Removal of Cataracts Through Small Corneal Incision After Division with Automated Loop System in Rabbit Eyes

Tavşan Gözlerinde Kataraktların Otomatize Kement Sistemi ile Bölündükten Sonra Küçük Korneal Kesiden Çıkarılması

Bahri AYDIN[1], Mesut ERDURMUŞ[2], Fatma YÜLEK[3], Erdem DİNÇ[4], Zeynel ARSLANYILMAZ[5], Hüseyin SERT[6], Gökhan GÜRELİK[7], İbrahim Fevzi HEPŞEN[8], Berati HASANREİSOĞLU[7]

ABSTRACT

Purpose: To evaluate the effectiveness of the automated loop system for fragmentation of the lens nucleus in an experimental rabbit model.

Materials and Methods: Sixteen albino New Zealand rabbits were grouped into three: In group 1 (n=6) soft rabbit lenses were divided into multiple pieces with automated loop system and removed through 5mm corneal incision. In group 2 (n=4), rabbit lenses were extracted by the same method as group 1. Thereafter, hard human lens was inserted into the anterior chamber; divided and removed by the loop system. Group 3 was composed of 6 rabbits that had ECCE surgery. The corneal edema, conjunctival hyperemia, intraocular pressures were evaluated on postoperative 2nd and 7th days with biomicroscopy and Schiotz tonometry.

Results: In group 1 and 2, soft rabbit nuclei and hard mature human nuclei could be divided into many small pieces by the automated loop system. No significant intraoperative and postoperative complications were developed in any of the treated rabbit eyes. The rate of the corneal edema in group 1 was similar to those of group 3. The corneal edema and conjunctival hyperemia rates were higher in the group 2 compared to both group 1 and group 3. However, the differences between groups for any of the parameters were not statistically significant (p>0.05).

Conclusion: The automated loop system divided both the soft rabbit and hard human nucleus successfully into multiple pieces and the nucleus pieces can easily be removed from 5 mm corneal incision.

Key Words: Automated loop system, hard cataracts, phacofragmentation, cataract surgery.

ÖZ

Amaç: Lens nükleusunun fragmantasyonu için kullanılan otomatize kement sisteminin etkinliğini deneysel tavşan modelinde değerlendirmek.

Gereç ve Yöntem: On altı adet albino Yeni Zelanda tavşanı üç gruba ayrıldı: Grup 1'de (n=6) yumuşak tavşan lensleri otomatize kement sistemi ile birçok parçaya bölündü ve 5 mm'lik korneal kesiden çıkarıldı. Grup 2'de tavşan lensleri grup 1 ile aynı yöntem kullanılarak çıkartıldı. Daha sonra sert insan lensi ön kamaraya yerleştirildi ve kement sistemi ile bölünüp çıkarıldı. Grup 3'de yer alan 6 tavşana EKKE cerrahisi yapıldı. Postoperatif 2. ve 7. günde biomikroskop ve Schiotz tonometrisi ile korneal ödem, konjonktival hiperemi, intraoküler basınç değerlendirildi.

Bulgular: Grup 1 ve 2'de yumuşak tavşan nükleusu ve matür insan nükleusu otomatize kement sistemi ile birçok küçük parçaya bölünebildi. Tedavi edilen hiç bir tavşan gözünde intraoperatif ve postoperatif anlamlı komplikasyon gelişmedi. Korneal ödem oranı grup 1 ve grup 3 arasında benzerdi. Korneal ödem ve konjonktival hiperemi oranı grup 2'de grup 1 ve grup 3 ile karşılaştırıldığında daha yüksekti. Bununla birlikte gruplar arasındaki hiç bir parametrede istatistiksel olarak anlamlı fark yoktu (p>0.05).

Tartışma: Otomatize kement sistemi ile hem yumuşak tavşan nükleusu ve hem de sert insan nükleusu başarılı bir şekilde birçok parçaya bölündü ve nükleus parçaları 5 mm'lik korneal kesiden kolay bir şekilde çıkarıldı.

