Importance of radiofrequency in ophthalmology

Importância da radiofrequência na oftalmologia

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ABSTRACT

This paper reviews and makes a critical analysis of radiofrequency in ophthalmology.

Localized heating of the cornea has been apllied since 1889 for different therapeutic and surgical objectives.The principle that heating corneal tissue causes shrinking of the collagen that changes the corneal curvature. After the approval of FDA in 2004, we initiated a multicenter study in Brazil coordinated by ABC School of Medicine that resulted in an analyses of 258 patients. Inconclusion the study showed that the procedure had a temporary result and the best results were obtained in patients between 45 and 55 years old without optical correction for far.We believe that the problem has not been solved yet and a great deal of research effort should be focused.

Keywords: *Radio waves/therapeutic use; Eye diseases/therapy; Corneal topography*

RESUMO

Este trabalho revisa e faz uma análise crítica da radiofrequência em oftalmologia.

O aquecimento da córnea tem sido realizado desde 1889 com diferentes finalidades terapêuticas e cirúrgicas. O princípio do aquecimento da córnea causa um enrugamento do colágeno que muda a curvatura da córnea. Após a aprovação da FDA em 2004, iniciou-se um estudo multicêntrico no Brasil coordenado pela Faculdade de Medicina do ABC que resultou na análise de 258 pacientes. Como conclusão o estudo mostrou que o procedimento tem um resultado temporário e que os melhores resultados foram obtidos em pacientes entre 45 e 55 anos de idade sem correção óptica para longe.

Acreditamos que o problema ainda não foi resolvido e que novas pesquisas devem ser realizadas.

Descritores: Ondas de rádio/uso terapêutico; Oftalmopatias/terapia; Topografia da córnea

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Introduction

The first studies on radiofrequency date back to 1864, when the Scottish scientist James Clerk Maxwell, after observing the experiments made by Faraday, managed to produce an electromagnetic radiation that travelled through space with wave-like features and calculated that those waves propagated at the speed of light.[1-4]

The properties of electromagnetic radiation were confirmed in 1888 by the experiments of Heinrich Hertz, who used oscillating charges to produce high frequencies, around 500 Mc/s, for the first time. Due to the importance of Hertz's experiments, the unit c/s (cycles per second) was named after him (Hz).

Further technological developments made it possible to produce higher frequencies up to 300 GHz (300 x 10^6 kHz). Such frequencies, classified as SHF (Super High Frequencies) and EHF (Extremely High Frequencies), can be used for communication and also have the property of being absorbed by water (H_2O) or oxygen (O_2) molecules.[3,4]

Studies on the absorption of electromagnetic waves by water and oxygen showed that waves of shorter wavelength and higher frequency produce heat in the irradiated area.

In ophthalmology, radiofrequency was initially used for refractive surgery in 1980 with the works of Rowsey et al. and Doss and Rowsey, who used it to treat keratoconus. The technology was later used for several conditions, such as ocular plastic surgery, conjunctival surgery, glaucoma surgery and complications of cataract surgery.[5-18]

Radiofrequency for treating refractive errors

In the United States of America, after approval by the Federal Drug Administration (FDA) on April 11, 2002, a device named "ViewPoint™ CK System", from Refractec, Inc., California, was launched in the market. The system, based on the concepts of thermokeratoplasty, applies a high frequency, low energy electrical current to the corneal stroma, producing a temperature sufficient to shrink collagen fibres (Figure 1). The device has been approved by the FDA for the treatment of hyperopia from +0.75 to +3.25D with astigmatism < -0.75 D and a difference up to 0.50D between visual acuity with and without cycloplegia in persons over 40 years of age.[19 -31]

On February 6, 2004 the FDA approved the same technology for the correction of presbyopia, aiming at balanced vision.

