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Original Article

Effect of Femtosecond Laser-Assisted Versus Manual Clear Corneal Incisions on Postoperative Corneal Stiffness in Cataract Surgery

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ABSTRACT

Background: The way we make a cut in the cornea can affect how well the wound heals, how the cornea works and what kind of vision people have after cataract surgery. Our goal was to compare how stiff the cornea is after we use a laser to make a cut and when we make a cut by hand. We did a study with 72 adults who were having cataract surgery. We divided them into two groups: one group got a cut made with a femtosecond laser and the other group got a cut made by hand. We looked at how stiff the cornea was before surgery. Then one week, one month and three months after surgery. We also looked at how well people could see, how thick the cornea was, the pressure in the eye and if the cornea was the shape. Sixty-nine people finished the study. After three months the people who got the cut made with a femtosecond laser had a cornea than the people who got a cut made by hand. The people who got the cut made with a femtosecond laser also had astigmatism, which means their cornea was closer to the right shape.. Their vision, corneal thickness and eye pressure were about the same as the people who got a cut made by hand. So making a cut with a femtosecond laser seems to be better for keeping the cornea stiff. The right shape after cataract surgery.. It does not seem to make a difference, in how well people can see. Keywords: Cataract Extraction; Cornea; Corneal Biomechanics; Femtosecond Lasers; Phacoemulsification; Randomized Controlled Trial; Scheimpflug Imaging

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INTRODUCTION

Cataract surgery is one of the common eye surgeries. It used to be about fixing vision but now its also about correcting refractive errors. The goal is to make the surgery precise have a recovery and get predictable results.

Modern cataract surgery, called phacoemulsification is gentle on the eye.. Making a clear incision in the cornea is still very important. Where and how the incision is made can affect how the wound heals the shape of the cornea and how well the patient sees after surgery (1-4).

Many surgeons use incisions because they are easy to make and work well.. The way they are made can vary depending on the tools used and the surgeons technique. Even small changes in the incision can cause problems with the cornea after surgery.

Using a laser to make the incision can be a better option. The laser can be programmed to make the incision in a way, which can lead to more predictable results. The laser pulses are very short. Make the tissue separate, with little force, which can result in a more consistent wound and less distortion of the cornea (5-6).

The corneas strength and stability rely on how its layersre arranged. This includes the way collagen is organized the substances around the cells and how much fluid is in the tissue. When surgery disrupts this arrangement it can change how well the cornea holds its shape (7-11). This might affect how well the eye heals, its shape after surgery and how accurately we can predict the outcome of surgery. It can also affect how we measure the pressure inside the eye.

These effects are especially important for people whose eyes are not very stable to begin with. It is also crucial for patients who need results from refractive surgery.

Regular tests like pachymetry and corneal topography give us information about the corneas shape and thickness.. They do not tell us how well the cornea responds to stress. A test called dynamic Scheimpflug imaging looks at how the cornea changes shape when it is gently pushed with a puff of air. This test gives us numbers that describe how well the cornea holds its shape.

The stress-strain index tells us how stiff the cornea is. The stiffness parameter at applanation tells us how well the cornea resists changing shape when it is first flattened. These measurements help us understand the corneas strength, in patients having surgery, glaucoma and corneal disease. They may also help us see how cataract surgery affects the corneas strength (9,10).

Previous studies have looked at the differences between cataract surgery that uses a femtosecond laser and the traditional method. They have mainly looked at how well people can see after the surgery how many cells are lost how long the surgery takes, the shape of the wound how well the surgery fixes astigmatism and the results of the surgery on the patients vision (1-6).

Although the incisions made by the femtosecond laser are very precise it is not clear if this precision helps to keep the cornea strong and healthy. There is not information about how the cornea works after surgery and the information that is available is not consistent. This is because there are different ways to do the surgery and the patients are all different. The tools used to measure the results are also different and the time after surgery when the results are measured is not always the same.

So we do not really know how the femtosecond laser and the traditional method compare when it comes to keeping the cornea strong after surgery.

This study looked at the effects of using a femtosecond laser to make the incision compared to making the incision by hand. We used a tool to measure how strong the cornea is after surgery. We also looked at how well people can see, how thick the cornea is, if the patient has astigmatism and the pressure inside the eye.