Anahtar Kelimeler: Otomatize kement sistemi, sert kataraktlar, fakofragmantasyon, katarakt cerrahisi.

1- M.D. Asistant Professor, Mersin University Faculty of Medicine, Department of Ophthalmology, Mersin/TURKEY
AYDIN B., baydunus@tyahoo.com
2- M.D. Asistant Professor, Abant İzzet Baysal University Faculty of Medicine, Department of Ophthalmology, Bolu/TURKEY
ERDURMUŞ M., merdurmus@yahoo.com
3- M.D. Associate Professor, Atatürk Trainig and Research Hospital Eye Clinic, Ankara/TURKEY
YÜLEK F., fatmayulekt@yahoo.com
4- M.D., Mersin University Faculty of Medicine, Department of Ophthalmology, Mersin/TURKEY
DİNÇ E., erdem_dinc@hotmail.com
5- M.D. Asistant, Fatih University Faculty of Medicine, Department of Ophthalmology, Ankara/TURKEY
ARSLANYILMAZ Z., arslanyilmaz@yahoo.com
6- M.D. Asistant Professor, Fatih University Faculty of Medicine, Department of Anesthesiology and Reanimation, Ankara/TURKEY
SERT H., serthuseyin@yahoo.com
7- M.D. Professor, Mersin University Faculty of Medicine, Department of Ophthalmology, Mersin/TURKEY
GÜRELİK G., gurelik@gazi.edu.tr
HASANREİSOĞLU B., berati@gazi.edu.tr
8- M.D. Professor, Fatih University Faculty of Medicine, Department of Ophthalmology, Ankara/TURKEY
HEPŞEN İ.F.,

Geliş Tarihi - Received: 12.01.2012
Kabul Tarihi - Accepted: 21.02.2012
Glo-Kat 2012;7:7-12

Yazışma Adresi / Correspondence Adress: M.D., Erdem DİNÇ
Mersin University Faculty of Medicine, Department of Ophthalmology, Mersin/TURKEY

Phone: +90 324 337 43 00
E-Mail: zaferdr2000@gmail.com

INTRODUCTION

One of the main problems in current cataract surgery is the surgical manipulation of the mature and hard cataracts. Surgical removal of hard and mature cataracts by phacoemulsification method may increase rates of complications such as endothelial cell loss and posterior capsular rupture.[1, 2]

On the other hand performing extracapsular cataract extraction surgery (ECCE) in these eyes may cause problems like wound healing and induced astigmatism.[3] These obstacles in the management of mature hard cataracts have led to development of alternative surgical techniques in recent years. Initially division of the nucleus by the help of a loop made of steel wire was described by Keener and later on various manual phacofragmentation techniques have been developed.[4] These techniques have aimed mainly to fragment the cataractous lens without ultrasound energy and to express it from a corneal or corneoscleral incision that is as small as possible.

With this study we aim to evaluate the effectiveness and possible complications of the automated loop (means lasso in Turkish) system developed by our team for fragmentation of the lens nucleus in an experimental rabbit model.

MATERIALS AND METHODS

Animals

Sixteen albino New Zealand rabbits were involved in the study. They were divided into three groups: The group 1 was composed of 6 rabbits whose soft lens was divided into multiple pieces with automated loop system and removed through 5 mm corneal incision. The group 2 was composed of 4 rabbits whose lens was divided and removed with automated loop system. Thereafter hard human lens was inserted into the anterior chamber and this second lens was also removed by the same system.

In this second group, we aimed to evaluate if the loop system can effectively divide hard human nucleus. The control group (group 3) was composed of 6 rabbits that had ECCE surgery.

The Animal Ethics Committee approval was provided from Fatih University Medical Faculty. All the animals were treated in accordance with the declaration of Helsinki.

Automotized Loop System

This system consists of power and control panel, motion and power transfer cable, handpiece, loop mechanism and foot pedal (Figure 1).

