Nanosecond laser–assisted cataract surgery: Endothelial cell study

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PURPOSE: To evaluate corneal endothelial cell density (ECD) and morphology after cataract surgery using coaxial ultrasound (US) phacoemulsification or a recently introduced coaxial nanosecond laser technique.

SETTING: Department of Ophthalmology, Medical University of Sofia, Sofia, Bulgaria.

DESIGN: Prospective cohort study.

METHODS: Coaxial US phacoemulsification was performed in 1 eye (US group) and coaxial nanosecond laser–assisted cataract surgery in the contralateral eye (laser group) of the same patient. Nuclear sclerosis was graded from nuclear opalescence (NO) 3, nuclear color (NC) 3 to NO4, NC4 using the Lens Opacities Classification System III. The central ECD, coefficient of variation (CoV) in cell size (objective measure of polymegethism), and percentage of hexagonal cells (an index of pleomorphism) were evaluated.

RESULTS: Eighty-two eyes (41 patients) had uneventful surgery. The mean ECD was 2517 cells/mm^2 ± 137 (SD) preoperatively and 2287 ± 155 cells/mm^2 at 2 years in the US group and 2521 ± 233 cells/mm^2 and 2420 ± 292 cells/mm^2, respectively, in the laser group (both $P < .001$). The mean CoV was 0.27 ± 2.4 preoperatively and 0.30 ± 2.4 at 2 years in the US group and 0.27 ± 2.8 and 0.27 ± 2.0, respectively, in the laser group (both $P < .001$). The mean percentage of hexagonal cells was 42.3% ± 3.6% preoperatively and 37.74% ± 3.54% at 2 years in the US group and 42.8% ± 3.2% and 43.00% ± 2.68%, respectively, in the laser group (both $P < .001$).

CONCLUSION: Nanosecond laser phacoemulsification had advantages over US phacoemulsification in terms of endothelial cell structure preservation.

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The number of cataract surgeries is continually increasing, starting from approximately 20 million surgeries in 2010 and expecting to reach 32 million procedures globally by 2020.[1] Ultrasound (US) phacoemulsification, used since the early 1970s, has been progressively refined and is now the standard reference for effective cataract surgery.

Modern cataract surgery is one of the most successful types of surgery in terms of the improvement in the patient's quality of life. The expected outcomes today include reduced surgical trauma, smaller incisions, improved intraoperative ocular stability, and the advanced performance capabilities of intraocular lenses (IOLs). Ophthalmic surgeons are in a constant search of refined techniques and instrumentation (tools, devices) to minimize surgical trauma and improve the patient's surgical outcomes.

Ultrasound energy might affect the ocular structures and has been implicated in the pathogenesis of endothelial cell loss and cystoid macular edema.[2,3] Corneal endothelial cell damage is one of the most frequent early postoperative complications of phacoemulsification. This complication can lead to corneal edema and serious visual disturbances. Postoperative corneal endothelial cell loss is related to many factors, including phacoemulsification time and energy, cataract density, corneal pathology, anterior chamber depth, axial length, ocular trauma, free radical development, mechanical

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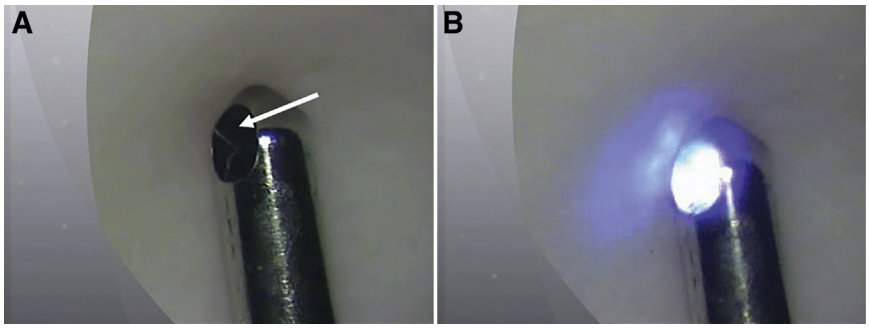


Figure 1. Nanosecond laser tip 20-gauge without sleeve. *A*: One millimeter aspiration opening titanium target (*white arrow*). *B*: Nanosecond laser tip at the time of plasma formation.

and heat injury, phacoemulsification technique, surgeon experience, and use of ophthalmic viscosurgical devices (OVDs).[4–10]

This study compared the corneal endothelial cell density (ECD) and corneal endothelial cell morphology in patients having bilateral cataract surgery performed using coaxial US phacoemulsification in 1 eye and coaxial nanosecond laser–assisted cataract surgery in the contralateral eye. Using a nanosecond laser for cataract removal has a relatively long history. Since the first report of phacolysis of a human cataractous lens by a neodymium:YAG (Nd:YAG) laser,[11] the technology has advanced considerably. This technology uses a pulsed Nd:YAG (1064 nm) laser that is transferred to the probe by a quartz fiber optic and is focused on a titanium target within the probe tip (Figure 1).