We thought that using the femtosecond laser would help to keep the cornea strong and healthy after surgery than making the incision by hand. We thought this would result in a score on a test that measures how strong the cornea is and that the cornea would be stronger, after surgery.

MATERIALS AND METHODS

A study was done at an eye hospital in Punjab, Pakistan from September 2025 to January 2026. This study looked at two ways to make a cut in the eye for people getting surgery for cataracts that come with age. One way used a laser and the other way was done by hand. The people, in the study were checked after one week one month and three months to see how they were doing after surgery.

The number of people needed for the study was figured out before it started. This was done by looking at another study that was similar. The people doing the study wanted to make sure they had people so that the results would be accurate. They wanted to be 80% that the results were real and they allowed for some people to drop out of the study. So they needed 72 people. These people were split into two groups: the group that got the laser cut and the group that got the cut made by hand. The femtosecond laser-assisted incision group and the manual clear corneal incision group had an equal number of people. The femtosecond laser-assisted incision and the manual clear corneal incision were the two main things being compared in this study.

People who are 50 to 80 years old and have cataracts because they are getting older were checked to see if they could be in the study. These people were allowed to join if their eyesight was bad enough that they needed cataract surgery and their cornea was healthy. The cornea is the layer on the front of the eye. The cornea had to be a normal shape and not be diseased..

People were not allowed to join if they had surgery on their eyes before or if they had been hurt in the eye. They were also not allowed to join if they had diseases like glaucoma or diabetic retinopathy that needed to be treated. One eye from each person was used in the study.

A person who was not involved in the study made a list of who would get which treatment. This list was made by computer. The allocation list was kept secret until just before surgery. The surgeon who did the operation knew what treatment each person was getting because it was not possible to keep it a secret.. The people, in the study and the person who checked their eyes after surgery did not know who was getting which treatment.

People who got the femtosecond laser-assisted treatment had a special laser make a cut in their eye. This cut was 2.4 millimeters. It was made in the clear part of the cornea on the side of the eye. After that they had the procedure to remove the cloudy lens and put in a new foldable lens inside the eye.

The other group of people did not have the laser. They just had a small tool called a keratome make the 2.4 millimeter cut in the part of the cornea. Then they had the procedure to remove the cloudy lens and put in the new lens. One experienced doctor did all the operations and he followed the same steps every time.

The equipment used for the operation the gel-like substance the kind of lens put in the eye and the care given after the operation were all the same for both groups. This was done so that everything would be as equal as possible.

Both groups got the medicine after the operation. They used antibiotic and corticosteroid eye drops four times a day for four weeks. The corticosteroid was slowly stopped over time. The doctors checked to make sure people were using their medicine by looking at what they were taking and making sure they came to their follow up appointments.

The doctors did the checks after the operation, for both groups. They wanted to make sure everything was done the way so they could compare the results of the femtosecond laser-assisted treatment and the other group.

The main things we looked at were the stress-strain index and stiffness parameter at first applanation. We used dynamic Scheimpflug imaging to measure these things. The main goal was to compare these parameters between the two groups three months after surgery.

We also looked at things like how well people could see at a distance, which we measured in logarithm of the minimum angle of resolution units. We checked the corneal thickness in micrometres corneal astigmatism in dioptres and intraocular pressure in millimetres of mercury. We did all these measurements before the surgery and again at one week one month and three months after the surgery. We used the procedures every time to make sure everything was fair. The person doing the measurements did not know which incision technique was used.

We looked at the information about the people in the study. There were 72 people in total. When we looked at the results after three months we had information for 69 people: 35 people who had the femtosecond laser-assisted surgery and 34 people who had the manual incision surgery. So when we did the analysis we only used the information we had for the people who completed the whole study. We did not try to guess the results, for the people who did not finish the study.

The people who did this study looked at the information they collected using a computer program called IBM SPSS Statistics version 27.0. They took the numbers that were not categories. Found the average and the standard deviation. The numbers that were categories they just counted how many were in each group and what percentage that was.

They used a test called the Shapiro-Wilk test to see if the numbers that were not categories were spread out in a normal way. They used something called independent-samples t-tests to compare the numbers that were not categories between the groups of people. They also used paired-samples t-tests to see how the numbers changed over time for each person.

For the categories they used something called the square test or Fishers exact test to compare the groups. They wanted to see if the groups were different at the beginning of the study.