For the adoption of the technology in Brazil, the Department of Ophthalmology of ABC Medical School, with the approval of the Ministry of Health, prepared a National Protocol for the Study of Radiofrequency in Ophthalmology. The protocol began in 2002 with 300 operations using an animal model. This study established the criteria for optimal power and application time to obtain the best effects on the corneal stroma — a power of 0.6W, with 0.60 seconds per pulse (Figures 1, 2 and 3).

In the second stage of the protocol 40 volunteers were selected, 20 of them hyperopic and 20 presbyopic. The volunteers underwent radiofrequency therapy at the Eye Institute of the ABC Medical School.

After this pilot phase, having established the optimal radiofrequency parameters for the correction of refractive errors, a multicenter study was conducted on the treatment of presbyopia in 45 reference centres throughout Brazil.[27,28,32]

The study, concluded in 2010, assessed the anatomical behaviour of the cornea in 258 patients and showed that, after undergoing radiofrequency therapy, all patients had an abrupt increase in corneal curvature (Chart 1). After this initial peak

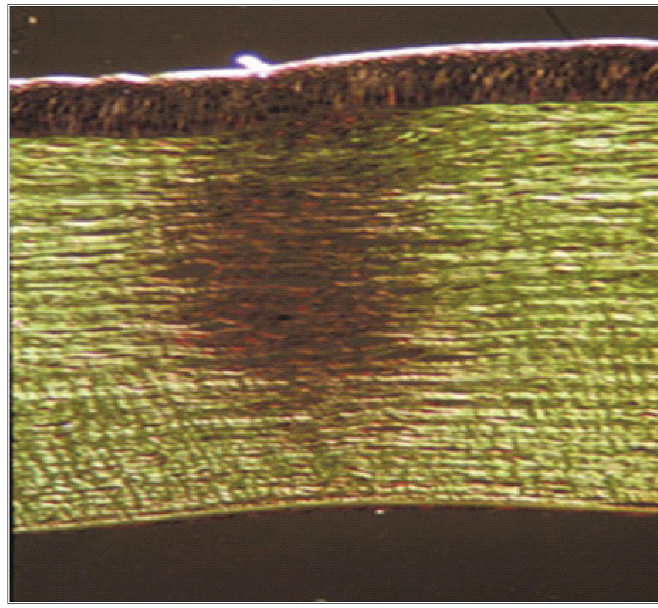


Figure 1: Collagen shrinking

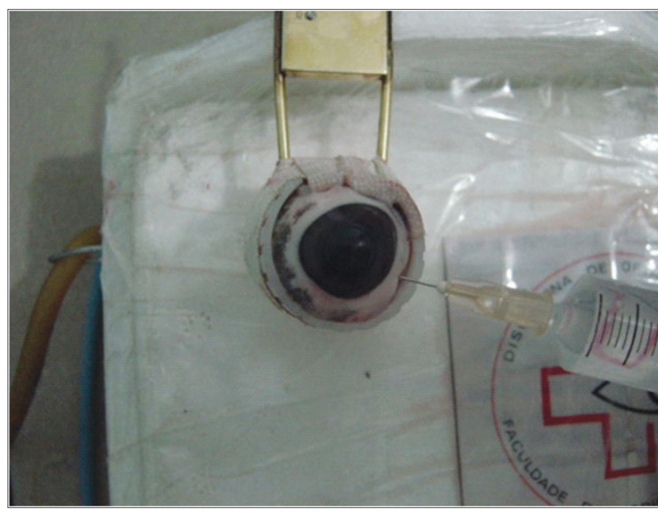


Figure 2: Applying saline solution

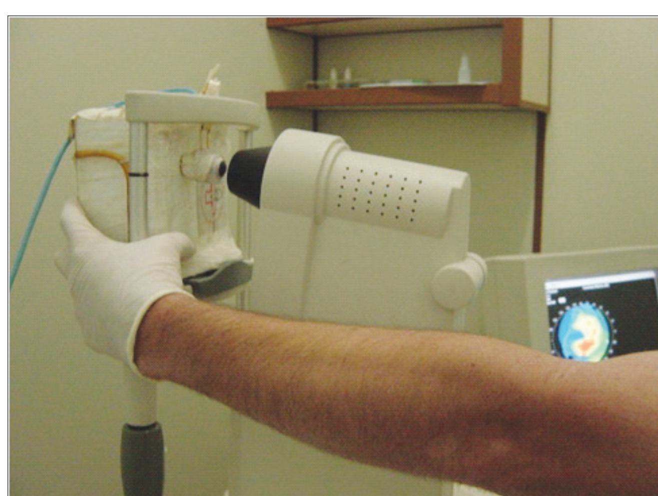


Figure 3: Corneal topography

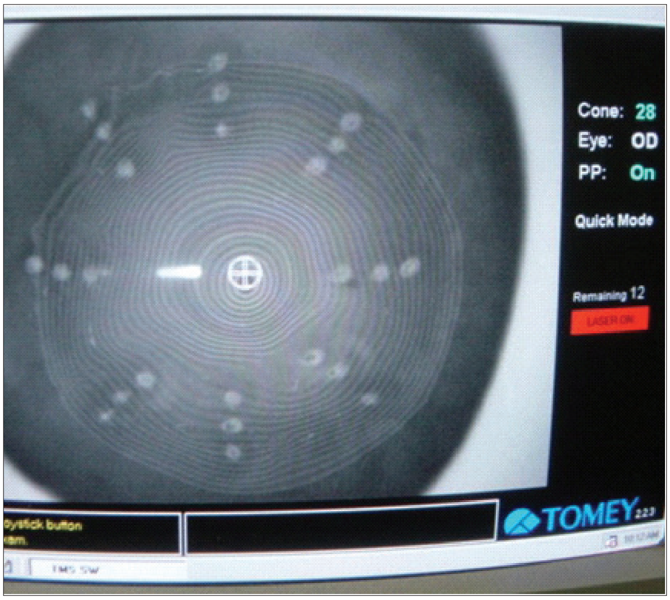
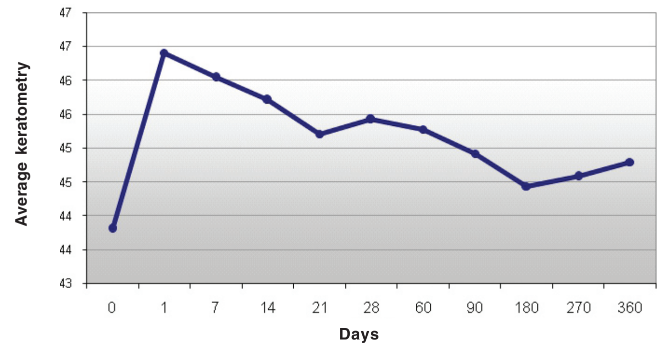


Figure 4: Corneal topographic map

Chart 1

Average keratometry



Days	0	1	7	14	21	28	60	90	180	270	360
Average	43,81	46,41	46,04	45,71	45,21	45,42	45,28	44,92	44,44	44,58	44,79
Stand. Dev.	1,54	1,91	1,84	1,74	2,65	1,64	1,51	1,69	1,66	1,49	1,78
N	159	115	127	114	103	109	88	84	71	34	19

Chart 2

Efficacy in 90 days

Near visual acuity without correction preoperative x
Near visual acuity without correction preoperative