PATIENTS AND METHODS

This prospective cohort study evaluated the postoperative ECD and corneal endothelial cell morphology in both eyes of the same patient over a 24-month follow-up. Ultrasound coaxial phacoemulsification was performed in 1 eye (US group), and coaxial cataract surgery assisted using a recently introduced nanosecond laser was performed in the contralateral eye (laser group). Which eye would receive which procedure was decided by random selection.

Nanosecond Laser

In this study, an updated laser system (Cetus, ARC Laser GmbH) was used. Each pulse releases 7.5 mJ of laser energy for 5 ns. The pulsing photic energy impacts the titanium target located within the probe tip, which in turn leads to optical breakdown and plasma formation. This creates a shockwave that emanates from the tip in a cone-like fashion.[12] These shockwaves are used to disrupt the substance of the cataract. The fragmented particles of the cataract are then aspirated out of the eye through the aspiration port, the lumen of which is also contained within the laser probe. The system received the Conformité Européenne mark for clinical use in the European Union and 510K approval from the U.S. Food and Drug Administration for clinical use in the United States. The coaxial laser probe for 2.4 mm incisions (Figure 2) was used in all cases.

Patient Assessment

Nuclear sclerosis was graded from nuclear opalescence (NO) 3, nuclear color (NC) 3 to NO4, NC4 using the Lens Opacities Classification System III.[13]

Endothelial cell density and endothelial cell size variability were determined preoperatively and 24 months after surgery in both groups. The endothelium of the central cornea was examined and imaged with a noncontact specular microscope (EM935, Haag-Streit). Endothelial structure was evaluated using the following parameters recorded from the noncontact specular microscope system: mean ECD (cell/mm^2), mean cell area (μm^2), coefficient of variation (CoV) in cell size, and the percentage of hexagonal cells. The CoV in cell size (standard deviation divided by the mean cell area) was used as an index of the extent of

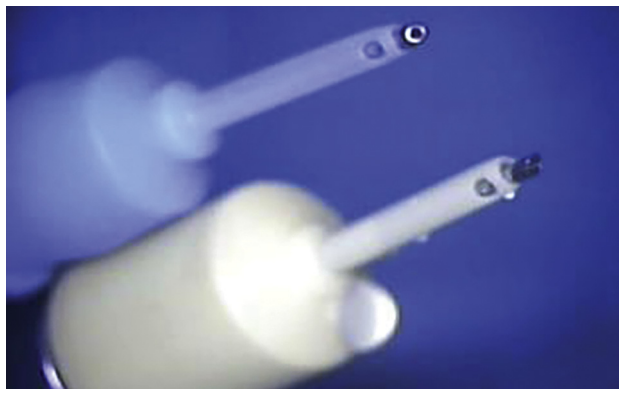


Figure 2. Coaxial US tip (*yellow sleeve*) and nanosecond laser tip (*blue sleeve*).

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Table 1. Fluidic parameters by group.

Parameter	US Group	Laser Group
Bottle height (cm)	100	100
Power	40%	7.5 mJ
Vacuum (mm Hg)	350	350
Aspiration flow rate (cc/min)	40	40

US = ultrasound

variation in the cell area (polymegathism). The percentage of hexagonal cells in the analyzed area was used as an index of variation in cell shape (pleomorphism).

The procedure for specular noncontact microscopy involved 3 successive acquisitions from the central cornea. The examiner for the analysis manually marked a minimum of 200 contiguous cells using a built-in software program.[14]

Also, the corneal transparency on the first day postoperatively was assessed with a slitlamp examination. Only transparent corneas were analyzed.

Surgical Technique

The same surgeon (I.T.) performed all cataract procedures. The surgical protocol for both groups was based on the standard small-incision clear corneal technique (Table 1). Under topical anesthesia, 3 corneal tunnels were created (2.4 mm main incision and 2 side ports) using diamond knives (Accutome, Inc.), followed by 4-quadrant prechop of the crystalline lens. The fluidics system used (Megatron S3 VIP, Geuder AG) had flow-control aspiration and a vacuum (venturi) control machine. A peristaltic pump was used for the entire surgical procedure. After bimanual cortical cleanup and viscoexpansion of the capsular bag were complete, a hydrophobic acrylic IOL (SA60AT, Alcon Surgical, Inc.) was implanted.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 16.0, SPSS, Inc.). Both eyes of all subjects were analyzed. Variations in the corneal ECD and cell morphology in different groups were assessed using descriptive statistics, the 1-sample Kolmogorov-Smirnov test, the paired-samples *t* test, and the Wilcoxon signed-rank test.