The loop mechanism is the changeable piece that is placed around the nucleus inside the eye. The nucleus is divided by closure of the loop.

The loop mechanism is placed inside the handpiece and connected to the anterior end of the motion and power transfer cable that transfers the motion and the power generated in the power and control panel to the loop mechanism in the handpiece.

The posterior end of the motion and power transfer cable is connected to the motor mechanism in the power and control panel.

The opening and closure of the automated loop system is controlled by the foot pedal that is connected to power and control panel.

The main aims of automated loop system are the multiple opening and closure of the loop system that enable the division of the cataractous nucleus into many small pieces; and to let the surgeon to use the second hand for other surgical manipulations inside the eye. The wire of the automated loop is made of stainless steel wire rope covered with nylon with total thickness of 250 micron.

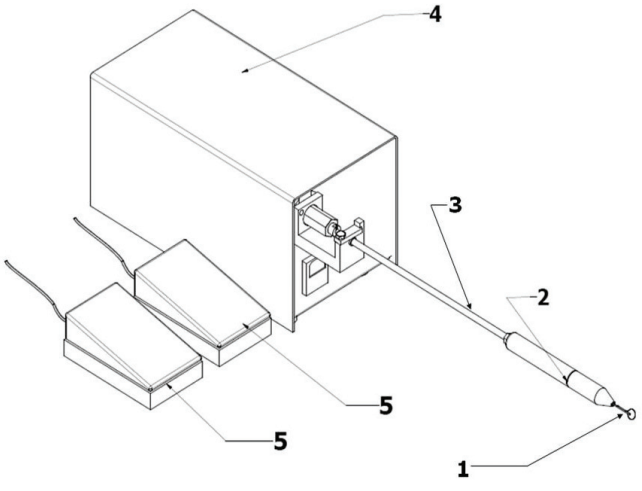

Figure 1: *Parts of the loop system were given: loop mechanism (1), handpiece (2), motion and power transfer cable (3), power and control panel (4), and foot pedal (5).*

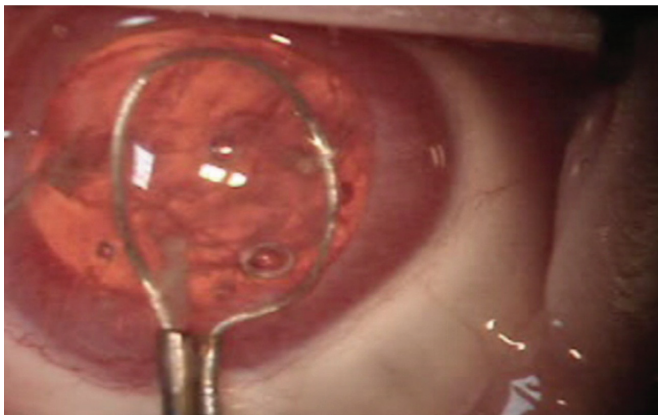

Figure 2: *Loop mechanism was opened in anterior chamber parallel to the rabbit nucleus surface.*

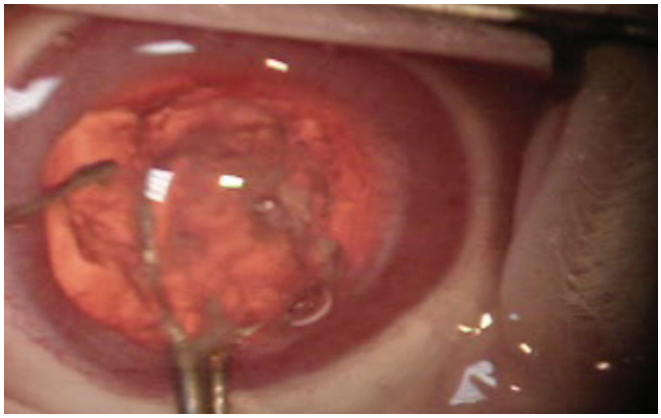

Figure 3: *Loop mechanism was dividing the soft rabbit nucleus in anterior chamber.*