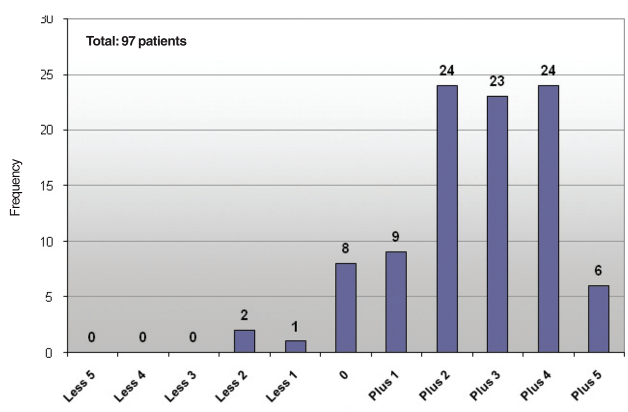
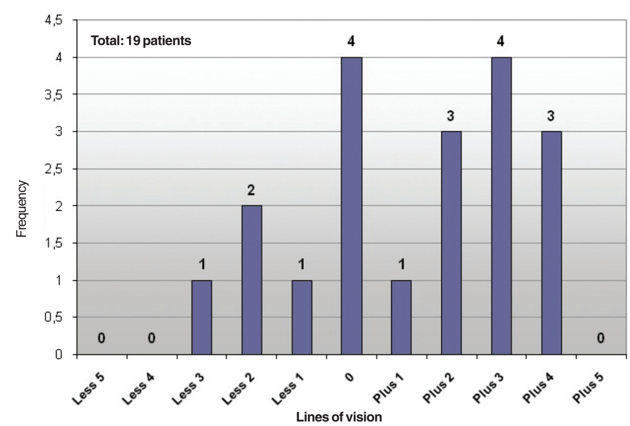


Chart 3

Efficacy in 360 days

Near visual acuity without correction preoperative x
Near visual acuity without correction preoperative



increase, the curvature decreased over time, with a loss of therapeutic effect.

The desired effects on near vision were observed in 88% of operated eyes 90 days after the procedure and were maintained in 70% after 360 days (Charts 2 and 3).

Safety analysis showed that 96.8% of patients maintained their preoperative binocular distance vision after 90 days, and 88% did so after 360 days (Charts 4 and 5).

In some cases (26.5%) distance vision improved without correction. It is important to note that in all cases distance vision worsens abruptly in the immediate postoperative period, but as the corneal curvature decreases, distance vision improves progressively without the expected loss of near vision.

The patients who had a greater loss of distance vision were the ones with higher degrees of latent hyperopia.

In the near vision chart (Chart 6) the percentage of patients with vision between J1 and J3 during the period of analysis remained high.

It was therefore concluded that the treatment of presbyopia with radiofrequency is **safe and effective** and that it produces a **temporary effect**.

Regarding the surgical technique, it is clear that the best results are obtained when the corneal surface is kept dry during the procedure and that centralisation and visualisation of corneal marks is facilitated when performed under a microscope with coaxial illumination (microscopes coupled with excimer laser devices hinder marking).

Furthermore it can be stated that this procedure is "surgeon dependent", i.e. the position of the probe and its depth of penetration, as well as corneal compression during application, are important factors for achieving best results, because bad centralisation of corneal marking leads to worse refractive outcomes, with high astigmatism and lower visual acuity.

Regarding the results of the procedure, distance visual acuity tends to be low in the immediate postoperative period, causing discomfort to most patients. On average, this discomfort decreases after 30 days with the stabilisation of corneal curvature. A partial loss of the therapeutic effect occurs approximately 6

Chart 4

Safety in 90 days

Near visual acuity without correction preoperative x Near visual acuity without correction preoperative

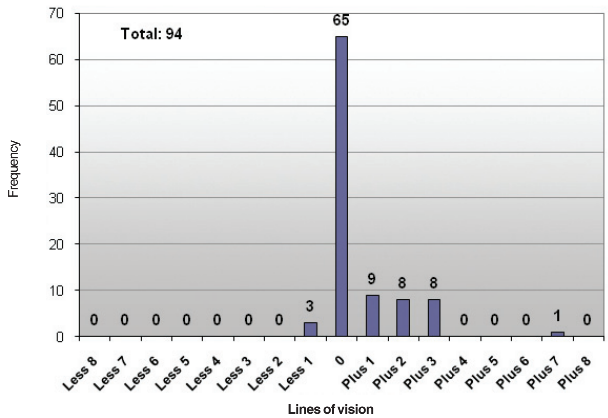


Chart 5

Safety in 360 days

Near visual acuity without correction preoperative x Near visual acuity without correction preoperative

