the combinations of methods may be beneficial.

In the recent times, maximum interest seems to be focused on CXL with one or two of other procedures. Same day CXL with topography guided PRK has been found to be superior to

other procedures for visual rehabilitation. With this combined procedure, patients with KC can improve visual and refractive outcomes in addition to the prevention of the disease progression (57).

It is reported that PRK after ICRS implantation and CXL is an effective and safe option for correcting residual refractive error and improving visual acuity in patients with moderate KC (58).

The other combined procedures for patients with KC are; contact lenses fitting after CXL, contact lenses fitting after ICRS implantation, contact lenses fitting after keratoplasty, toric intraocular refractive lens implantation after CXL, toric intraocular refractive lens surgery after ICRS implantation, and ICRS implantations followed by same-day PRK and CXL (56, 60-64).

### Conclusion

Consequently, many treatment options are available for KC. It is important to select the most suitable treatment method/methods at the right time for a patient with KC.

### References

- Rabinowitz YS. Keratoconus. *Surv Ophthalmol* 1998; 42: 297-319.
- Barnett M, Mannis MJ. Contact lenses in the management of keratoconus. *Cornea* 2011; 30: 1510-1516.
- Gonzalez-Meijome JM, Jorge J, de Almeida JB, Parafita MA. Soft contact lenses for keratoconus: Case report. *Eye Contact Lens* 2006; 32: 143-147.
- Edrington TB, Szczołka LB, Barr JT, Achtenberg JF, Burger DS, Janoff AM, Olafsson HE, Chun MW, Boyle JW, Gordon MO, Zadnik K. Rigid contact lens fitting relationships in keratoconus. *Optom Vis Sci* 1999; 76: 692-699.
- Edrington TB, Gundel RE, Libassi DP, Wagner H, Pierce GE, Walline JJ, Barr JT, Olafsson HE, Steger-May K, Achtenberg J, Wilson BS, Gordon MO, Zadnik K; CLEK STUDY GROUP. Variables affecting rigid contact lens comfort in the collaborative longitudinal evaluation of keratoconus (CLEK) study. *Optom Vis Sci* 2004; 81: 182-188.
- Betts AM, Mitchell GL, Zadnik K. Visual performance and comfort with the Rose K lens for keratoconus. *Optom Vis Sci* 2002; 79: 493-501.
- Jain AK, Sukhija J. Rose-K contact lens for keratoconus. *Indian J Ophthalmol* 2007; 55: 121-125.
- Rathi VM1, Mandathara PS, Dumpati S. Contact lens in keratoconus. *Indian J Ophthalmol* 2013; 61: 410-415.
- Mandathara Sudharman P, Rathi V, Dumapati S. Rose K lenses for keratoconus-An Indian experience. *Eye Contact Lens* 2010; 36: 220-222.
- Gunes A, Kubaloglu A, Bayramlar H. Rose K Lenses for Keratoconus. *Turk J Ophthalmol* 2012; 42: 88-90.
- Ozbek Z, Cohen EJ. Use of intralimbal rigid gas-permeable lenses for pellucid marginal degeneration, keratoconus, and after penetrating keratoplasty. *Eye Contact Lens* 2006; 32: 33-36.
- Sengor T, Kurma SA, Aki S, Ozkurt Y. High Dk piggyback contact lens system for contact lens-intolerant keratoconus patients. *Clin Ophthalmol* 2011; 5: 331-335.
- Abdalla YF, Elsahn AF, Hammersmith KM, Cohen EJ. SynergEyes lenses for keratoconus. *Cornea* 2010; 29: 5-8.
- Fernandez-Velazquez FJ. Severe epithelial edema in Clearkone SynergEyes contact lens wear for keratoconus. *Eye Contact Lens* 2011; 37: 381-385.
- Schorneck MM, Patel SV. Scleral lenses in the management of keratoconus. *Eye Contact Lens* 2010; 36: 39-44.
- Spoerl E, Huhle M, Seiler T. Induction of cross-links in corneal tissue. *Exp Eye Res* 1998; 66: 97-103.
- Wollensak G, Spoerl E, Seiler T. Riboflavin/ ultraviolet-A-induced collagen crosslinking for the treatment of keratoconus. *Am J Ophthalmol* 2003; 135: 62-627.
- Caporossi A, Mazzotta C, Baiocchi S, Caporossi T. Long-term results of riboflavin ultraviolet a corneal collagen cross-linking for keratoconus in Italy: the Siena eye cross study. *Am J Ophthalmol* 2010; 149: 585-593.
- Kanellopoulos AJ, Asimellis G. Keratoconus management: long-term stability of topography-guided normalization combined with high-fluence CXL stabilization (the Athens Protocol). *J Refract Surg* 2014; 30: 88-93.
- Goldich Y, Barkana Y, Wussuku Lior O, Marcovich AL, Hirsh A, Avni I, Zadok D. Corneal collagen cross-linking for the treatment of progressive keratoconus: 3-year prospective outcome. *Can J Ophthalmol* 2014; 49: 54-59.
- Schumacher S, Oeftiger L, Mrochen M. Equivalence of biomechanical changes induced by rapid and standard corneal crosslinking, using riboflavin and ultraviolet radiation. *Invest Ophthalmol Vis Sci* 2011; 52: 9048-9052.
- Kanellopoulos AJ. Long term results of a prospective randomized bilateral eye comparison trial of higher fluence, shorter duration ultraviolet A radiation, and riboflavin collagen cross linking for progressive keratoconus. *Clin Ophthalmol* 2012; 6: 97-101.