RESULTS

The study comprised 82 eyes of 41 patients. All surgeries were uneventful.

On slitlamp examination, there were no significant differences in the incidence of corneal edema, the mean 1-day postoperative uncorrected distance visual acuity (UDVA), or the percentage of eyes having a UDVA of 20/40 or better between the US group and the laser group. In the patients with nuclear sclerotic cataracts of average density, the immediate postoperative vision and corneal edema were similar between eyes in the US group and eyes in the laser group.

The mean ECD was 2517 cells/mm^2 ± 137 (SD) preoperatively and 2287 ± 155 cells/mm^2 2 years postoperatively in the US group and 2521 ± 233 cells/mm^2 and 2420 ± 292 cells/mm^2, respectively, in the laser group (Figure 3). The change was statistically significant in both groups ($P < .001$). The difference between the 2 groups was statistically significant and persisted over the 24-month follow-up.

The mean CoV was 0.27 ± 2.4 preoperatively and 0.30 ± 2.4 at 2 years in the US group and 0.27 ± 2.8 and 0.27 ± 2.0, respectively, in the laser group (Figure 4). The change was statistically significant in both groups ($P < .001$).

The mean percentage of hexagonal cells was 42.3% ± 3.6% preoperatively and 37.74% ± 3.54% 2 years postoperatively in the US group and 42.8% ± 3.2% preoperatively and 43.00% ± 2.68%, respectively, in the laser group (Figure 5). The change was statistically significant in both groups ($P < .001$).

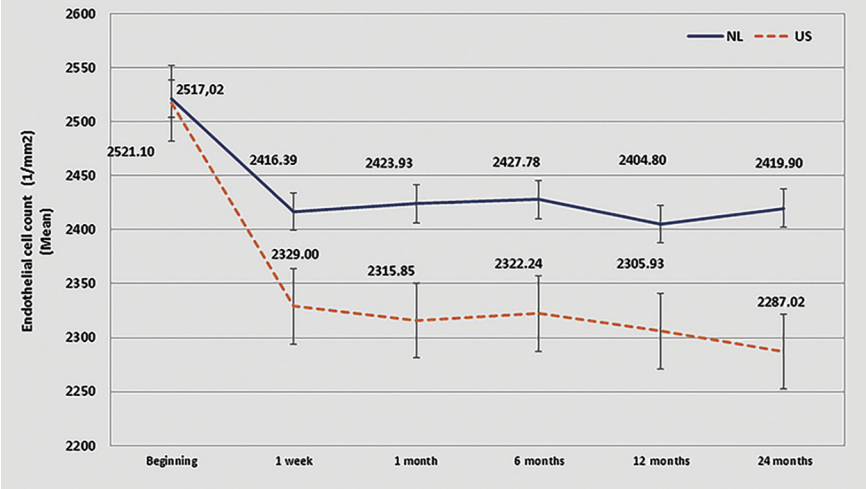


Figure 3. The ECD dynamics over a 24-month period ($P < .001$) (NL = nanosecond laser; US = ultrasound).

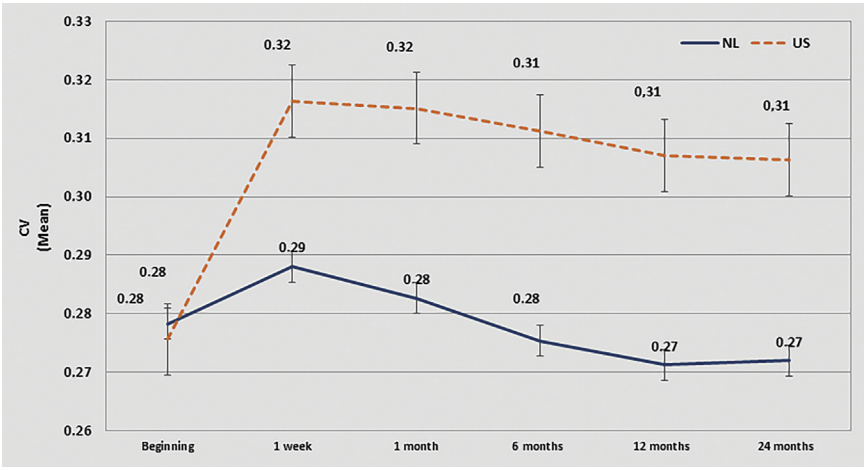


Figure 4. The mean CoV over a 24-month period ($P < .001$) (CV = coefficient of variation; NL = nanosecond laser; US = ultrasound).