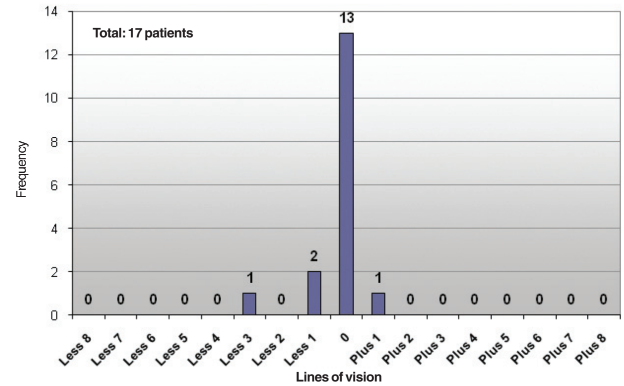
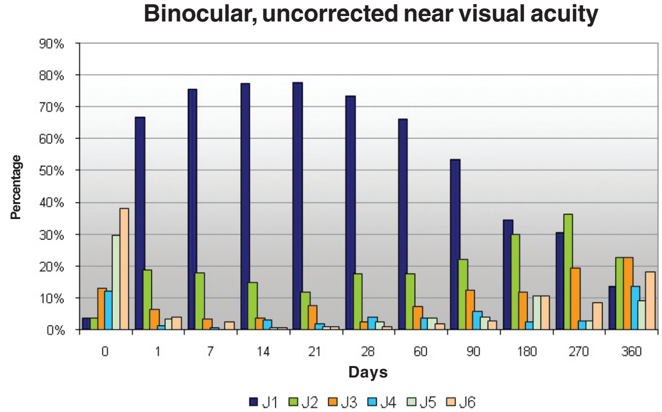


Chart 6

Binocular, uncorrected near visual acuity



		Days										
		0	1	7	14	21	28	60	90	180	270	360
Lines of Vision	J1	7	104	118	105	93	96	72	56	29	11	3
	J2	7	29	28	20	14	23	19	23	25	13	5
	J3	26	10	5	5	9	3	8	13	10	7	5
	J4	24	2	1	4	2	5	4	6	2	1	3
	J5	59	5	0	1	1	3	4	4	9	1	2
	J6	76	6	4	1	1	1	2	3	9	3	4
Total		199	156	156	136	120	131	109	105	84	36	22

		Days										
		0	1	7	14	21	28	60	90	180	270	360
Lines of Vision	J1	3,5%	66,7%	75,6%	77,2%	77,5%	73,3%	66,1%	53,3%	34,5%	30,6%	13,6%
	J2	3,5%	18,6%	17,9%	14,7%	11,7%	17,6%	17,4%	21,9%	29,8%	36,1%	22,7%
	J3	13,1%	6,4%	3,2%	3,7%	7,5%	2,3%	7,3%	12,4%	11,9%	19,4%	22,7%
	J4	12,1%	1,3%	0,6%	2,9%	1,7%	3,8%	3,7%	5,7%	2,4%	2,8%	13,6%
	J5	29,6%	3,2%	0,0%	0,7%	0,8%	2,3%	3,7%	3,8%	10,7%	2,8%	9,1%
	J6	38,2%	3,8%	2,6%	0,7%	0,8%	0,8%	1,8%	2,9%	10,7%	8,3%	18,2%
Total		100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

months after the procedure, when the patient reports a decrease in near visual acuity. There is also a phenomenon of decoupling between postoperative refraction and visual acuity in operated eyes, i.e., the measured refraction for distance vision does not match the visual acuity. This finding supports the theory of the "blend" effect described by Holladay where a multifocal corneal effect would occur due to the prolate central cornea which would be responsible for the improvement in near vision, and not the initially induced myopia.