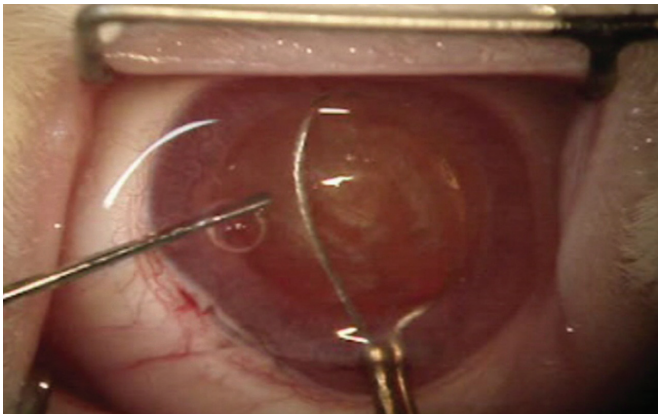

Figure 4: *Loop mechanism was placed around the hard human nucleus.*

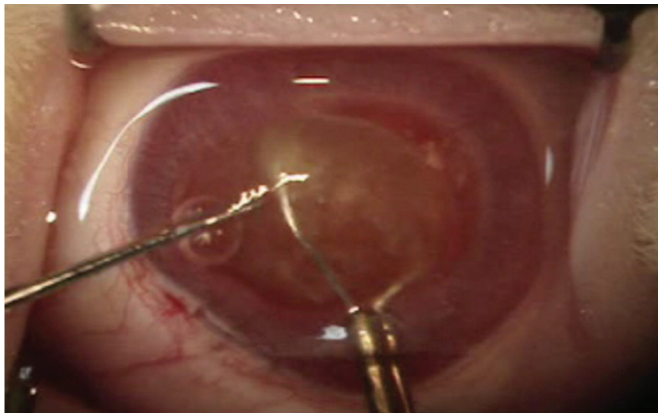

Figure 5: *Loop mechanism was dividing the hard human nucleus in anterior chamber.*

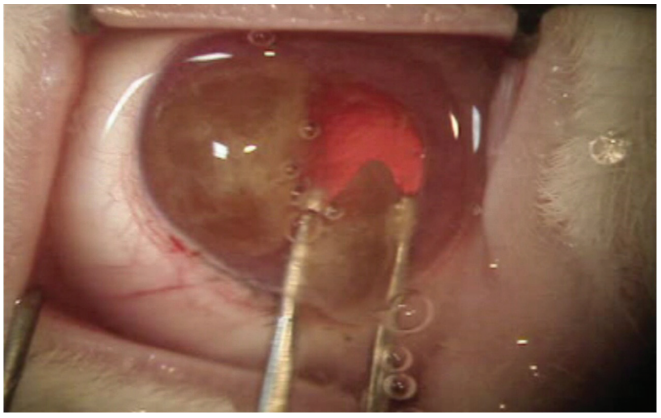

Figure 6: *Hard human nucleus pieces were removed with the use of serrated forceps.*

This wire is capable of multiple opening and closure without deformation at nucleus division. By the help of the foot pedal control of the loop system, freed seconds hand of surgeon provides better surgical control as the second hand can also be used in placing the loop around the nucleus and in other procedures inside the eye.

Surgical Procedure

In all groups dilatation of the pupil was achieved by applying one drop of phenylephrine (Mydfrin 2.5%, Alcon, Fort Worth, ABD) and one drop of tropicamide (Tropamid 0.5%, Bilim, Istanbul, Turkey) three times with 5 minute intervals to the rabbit eyes.

General anesthesia was accomplished with intramuscular injection of 50 mg/kg ketamine hydrochloride (Ketalar, Eczacibasi, Turkey) and 5 mg/kg xylazine hydrochloride (Rompun, Bayer, Germany) while proparacaine (Alcaine 0.5%, Alcon, Fort Worth, ABD) drops was used for the topical anesthesia.