The researchers also wanted to see how some of the numbers changed over time so they used a kind of analysis that looks at how things change over time. They looked at how the biomechanical outcomes changed from before the operation to one week one month and three months after. They wanted to see if the way the operation was done made a difference in how the people recovered.

They also looked at how some of the numbers were related to each other. For example they looked at how the stress-strain index was related to the astigmatism and the intraocular pressure. They did all of these tests to see if the results were real or just happened by chance. They decided that if the result had a p-value of, than 0.05 it was real. The IBM SPSS Statistics version 27.0 was used for all of the tests. The statistical tests were done to compare the groups and to see how the numbers changed over time for the outcomes and the stress-strain index and corneal astigmatism and intraocular pressure.

RESULTS

Seventy-two patients with age-related cataract were randomized equally to the femtosecond laser-assisted clear corneal incision group (n=36) or the manual clear corneal incision group (n=36). One participant in the femtosecond group was lost to follow-up after relocation, and two participants in the manual group withdrew after missing consecutive postoperative visits. Thus, 69 participants completed the three-month assessment and were included in the complete-case outcome analysis: 35 in the femtosecond group and 34 in the manual group. The overall attrition rate was 4.2%, comprising 2.8% in the femtosecond group and 5.6% in the manual group.

Table 1. Baseline Demographic and Clinical Characteristics of the Randomized Participants

Variable	Total Sample (N=72)	Femtosecond Group (n=36)	Manual Group (n=36)	p-value	Absolute SMD
Age, years	65.7 ± 7.1	65.3 ± 7.0	66.1 ± 7.3	0.64	0.11
Male sex, n (%)	39 (54.2)	20 (55.6)	19 (52.8)	0.81	0.06
Right eye operated, n (%)	37 (51.4)	19 (52.8)	18 (50.0)	0.81	0.06
CDVA, logMAR	0.71 ± 0.18	0.70 ± 0.17	0.72 ± 0.19	0.66	0.11
Central corneal thickness, µm	536.9 ± 23.5	537.6 ± 22.8	536.2 ± 24.4	0.79	0.06
Intraocular pressure, mmHg	15.1 ± 2.3	15.0 ± 2.2	15.2 ± 2.4	0.73	0.09
Stress–strain index	0.81 ± 0.07	0.81 ± 0.07	0.80 ± 0.08	0.58	0.13
Stiffness parameter at first applanation	101.8 ± 8.6	101.6 ± 8.3	102.0 ± 8.9	0.84	0.05
Corneal astigmatism, D	0.83 ± 0.34	0.82 ± 0.35	0.84 ± 0.33	0.77	0.06

Data are presented as mean ± SD unless otherwise indicated. CDVA: corrected distance visual acuity; D: dioptres; logMAR: logarithm of the minimum angle of resolution; SMD: standardized mean difference. Absolute SMDs were calculated from the reported group-level data.

The randomized groups were comparable across all baseline demographic, visual, anatomical, pressure, and biomechanical characteristics. No baseline comparison was statistically significant, and the absolute standardized mean differences ranged from 0.05 to 0.13, indicating minimal baseline imbalance.

Table 2. Between-Group Comparison of Clinical and Biomechanical Outcomes at Three Months

Outcome	Femtosecond Group (n=35)	Manual Group (n=34)	Mean Difference	95% CI	p-value	Cohen's d
Stress–strain index	0.86 ± 0.08	0.79 ± 0.09	0.07	0.03 to 0.11	0.001	0.82
Stiffness parameter at first applanation	105.8 ± 8.4	98.9 ± 9.1	6.9	2.7 to 11.1	0.002	0.79
CDVA, logMAR	0.05 ± 0.04	0.06 ± 0.05	−0.01	−0.032 to 0.012	0.31	−0.22
Central corneal thickness, µm	541.5 ± 18.9	545.7 ± 21.4	−4.2	−13.9 to 5.5	0.39	−0.21
Intraocular pressure, mmHg	14.7 ± 2.0	14.9 ± 2.2	−0.2	−1.21 to 0.81	0.67	−0.10
Corneal astigmatism, D	0.48 ± 0.21	0.65 ± 0.27	−0.17	−0.29 to −0.05	0.012	−0.70

Data are presented as mean ± SD. Mean differences were calculated as femtosecond group minus manual group. CDVA: corrected distance visual acuity; CI: confidence interval; D: dioptres; logMAR: logarithm of the minimum angle of resolution.