With respect to the indications of radiofrequency for the correction of presbyopia, ideally patients should have a preoperative visual acuity of 20/20 in both eyes without correction. Occasional hyperopia with cycloplegia should not exceed +0.50SD with +0.50CD in both eyes, to prevent any loss of distance vision postoperatively. The ideal age for the procedure is between 45 and 55 years due to the progressive nature of presbyopia and accommodative properties. Patients with very functional or completely ineffective accommodation should not undergo the procedure.

The temporary effect should be considered a positive feature of the procedure, because presbyopia may still be progressing at this age, therefore definitive procedures are contraindicated.

Reoperation may be indicated only when the therapeutic effect has remitted completely and, according to the literature, should be performed at the same sites as in the previous procedure.

Definite loss of corneal tissue does not occur with the procedure, the optical centre of the cornea is preserved, and the resulting monovision provides satisfactory distance visual acuity.

Several studies have also assessed the use of thermokeratoplasty with radiofrequency to correct astigmatism. Wen Xuet al. concluded in 2010 that the nomogram for conductive keratoplasty provides good results in the treatment of hyperopic astigmatism.[26]

Other Ophthalmic Indications

In modern medicine, many therapeutic techniques can be used for different purposes. The various types of lasers, as well as the various radiofrequency devices, can be used for cauterisation, coagulation, tissue contraction, vaporisation, and cutting.[33-39]

Radiofrequency can often be used to obtain results similar to lasers, but at lower costs, by simply modulating the frequency, power, exposure time and pulse and by using uni-, bi- or tripolar probes.[25,26,38,39]

Ocular plastic surgery

In ocular plastic surgery, radiofrequency has been used for blepharoplasty, excision of tumours, treatment of xanthelasma, trichiasis, and recanalisation of the nasolacrimal duct.[9.18]

Conjunctiva

In the conjunctiva, radiofrequency is used for coagulation, to treat pterygium and to remove tumours.[10]

Extrinsic ocular muscles

In strabismus, radiofrequency can be used to weaken medial or lateral extrinsic muscles in cases of mild strabismus and even to cut muscles during surgery.

Cornea

In external diseases, radiofrequency is used to treat keratoconus and bullous keratopathy.[11,12,24,30,33-37,40-45]

Cataract surgery

In cataract surgery, radiofrequency is more frequently used to perform anterior capsulorhexis and also posterior capsulorhexis in congenital cataract.[13,14]

Glaucoma

For glaucoma, several studies have shown that radiofrequency can be used to create transconjunctival fistulas in the trabecular meshwork with a device called the trabectome.

Referências

1 Rowsey JJ,Gaylor JR,Dahlstrom R, Doss JD. Los Alamos keratoplastytechniques. Contact Intraocul Lens Med J. 1980;6:1-12.

2 Doss JD,Rowsey JJ. A technique for the selective heating of corneal stroma. Contact Intraocul Lens Med J. 1980;6:13-7.

3 Rowsey JJ,Doss JD. Preliminary report of Los Alamos Keratoplasty Techniques. Ophthalmology. 1981;88(8):755-60.

4 Doss JD. Multipolar corneal-shaping electrode with flexible removable skirt.U.S. Patent 4 381 007, Apr 26. 1983.

5 RowseyJJ. Electrosurgical keratoplasty: update and retraction. InvestOphthalmol Vis Sci. 1987;28:S224.

6 Neumann SM,Kainer RA, Severin GA. Reaction of normal equine eyes to radio-frequency current-induced hyperthermia. Am J Vet Res. 1982;43(11):1938-44.

7 Glaze MB, Turk MA. Effects of radiofrequency hyperthermia on the healthy canine cornea. Am J Vet Res. 1986;47(4):913-8.

8 Paulino LV, Paulino E, Barros RA, Salles AG,Rehder JRCL. Alteração topográfica da curvatura corneana após aplicação de radiofrequência em modelo animal.ArqBras Oftalmol. 2005;68(4):451-6.