Eyelids and the surrounding area were cleaned with 10% povidone iodine and the eye was covered with a sterile drape and the lids were opened with an eyelid speculum.

The povidone iodine 10% was left on the corneal and conjunctival surface for three minute and then removed from the area by NaCl 0.09%. All the operations were performed under the surgical microscope.

In group 1, (n=6), 3 mm clear corneal incision was made on the right eyes of rabbits and the anterior chamber was filled with viscoelastic solution. Following capsulorhexis the rabbit nucleus was taken into the anterior chamber by hydrodissection.

The loop system in its closed form is inserted into the anterior chamber. Loop is opened parallel to the lens surface (Figure 2) by pressing “the open switch” of the foot pedal and placed around the nucleus.

By pressing on “the close switch” of the foot pedal, the loop was closed and the nucleus is divided (Figure 3).

The nucleus is divided into 4 to 6 pieces by multiple opening and closure of the loop system. Corneal incision was widened to 5 mm and small lens pieces were removed out of the eye with the help of serrated forceps.

Afterwards the corneal incision was closed with three 10/0 nylon sutures and the operation was finished with subconjunctival gentamycine and dexamethasone injection.

Table: *Distribution of corneal edema, conjunctival hyperemia and intraocular pressures in groups on postoperative second and seventh days (p>0.05).*

	Group 1 (n=6)		Group 2 (n=4)		Group 3 (n=6)	
	2nd day	7th day	2nd day	7th day	2nd day	7th day
Corneal Edema	2	-	3	1	2	-
Conjunctival Hyperemia	2	-	3	1	3	1
Intraocular pressure (mmHg)	18.8	17.6	18.3	19.2	18.0	17.3

In the rabbits of group 2, (n=4), the procedures described above in group I are performed without any difference as an initial step. Thereafter, corneal incision was widened to 10 mm. Mature human lens nüclei (all of which were black or brunecent grade 5 nüclei according to lens opacification classification system and provided by previous ECCE surgery on human) was inserted into the anterior chamber of the rabbit eye.

Corneal incision was closed with 10/0 nylon sutures on nasal side so that the corneal opening was reduced to 5 mm in size on the temporal side. The loop mechanism is introduced into the eye. It is opened and placed around the hard human nucleus and nucleus was divided into 4 to 6 pieces as described above (Figure 4 and 5). The pieces are removed out of the rabbit eye by the help of a serrated forceps (Figure 6). The incision is closed by 10/0 nylon sutures and the operation is finished by subconjuntival gentamycine and dexamethasone injection.

In the rabbits of the group 3 (control group), standard ECCE surgery was performed. The nucleus is taken into the anterior chamber and expressed out of the eye by irrigation after a 10 mm corneal incision and capsulorhexis were performed. Corneal incision is closed with 10/0 nylon sutures and the operation is finished by subconjuntival gentamycine and dexamethasone injection.

In the post operative period, topical antibiotic and steroid drops four times a day were applied. The corneal edema, conjunctival hyperemia (whether present or not), intraocular pressures were evaluated on postoperative 2nd and 7th days with biomicroscopy and Schiotz tonometry after the rabbits were anesthesized as described before. The weight used on the tonometer was 5.50 g. Corneal edema was graded according to the Efron scale.[5]

Absence of corneal edema was graded as 0, the corneal edema only detectable by biomicroscope as 1, the corneal edema that is detectable by eye but not obscuring the details of iris and anterior chamber as 2, the edema that is obscuring the details of iris as 3 and the edema completely hiding the iris details as grade 4 corneal edema.

Biostatistics

The ratio of corneal edema and conjunctival hyperemia between groups was compared by the chi-square test.

RESULTS

In group 1 and group 2, soft rabbit nuclei and hard mature human nuclei could be divided into 4 to 6 small pieces by the automated loop system without touching corneal endothelium and posterior capsular tear. Two eyes in group 1 had grade 2 corneal edema on the 2nd postoperative day whereas none of these eyes had corneal edema on 7th postoperative day (Table). Two rabbit had conjunctival hyperemia. Increased intraocular pressure was observed in none of the rabbits. In group 2, 2 eyes had grade 2 and one eye had grade 3 corneal edema and 3 eyes had conjunctival hyperemia on the 2nd postoperative day (Table).