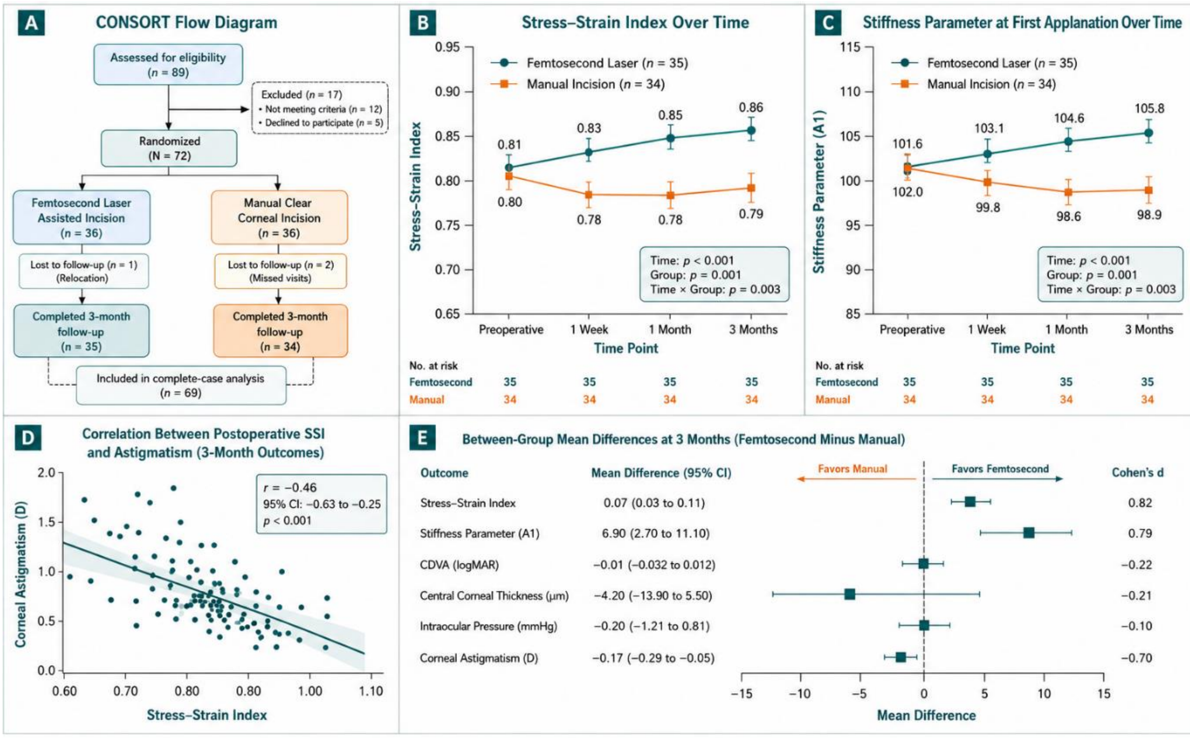
Confidence intervals and Cohen's d values were calculated from the reported means, standard deviations, and group sizes. Negative values for CDVA, intraocular pressure, central corneal thickness, and astigmatism indicate lower values in the femtosecond group.

At three months, the mean stress–strain index was higher in the femtosecond group than in the manual group (0.86±0.08 versus 0.79±0.09), corresponding to a mean difference of 0.07 (95% CI: 0.03 to 0.11; p=0.001). The standardized between-group effect was large (Cohen's d=0.82).

The stiffness parameter at first applanation was also higher after femtosecond laser-assisted incision creation (105.8±8.4 versus 98.9±9.1), with a mean difference of 6.9 units (95% CI: 2.7 to 11.1; p=0.002) and a moderate-to-large standardized effect (Cohen's d=0.79).

Corrected distance visual acuity, central corneal thickness, and intraocular pressure did not differ significantly between the groups at three months. The respective standardized effects were small, and all confidence intervals included the null value.

Postoperative corneal astigmatism was lower in the femtosecond group than in the manual group (0.48±0.21 D versus 0.65±0.27 D), producing a mean difference of −0.17 D (95% CI: −0.29 to −0.05; p=0.012) and a moderate standardized effect favouring femtosecond incision creation (Cohen's d=−0.70).