22. Kanellopoulos AJ. Long term results of a prospective randomized bilateral eye comparison trial of higher fluence, shorter duration ultraviolet A radiation, and riboflavin collagen cross linking for progressive keratoconus. *Clin Ophthalmol* 2012; 6: 97-101.
23. Cınar Y, Cingü AK, Türkcü FM, Cınar T, Yüksel H, Ozkurt ZG, Çaça I. Comparison of accelerated and conventional corneal collagen cross-linking for progressive keratoconus. *Cutan Ocul Toxicol* 2013 Oct 22. doi:10.3109/15569527.2013.834497. [Epub ahead of print]
24. Ertan A, Colin J. Intracorneal rings for keratoconus and keratectasia. *J Cataract Refract Surg* 2007; 33: 1303-1314.
25. Pinero DP, Alio JL. Intracorneal ring segments in ectatic corneal disease - A review. *Clin Experiment Ophthalmol* 2010; 38: 154-167.
26. Zare MA, Hashemi H, Salari MR. Intracorneal ring segment implantation for the management of keratoconus: Safety and efficacy. *J Cataract Refract Surg* 2007; 33: 1886-1891.
27. Kubaloglu A, Sari ES, Cınar Y, Koytak A, Kurnaz E, Öztürk Y. Intrastromal corneal ring segment implantation for the treatment of keratoconus. *Cornea* 2011; 30: 11-17.
28. Sinjab MM. Quick guide to the management of keratoconus. A systematic step-by-step approach. Dordrecht; Springer-Verlag Berlin Heidelberg; 2012: 59-93.
29. Vega-Estrada A, Alio JL, Brenner LF, Javaloy J, Plaza Puche AB, Barraquer RI, Teus MA, Murta J, Henriques J, Uceda-Montanes A. Outcome analysis of intracorneal ring segments for the treatment of keratoconus based on visual, refractive, and aberrometric impairment. *Am J Ophthalmol* 2013; 155: 575-584.
30. Fukuoka S, Honda N, Ono K, Mimura T, Usui T, Amano S. Extended long-term results of penetrating keratoplasty for keratoconus. *Cornea* 2010; 29: 528-530.
31. Pramanik S, Musch DC, Sutphin JE, Farjo AA. Extended long-term outcomes of penetrating keratoplasty for keratoconus. *Ophthalmology* 2006; 113: 1633-1638.
32. Jensen LB, Hjortdal J, Ehlers N. Longterm follow-up of penetrating keratoplasty for keratoconus. *Acta Ophthalmol* 2010; 88: 347-351.
33. Melles GR, Lander F, Rietveld FJ, Remeijer L, Beekhuis WH, Binder PS. A new surgical technique for deep stromal, anterior lamellar keratoplasty. *Br J Ophthalmol* 1999; 83: 327-333.
34. Anwar M, Teichmann KD. Big-bubble technique to bare Descemet's membrane in anterior lamellar keratoplasty. *J Cataract Refract Surg* 2002; 28: 398-403.