On the 7th post operative day the eye with grade 3 corneal edema was again edematous (Grade 3). The postoperative edema disappeared in all eyes after two weeks of follow up. In group 3, one eye had grade 1 and one eye had grade 2 corneal edema on the 2nd postoperative day and none of the eyes had corneal edema on the 7th postoperative day. Three eyes had conjunctival hyperemia (Table).

The ratio of cornel edema, anterior chamber reaction and conjunctival hyperemia between groups was not statistically significant by the chi square test (p>0.05). In any of the rabbit eyes, no significant intraoperative and postoperative complications like posterior capsular tear, endophthalmitis or retinal detachment were developed.

DISCUSSION

Phacoemulsification in hard cataracts may cause several problems. High energy needed in phacoemulsification of hard cataracts may damage endothelial cells.[6] Loss of the endothelial cells that have regenerative ability may cause permanent corneal edema and bullous keratopathy.

On the other hand, using phacoemulsification technique in these kinds of hard cataracts increases the rates of complications such as posterior capsular rupture, corneal burns, iris trauma and retinal detachment.[1-3,7] For these reasons extracapsular cataract extraction (ECCE) is preferred in the surgical treatment of hard mature cataracts in many clinics despite it is an older technique. The cataractous lens is removed as a whole from a 9-12 mm corneal incision and intraocular lens is placed in the eye and the incision is closed with many sutures in the ECCE surgery. The wound healing usually takes about six months with this method and problems like irritation and foreign body sensation and pain occur frequently during postoperative period.[7-8] Surgically induced astigmatism due to large incision and the sutures may worsen the visual quality.[9-10] The visual rehabilitation is much slower than phacoemulsification and irregular astigmatism that can not be corrected with eye glasses can be observed in some patients.[9-11]

The risks that phacoemulsification of hard cataracts can bring and the postoperative wound healing problems in ECCE surgery has led to development of the alternative surgical methods in the treatment of mature hard cataracts.[12-14] The nucleus that is taken into the anterior chamber is divided and these pieces are removed from the eye from incisions of various sizes in these manual phacofragmentation methods.[4,13-14] Manuel phacofragmentation techniques with small incision include: phacosection (bisection, trisection), snare technique, nylon loop technique, mini-nuc, manual multiphacofragmentation, quarters extraction technique, prechop manual phacofrafragmentation, SLIMCE-K and phacosandwich technique.[14-22]

Kongsap has performed cataract surgery in 105 patients with the nylon loop technique by bisecting the nucleus by a nylon loop and removing the pieces from 5 mm corneal incision and has not reported any important complication.[23] Bhattacharya has reported that hard cataracts can be removed from from 5-6 mm incision by using stainless steel loop without any significant complication.[16] Similarly Kosakarn has trisected the nucleus in 120 patients by using double nylon loop and removed the lens from a 4-4.5 mm corneal incision.[17] In our study we have shown that we can remove both the soft nucleus of the rabbit and the hard human lens placed in the rabbit eyes by the automated loop system through 5 mm corneal incision. Major limitation to a decreased corneal incision size was difficulty in removal of the nucleus pieces by forceps which can be solved by specially designed lens removal forceps with thinner tips and more suitable shapes. The authors mentioned above have sectioned cataractous lens by the help of a nylon loop or a stainless steel wire loop. Opening or closure of the loop during division of the lens requires use of both hands.[13-17] In our automated loop system, the movement of the wire loop is provided by a motorized system which is controlled by a foot pedal. By the help of the foot pedal control of the loop system, freed second hand can also be used in placing the loop around the nucleus and in other procedures inside the eye.