9 Polyak SL. Historical appendix to the human eye in anatomical transparencies. Rochester, New York: Baush& Lomb; 1943. 30p.

10 Waring GO 3rd, Lynn MJ, McDonnell PJ. Results of the prospective evaluation of radial keratotomy (PERK) study 10 years after surgery. Arch Ophthalmol. 1994;112(10):1298-308.

11 Stevens SX,Polac PJ, Young DA. Complications of radial keratotomy. In: Krachmer JH, Mannis MJ, Jolland EJ, Palay DA. Cornea:text and color atlas [CD-ROM]. St Louis: Mosby; 1998. 3(168).

12 Gasset AR,Shaw EL, Kaufman HE,Itoi M,Sakimoto T, Ishii Y.Thermokeratoplasty. Trans Am AcadOphthalmolOtolaryngol. 1973;77(4):OP441-54.

13 Caster AI. The Fyodorov technique of hyperopia correction by thermal coagulation: a preliminary report. J RefractSurg. 1988;4:105-8.

14 Neumann AC,Fyodorov S, Sanders DR. Radial thermokeratoplasty for the correction of hyperopia. RefractCorneal Surg. 1990;6(6):404-12.

15 Fyodorov S, Avashina A, Alexandrova OG. Analysis of surgical results of astigmatism correction by the technique of thermalcoagulation and evaluation of accuracy of refractive effect prediction. OphthalmolSurg. 1990;3(1):3-12.

16 Feldman ST, Ellis W,Frucht-Pery J,ChayetA, Brown SI. Regression of effect following radial thermokeratoplasty in humans. RefractCorneal Surg. 1989;5(5):288-91.

17 Barraquer JI. Modification of refraction by means of intra-corneal inclusions. IntOphthalmolClin. 1966;6(1):53-78

18 Werblin TP,Klyce SD. Epikeratophakia: the surgical correction of aphakia. I.Lathing of corneal tissue. Curr Eye Res. 1981;1(3):123-9.

19 Werblin TP, Kaufman HE. Epikeratophakia: the surgical correction of aphakia. II.Preliminary results in a non-human primate model. Curr Eye Res. 1981;1(3):131-7.

20 Werblin TP, Kaufman HE, Friedlander MH, Granet N. Epikeratophakia: the surgical correction of aphakia. III.Preliminary results of a prospective clinical trial. Arch Ophthalmol. 1981;99(11):1957-60.