35. Steven P, Le Blanc C, Lankenau E, Krug M, Oelckers S, Heindl LM, Gehlsen U, Huettmann G, Cursiefen C. Optimising deep anterior lamellar keratoplasty (DALK) using intraoperative online optical coherence tomography (iOCT). *Br J Ophthalmol* 2014 Mar 3. doi: 10.1136/bjophthalmol-2013-304585. [Epub ahead of print]
36. Bahar I, Kaiserman I, Srinivasan S, Ya-Ping J, Slomovic AR, Rootman DS. Comparison of three different techniques of corneal transplantation for keratoconus. *Am J Ophthalmol* 2008; 146: 905-912.
37. Watson SL, Ramsay A, Dart JK, Bunce C, Craig E. Comparison of deep lamellar keratoplasty and penetrating keratoplasty in patients with keratoconus. *Ophthalmology* 2004; 111: 1676-1682.
38. Kim KH, Choi SH, Ahn K, Chung ES, Chung TY. Comparison of refractive changes after deep anterior lamellar keratoplasty and penetrating keratoplasty for keratoconus. *Jpn J Ophthalmol* 2011; 55: 93-97.
39. Funnell CL, Ball J, Noble BA. Comparative cohort study of the outcomes of deep lamellar keratoplasty and penetrating keratoplasty for keratoconus. *Eye (Lond)* 2006; 20: 527-532.
40. Reinhart WJ, Musch DC, Jacobs DS, Lee WB, Kaufman SC, Shtein RM. Deep anterior lamellar keratoplasty as an alternative to penetrating keratoplasty: a report by the American Academy of Ophthalmology. *Ophthalmology* 2011; 118: 209-218.
41. Asbell PA, Maloney RK, Davidorf J, Hersh P, McDonald M, Manche E; Conductive Keratoplasty Study Group. Conductive keratoplasty for the correction of hyperopia. *Trans Am Ophthalmol Soc* 2001; 99: 79-84.
42. McDonald MB, Durrie D, Asbell P, Maloney R, Nichamin L. Treatment of presbyopia with conductive keratoplasty: six-month results of the 1-year United States FDA clinical trial. *Cornea* 2004; 23: 661-668.
43. Alió JL, Claramonte PJ, Cáliz A, Ramzy MI. Corneal modeling of keratoconus by conductive keratoplasty. *J Cataract Refract Surg* 2005; 31: 190-197.
44. Lyra JM, Trindade FC, Lyra D, Bezerra A. Outcomes of radiofrequency in advanced keratoconus. *J Cataract Refract Surg* 2007; 33: 1288-1295.
45. Kato N, Toda I, Kawakita T, Sakai C, Tsubota K. Topography-guided conductive keratoplasty: treatment for advanced keratoconus. *Am J Ophthalmol*. 2010; 150: 481-489.
46. Ormonde S. Refractive surgery for keratoconus. *Clin Exp Optom* 2013; 96: 173-182.