When we compare the groups in our study, the corneal edema in the rabbit eyes with soft nucleus treated with the automated loop system (Group 1) were similar to those of control group (Group 3), the rabbit eyes with soft nucleus treated with ECCE surgery. However the rate of conjunctival hyperemia was higher in the control group when compared to group 1, although the difference was not statistically significant ($p>0.05$). The corneal edema and conjunctival hyperemia rates were higher in the group 2 compared to both group 1 and group 3 ($p>0.05$). Increased corneal edema means that more endothelial cell was injured during the procedure.

Group 2 was formed to test if this system was effective in the division of hard human lens. Differences in corneal edema and conjunctival hyperemia rates are thought to be due to the accumulated trauma of consecutive surgeries in group 2 rabbits: removal of soft nucleus from rabbit eye with the help of loop system, placement of human hard nucleus into the rabbit eye and removal of the hard nucleus from the same rabbit eye by the loop system. In total, these results show that the automated loop system for hard mature cataracts may offer the safety of ECCE surgery together with decreased incision size and increased patient comfort.

In previous human studies, steel wire and nylon loop systems could not be opened after closure which means that only one division is possible.[16-17,23] The wire of the automated loop is made of stainless steel wire rope covered with nylon with a total thickness of 250 micron. This wire is capable of multiple opening and closure without deformation during nucleus division. The multiple opening and closure of the loop system have enabled the division of the lens nucleus into many small pieces in our study. In addition, we were able to section both the soft rabbit nucleus and the hard human nucleus into several pieces by the loop system. The thinnest wire with the ability to close and open several times without deformity in shape that we could find had a 250 micron thickness. The sectioning process would be easier and safer by the use of a thinner wire with the same properties.

Current modern cataract surgery techniques have been greatly enhanced after introduction of microincisional cataract surgery, torsional phacoemulsification and femtosecond laser. However, there are still important problems in the management of advanced hard cataracts.

Torsional phacoemulsification has decreased the effective ultrasound time and cumulative dissipated energy in moderate cataracts but not in the hard cataract.[24] Endothelial cell loss was still high in microincisional coaxial phacoemulsification similar to conventional phacoemulsification in hard cataracts.[25] Femtosecond laser seems to be unable to divide opaque hard cataracts despite it will be helpful for capsulorexis in these cases. Therefore, there was a need for lens division and removal system for advanced hard cataracts. All of these new technologies and current phacoemulsification systems are very expensive and could not be afforded in poor undeveloped countries. Therefore, easy-to-produce and cheap automated loop system could be a good alternative for cataract removal especially for undeveloped countries.

One of the major drawback of this study was the lack of endothelial cell count before and after the operations to compare endothelial damage between groups. As we did not get specular microscopy or confocal microscopy during the study, we could not perform endothelial cell count. The relatively low number of the rabbits in groups also limits the power of the current study.

In conclusion, this rabbit study has shown that the automated loop system divided both the soft rabbit and hard human nucleus successfully and the nucleus pieces can easily be removed from 5 mm corneal incision. The automated loop system may offer the safety of ECCE surgery together with decreased incision size and increased patient comfort for hard mature cataracts. The automated loop system can be more effective and reliable with a thinner wire that can open and close several times without deformation.

Acknowledgments: Authors thank to Tacettin Ileri and the MAKIM Company for their unlimited and very helpful support in designing and production of the Automated Loop System.