DISCUSSION

This contralateral-eye study compared an established emulsification technique (US energy) with another technique (nanosecond laser–assisted) using the same fluidics from the same phaco machine for cataract extraction. The 2 study groups were equally matched in mean lens density.

The 2 groups had similar corneal transparency and visual rehabilitation results. Also, the findings with the nanosecond laser–assisted technique as well as with US phacoemulsification were comparable with those reported in the literature.[15–21]

Cataract surgery can lead to a reduction in ECD, a proportional increase in the mean cell size, and a disruption of the normal hexagonal pattern.[22,23] Although modern US phacoemulsification has minimized endothelial damage, all surgical procedures that involve entry into the anterior segment will inevitably damage a proportion of the endothelial cells as a result of intraoperative corneal manipulations.[23,24]

Analysis of cell shape and pattern is a more sensitive indicator of endothelial damage than ECD.[25] The intercellular space becomes larger during the healing period. After surgical trauma, the undamaged endothelial cells undergo morphologic changes to fill the cell-free areas and restore normal function. Once endothelial repair is complete, the intercellular space is reduced to its previous size and the endothelial layer is restored.[26]

Regarding normalization of the morphometric indices in our study, there was a significant difference between the 2 groups. The US group showed such a tendency toward normalization up to 8 months after surgery. In contrast, stabilization of the endothelial monolayer occurred by 1 month in the nanosecond laser group.

Schultz et al.,[27] Galin et al.,[28] and Kraff et al.[29] also found stabilization of the corneal endothelium 3 months after cataract surgery based on the normalization of the postoperative morphologic status. However, it is not clear exactly how long it takes the

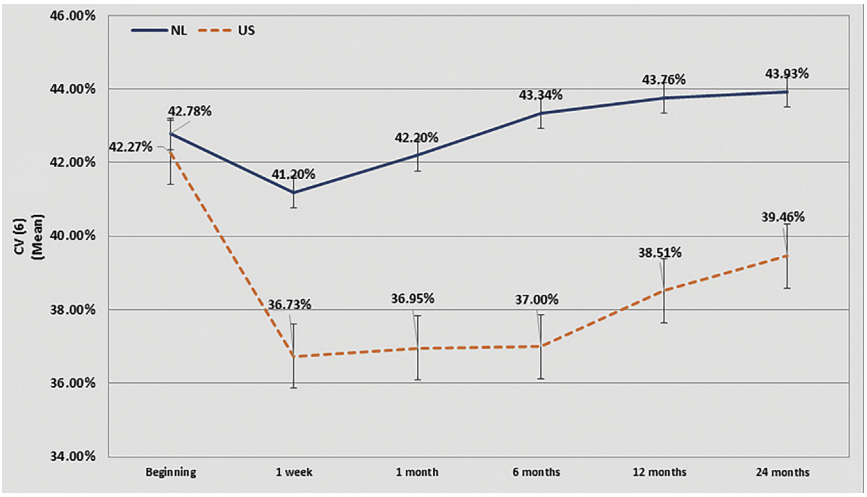


Figure 5. The mean CoV of hexagonal cells over a 24-month period ($P < .001$) (CV = coefficient of variation; NL = nanosecond laser; US = ultrasound).

endothelial cell count to stabilize after US cataract surgery. Liesegang et al.[30] and Bourne et al.[31] reported continued endothelial cell loss several years after IOL implantation. It is also possible that the time to apparent return to normalcy of the cornea after cataract surgery might be approximately 3 months, as evidenced by epithelial thickness normalization.[32] There is also evidence of continuing cell loss despite an apparent normalization of the endothelial morphologic characteristics after cataract surgery.[33]

In conclusion, nanosecond laser cataract surgery appears to be an alternative to small-incision US phacoemulsification. It is minimally invasive, and the recovery period for the endothelium is shorter. In this study, nanosecond laser cataract surgery was an effective procedure for NO3, NC3 to NO4, NC4 of nuclear sclerosis. For higher grades of nuclear sclerosis, further improvements in technical-related and surgical-related parameters are required. Further studies are necessary to evaluate the safety and efficacy of this technique for cataract removal.

WHAT WAS KNOWN

- An updated version of a nanosecond laser, formerly known as the photolysis device, changes the endothelium after cataract surgery.

WHAT THIS PAPER ADDS

- Nanosecond laser phacoemulsification preserved the endothelial cell structure better than US phacoemulsification.

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