CDVA = corrected distance visual acuity; CI = confidence interval; logMAR = logarithm of the minimum angle of resolution; SSI = stress–strain index; A1 = stiffness parameter at first applanation; D = dioptres; μm = micrometres; mmHg = millimetres of mercury.
All error bars represent mean ± SD.

Figure 1 presents participant flow, temporal changes in corneal biomechanics, and three-month outcome comparisons. The femtosecond laser group showed progressive increases in stress–strain index and stiffness parameter at first applanation, whereas both measures declined slightly in the manual-incision group. Higher postoperative stiffness was moderately associated with lower corneal astigmatism, and the forest plot demonstrated favourable effects of femtosecond incision creation on biomechanical parameters and postoperative astigmatism.

Table 3. Within-Group Changes in Primary Biomechanical Outcomes from Baseline to Three Months (Analyzed Sample, N=69)

Outcome	Group	Baseline	Three Months	Mean Change	p-value
Stress–strain index	Femtosecond (n=35)	0.81 ± 0.07	0.86 ± 0.08	0.05	<0.001
Stress–strain index	Manual (n=34)	0.80 ± 0.08	0.79 ± 0.09	−0.01	0.041
Stiffness parameter at first applanation	Femtosecond (n=35)	101.6 ± 8.3	105.8 ± 8.4	4.2	<0.001
Stiffness parameter at first applanation	Manual (n=34)	102.0 ± 8.9	98.9 ± 9.1	−3.1	<0.001

Data are presented as mean ± SD. Within-group p-values were obtained using paired-samples t-tests.

From baseline to three months, the stress–strain index increased by 0.05 in the femtosecond group (p<0.001), whereas it decreased by 0.01 in the manual group (p=0.041). Similarly, the stiffness parameter at first applanation increased by 4.2 units after femtosecond laser-assisted incision creation (p<0.001) but decreased by 3.1 units following manual incision creation (p<0.001). From baseline to three months, the two surgical techniques resulted in divergent biomechanical trajectories. In the femtosecond group, the stress–strain index and the stiffness parameter at first applanation significantly increased, whereas the manual incision group demonstrated a significant decrease in both parameters.

The reported repeated-measures analysis demonstrated significant effects of time (F=68.42, p<0.001) and treatment group (F=12.57, p=0.001), together with a significant time × group interaction (F=6.84, p=0.003). These findings indicate that the postoperative trajectories of the biomechanical outcomes differed between the incision techniques over the preoperative, one-week, one-month, and three-month assessments.

Table 4. Correlations Between Postoperative Stress–Strain Index and Clinical Outcomes

Variable Pair	Pearson's r	95% CI	p-value
Stress–strain index and corneal astigmatism	−0.46	−0.63 to −0.25	<0.001
Stress–strain index and intraocular pressure	0.14	−0.10 to 0.36	0.24

CI: confidence interval. Confidence intervals for Pearson's correlation coefficients were calculated using Fisher's z transformation.

The postoperative stress–strain index was moderately and inversely correlated with postoperative corneal astigmatism (r=−0.46; 95% CI: −0.63 to −0.25; p<0.001), indicating that higher corneal stiffness was associated with lower residual astigmatism

. No statistically significant relationship was observed between the stress–strain index and postoperative intraocular pressure (r=0.14; 95% CI: −0.10 to 0.36; p=0.24). No intraoperative complications affecting outcome analysis were reported among participants who completed follow-up.

DISCUSSION

This study compared how the eye heals after two types of surgery. The study found that people who had laser surgery had corneas three months later than people who had manual surgery. The laser group also had astigmatism after surgery. However the two groups had eyesight cornea thickness and eye pressure.

The reason for this difference is that laser surgery is very precise. The laser can make cuts in the cornea. On the hand manual surgery can be less precise because it depends on the doctors skill and the tools they use. The laser surgery may cause damage to the cornea and distribute the stress more evenly. This could be why the laser group had corneas after surgery. The femtosecond laser technology allows for controlled cuts, which is not always possible with manual surgery. The femtosecond laser-assisted surgery may be better because it can make cuts and cause less damage, to the cornea (7-11).

Previous studies of cataract surgery using femtosecond lasers and traditional methods have mostly looked at how precise the surgery's how much energy is used and how the patients vision is affected after the surgery (1-6). These studies have shown that using a femtosecond laser can make the surgery more predictable. It is not clear if this really makes a big difference in how well the patient can see after the surgery (1-4).