KAYNAKLAR/REFERENCES

1. Artzen D, Lundstrom M, Behndig A, et al. Capsule complication during cataract surgery: Case control study of preoperative and intraoperative risk factors: Swedish Capsule Study Rupture Study Group report 2. J Cataract Refract Surg 2009;35:1688-93.
2. Bourne RR, Minassian DC, Dart JK, et al. Effect of cataract surgery on the corneal endothelium: modern phacoemulsification compared with extracapsular cataract surgery. Ophthalmology 2004;111:679-85.
3. George R, Rupauliha P, Sripriya AV, et al. Comparison of endothelial cell loss and surgically induced astigmatism following conventional extracapsular cataract surgery, manual small-incision surgery and phacoemulsification. Ophthalmic Epidemiol 2005;12:293-7.
4. Keener GT. The nucleus division technique for small incision cataract extraction. In: Rozakis GW, editor. Cataract Surgery: Alternative small incision techniques. 1sted. New Delhi: Jaypee Brothers 1995:163-91.
5. Efron N, Morgan PB, Katsara SS. Validation of grading scales for contact lens complications. Ophthal Physiol Opt 2001;21:17-29.
6. Singh R, Vasavada AR, Janaswamy G. Phacoemulsification of brunescent and black cataracts. J Cataract Refract Surg 2001;27:1762-9.
7. Chan E, Mahroo OA, Spalton DJ. Complications of cataract surgery. Clin Exp Optom 2010;93:379-89.
8. Flaxel JT, Swan KC. Limbal wound healing after cataract extraction. A histologic study. Arch Ophthalmol 1969;81:653-9.
9. Hall GW, Campion M, Sorenson CM, et al. Reduction of corneal astigmatism at cataract surgery. J Cataract Refract Surg 1991;17:407-14.
10. McQueen BR, Martinez CE, Klyce SD. Corneal topography in cataract surgery. Curr Opin Ophthalmol 1997;8:22-8.
11. El-Maghraby A, Anwar M, el-Sayyad F, et al. Effect of incision size on early postoperative visual rehabilitation after cataract surgery and intraocular lens implantation. J Cataract Refract Surg 1993;19:494-8.
12. Blumenthal M, Ashkenazi I, Assia E, et al. Small-incision manual extracapsular cataract extraction using selective hydrodissction. Ophthalmic Surg 1992;23:699-701.
13. Quintana MC. Manual small-incision ECCE with nylon-loop phacosection and foldable IOL implantation. In: Gutierrez Carmona FJ, ed, Phaco Without Phaco: ECCE and Manual Small-Incision Techniques for Cataract Surgery. Delhi, India, Jaypee Brothers 2005:310-8.
14. Kosakarn P. Manual phacocracking. Asian J Ophthalmol 2004;4:6-8.
15. Ravindra MS. Nucleus management in manual small incision cataract surgery by phacosection. Indian J Ophthalmol 2009;57:41-3.
16. Bhattacharya D. Nuclear management in manual small incision cataract surgery by snare technique. Indian J Ophthalmol 2009;57:27-9.
17. Kosakarn P. Double nylon loop for manual small incision cataract surgery. J Cataract Refract Surg 2009;35:422-4.
18. Bartov E, Isakov I, Rock T. Nucleus fragmentation in a scleral pocket for small incision extracapsular cataract extraction. J Cataract Refract Surg 1998;24:160-5.
19. Gutiérrez-Carmona FJ. Manual multi-phacofragmentation through a 3.2 mm clear corneal incision. J Cataract Refract Surg 2000;26:1523-8.
20. Akura J, Kaneda S, Ishihara M, et al. Quarters extraction technique for manual phacofragmentation(1). J Cataract Refract Surg 2000;26:1281-7.
21. Kongsap P. Corneal endothelial cell loss between the Kongsap manual phacofragmentation and phacoemulsification. J Med Assoc Thai 2008;91:1059-65.
22. Kongsap P. Sutureless large-incision manual cataract extraction using the Kongsap technique: outcome of a prospective study. Int J Ophthalmol 2010;3:241-4.
23. Kongsap P. Small incision extracapsular cataract surgery using the nylon loop technique. Asian J Ophthalmol 2006;8:135-8.
24. Kim DH, Wee WR, Lee JH, Kim MK. The comparison between torsional and conventional mode phacoemulsification in moderate and hard cataracts. Korean J Ophthalmol 2010; 24:336-40.
25. Wilczynski M, Supady E, Loba P, et al. Results of coaxial phacoemulsification through a 1.8-mm microincision in hard cataracts. Ophthalmic Surg Lasers Imaging 2011;42:125-31.