21 Busin M,Cusumano A,Spitznas M. Epithelial interface cysts after epikeratophakia. Ophthalmology. 1993;100(8):1225-9.

22 Durrie DS,Habrich DL,Dietze TR. Secondary intraocular lens implantation vsepikeratophakia for the treatment of aphakia. Am J Ophthalmol. 1987;103(3 Pt 2):384-91.
23 Berjano EJ, Navarro E,Ribera V,Gorris J,AlióJL. Radiofrequency heating ofthe cornea: an engineering review of eletrodes and aplicators. Open Biomed Eng J. 2007;1:71-6.
24 Cormier G,Brunette I,BoisjolyHM,LeFrancois M,ShiZH,QuertinMC. Anterior stromalpunctures for bullous keratopathy. ArchOphthalmol.1996;114(6):654-8.
25 McDonald MB,Talamo JH. Myopic photorefractive keratectomy: the experience in the US with the Visixexcimer laser. In: Salz JJ, McDonnell PJ, McDonald MB, editors. Corneal laser surgery. St Louis: Mosby; 1995. p 45-55.
26 Xu W,Ye P,Yao K,Ma J,Xu H. Conductive keratoplasty for the treatment of astigmatism induced by corneal trauma or incision.J RefractSurg.2010;26(1):33-42.
27 Berjano EJ,Saiz J,Ferrero JM. Radio-frequency heating of the cornea: theoretical model and in vitro experiments. IEEE Trans Biomed Eng. 2002;49(3):196-205.
28 Mulet ME,Alió JL, Salem TF,Berjano EJ. Corneal thermal lesions with radiofrequency currents for thermokeratoplasty. InvestOphthalmol Vis Sci. 2000;41:S919.
29 Berjano EJ,Saiz J,Alió JL, Ferrero JM. Ring electrode for radio-frequency heating of the cornea: modelling and in vitro experiments. MedBiolEngComput. 2003;41(6):630-9.
30 Lyra JM,Trindade FC,Lyra D,Bezerra A. Outcomes of radiofrequency in advanced keratoconus. J Cataract Refract Surg. 2007;33(7):1288-95.Erratum inJ Cataract Refract Surg. 2007;33(10):1679.
31 Pearce JA. Numerical model study of radio frequency conductive keratoplasty in the cornea for correction of hyperopia.Proc Second Joint EMBS/BMES Conf. 2002;3:2149-50.
32 Berjano EJ,Alió JL,Saiz J. Modeling for radio-frequency conductive keratoplasty: implications for the maximum temperature reached in the cornea.Physiol Meas. 2005;26(3):157-72.
33 Alió JL,Claramonte PJ,Cáliz A,Ramzy MI. Corneal modeling of keratoconus by conductive keratoplasty. J Cataract Refract Surg. 2005;31(1):190-7.
34 McDonald MB,Hersh PS, Manche EE, Maloney RK,Davidorf J,Sabry M; ConductiveKeratoplastyUnited StatesInvestigatorsGroup. Conductivekeratoplasty for the correction of low to moderate hyperopia: U.S. clinical trial 1-year results on 355 eyes. Ophthalmology. 2002;109(11):1978-89; discussion 1989-90.
35 Seiler T, McDonnell PJ. Excimer laser photorefractive keratectomy. SurvOphthalmol. 1995;40(2):89-118.Review.
36 Colliac JP,Shammas HJ. Optics for photorefractive keratectomy. J Cataract Refract Surg. 1993;19(3):356-63.
37 Knight SA. Introduction to ultra-high-frequency radio engineering. London: Pitman & Sons; 1975. p. 3-8.
38 Seiler T,Matallana M,Bende T. Laser thermokeratoplasty by means of a pulsed holmium:YAG laser for hyperopic correction. RefractCorneal Surg. 1990;6(5):335-9.
39 Koch DD,Kohnen T, McDonnell PJ,Menefee R, Berry M. Hyperopia correction by non-contact holmium:YAG laser thermal keratoplasty: U.S. phase IIA clinical study with 2-year follow-up. Ophthalmology. 1997;104(11):1938-47.
40 Pallikaris IG,Naoumidi TL,Astyrakakis NI. Conductive keratoplasty to correct hyperopic astigmatism. J Refract Surg. 2003;19(4):425-32
41 Kormann RB, Moreira H.Eletrólise com radiofrequência no tratamento da triquíase. ArqBras Oftalmol. 2007;70(2):276-80.
42 Fonseca Junior NL, Lucci LMD, Paulino LV,Rehder JRVL. O uso do laser de argônio no tratamento da triquíase. ArqBras Oftalmol.2004;67(2):277-81.
43 Macedo AC,Ishirara C,FairbanksD,VitielloNetoV,Rehder JRCL. Micropuntura com radiofrequência no tratamento da ceratopatiabolhosa sintomática.RevBras Oftalmol.2010;69(3):152-8.
44 Gomes JA,Haraguchi DK,Zambrano DU,IzquierdoJúnior L, Cunha MC, deFreitas D. Anterior stromal puncture in the treatment of bullous keratopathy: six-month follow-up. Cornea. 2001;20(6):570-2.
45 Mosaed S, Rhee DJ,Filippopoulos T,Tseng H,Deokule S,Weinreb RN. Trabectomeoutcomes in adult open angle glaucoma patients – on year follow-up. ClinSurg J Ophthalmol.2010;28:8.

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