47. Tahzib NG, Nuijts RM, Wu WY, Budo CJ. Longterm study of Artisan phakic intraocular lens implantation for the correction of moderate to high myopia: ten-year follow-up results. *Ophthalmology* 2007; 114: 1133-1142.
48. Landes M, Worst JG, van Rij G. Long-term results of correction of high myopia with an iris claw phakic intraocular lens. *J Refract Surg* 2000; 16: 310-316.
49. Menezo JL, Peris-Martinez C, Cisneros AL, Martinez-Costa R. Phakic intraocular lenses to correct high myopia: Adatomed, Staar, and Artisan. *J Cataract Refract Surg* 2004; 30: 33-44.
50. Budo C, Bartels MC, van Rij G. Implantation of Artisan toric phakic intraocular lenses for the correction of astigmatism and spherical errors in patients with keratoconus. *J Refract Surg* 2005; 21: 218-222.
51. Venter J. Artisan phakic intraocular lens in patients with keratoconus. *J Refract Surg* 2009; 25: 759-764.
52. Sedaghat M, Ansari-Astaneh MR, Zarei-Ghanavati M, Davis SW, Sikder S. Artisan iris-supported phakic IOL implantation in patients with keratoconus: a review of 16 eyes. *J Refract Surg* 2011; 27: 489-493.
53. Kato N, Toda I, Hori-Komai Y, Sakai C, Arai H, Tsubota K. Phakic intraocular lens for keratoconus. *Ophthalmology* 2011; 118: 605.
54. Moshirfar M, Gregoire FJ, Mirzaian G, Whitehead GF, Kang PC. Use of Verisyse iris-supported phakic intraocular lens for myopia in keratoconic patients. *J Cataract Refract Surg* 2006; 32: 1227-1232.
55. Kasparova EA, Kasparov AA. Six-year experience with excimer laser surgery for primary keratoconus in Russia. *J Refract Surg* 2003; 19 (Suppl): 250-254.
56. Chelala E, Rami HE, Dirani A, Fadlallah A, Fakhoury O, Warrak E. Photorefractive keratectomy in patients with mild to moderate stable keratoconus: a five-year prospective follow-up study. *Clin Ophthalmol* 2013; 7: 1923-1928.
57. Kanellopoulos AJ. Comparison of sequential vs same-day simultaneous collagen cross-linking and topography-guided PRK for treatment of keratoconus. *J Refract Surg* 2009; 25: 812-818.
58. Dirani A, Fadlallah A, Syed ZA, Chelala E, Khoueir Z, Cherfan G, Jarade E. Non-topography-guided photorefractive keratectomy for the correction of residual mild refractive errors after ICRS implantation and CXL in keratoconus. *J Refract Surg* 2014; 30: 266-271.
59. Severinsky B, Wajnsztajn D, Frucht-Pery J. Silicone hydrogel mini-scleral contact lenses in early stage after corneal collagen cross-linking for keratoconus: a retrospective case series. *Clin Exp Optom* 2013; 96: 542-546.
60. Moreira LB, Bardal RA, Crisigiovanni LR. Contact lenses fitting after intracorneal ring segments implantation in keratoconus. *Arq Bras Oftalmol* 2013; 76: 215-217.
61. Severinsky B, Behrman S, Frucht-Pery J, Solomon A. Scleral contact lenses for visual rehabilitation after penetrating keratoplasty: Long term outcomes. *Cont Lens Anterior Eye* 2014; 37: 196-202.
62. Shafik Shaheen M1, El-Kateb M, El-Samadouny MA, Zaghoul H. Evaluation of a toric implantable collamer lens after corneal collagen crosslinking in treatment of early-stage keratoconus: 3-year follow-up. *Cornea* 2014; 33: 475-480.
63. Coskunseven E, Onder M, Kymionis GD, Diakonis VF, Arslan E, Tsiklis N, Bouzoukis DI, Pallikaris I. Combined Intacs and posterior chamber toric implantable collamer lens implantation for keratoconic patients with extreme myopia. *Am J Ophthalmol* 2007; 144: 387-389.
64. Al-Tuwairqi W, Sinjab MM. Intracorneal ring segments implantation followed by same-day topography-guided PRK and corneal collagen CXL in low to moderate keratoconus. *J Refract Surg* 2013; 29: 59-63.