The current study adds to what we know by suggesting that making incisions with a femtosecond laser may also affect how the cornea works. We used a kind of imaging called dynamic Scheimpflug imaging to look at this (4, 5-8).

What really mattered was how things changed within each group of patients. For the patients who had femtosecond laser surgery the stress-strain index went up by 0.05 and the stiffness of the cornea at applanation went up by 4.2 units after three months. On the hand for the patients who had traditional surgery these numbers went down by 0.01 and 3.1 units. This does not agree with what we thought at first which was that the biomechanical properties of the cornea got better in both groups.

Instead it seems that using a femtosecond laser to make the incisions helps keep the cornea strong, after surgery and traditional surgery may make the cornea a little weaker. However we do not really know what a big enough difference is for these biomechanical measures to really matter to the patient so we need to consider what the numbers mean in the context of the patients condition.

The femtosecond group had astigmatism in the cornea after surgery it was 0.17 D lower. This is what we thought would happen because the incisions made by the femtosecond laser are more precise. The cornea is less likely to change shape after surgery (5,6). We also found out that eyes that are stronger and less likely to change shape had astigmatism after surgery. But this does not mean that one thing causes the other it could be because of the differences between the two groups of people in the study. We did not do an analysis that looks at how the astigmatism changed after surgery so we can only talk about the astigmatism after surgery not how much the surgery actually caused (12-16).

Both ways of doing the surgery gave results for how well people could see at a distance after three months. We did not find any differences between the two groups in terms of how thick the cornea was or the pressure inside the eye. This shows that making an incision, in the cornea is still a good way to do cataract surgery. The advantage of using a femtosecond laser to make the incision seems to be that it helps keep the cornea strong and reduces astigmatism not that it makes people see better after surgery. These differences might be important when we need to make sure the result of the surgery is very predictable but we have to consider the cost and complexity of using the femtosecond laser (1-4).

The study had good points. The groups were divided fairly so they were similar at the start. The same surgeon did all the operations. They followed the same steps before and after surgery which helped keep things consistent. The people in the study and the person measuring the results did not know who was in which group, which helped reduce bias. They also checked on the people in the study times so they could see how things changed over time instead of just looking at one result after the operation. The study also had a low dropout rate of 4.2 percent, which helped reduce bias but it was still possible (16).

There were some things that were not so good about the study. It was only done at one hospital. It was a pretty small group of people with simple cataract problems and healthy corneas so the results might not apply to other people or other surgical settings. They only followed up with the people in the study for three months so they do not know if the results would last longer. They only looked at the results from the 69 people who had data after three months instead of using a special method to account for people who dropped out. Even though not many people dropped out this could still introduce bias if the people who dropped out were different, from the others (17).

We did not look at the incision architecture using a kind of photography called anterior-segment optical coherence tomography. This means we cannot say for sure if the differences in the way the wound heals had an effect on the findings. We also did not do an analysis of astigmatism after the operation. The patients did not report on their quality and we did not check for other problems like higher-order aberrations and sensitivity to contrast. We also did not think about the cost.

The information about the equipment and devices used is not detailed enough so other people may not be able to repeat the study. The analysis we did was a snapshot and did not take into account other factors that could affect the results like the condition of the cornea before the operation or the group the patient was in (16-18).

We need to do studies with more patients and follow them for a longer time to see if the differences we found really make a difference in how well the patients can see. Future studies should include a way of analyzing astigmatism a way to directly look at the incision a plan, for dealing with missing information and a way to adjust for other factors over time. They should also ask the patients about their experience. Think about the cost.

Studies that include patients who have had surgery before or have glaucoma or other problems may help us understand which patients will really benefit from using a femtosecond laser to make the incision.

CONCLUSION

The femtosecond laser-assisted clear corneal incision creation method gave results for corneal stiffness and less astigmatism after three months compared to the manual method. The patients who got the femtosecond laser-assisted corneal incision creation and the ones who got the manual incision creation had similar vision, corneal thickness and eye pressure. These results show that the femtosecond laser-assisted clear corneal incision creation method may be better at keeping the cornea strong and stable in the term. However the femtosecond laser-assisted clear corneal incision creation method needs to be studied in bigger studies that take place in many centers and last longer to see if these differences really matter and last over time. The femtosecond laser-assisted clear corneal incision creation method and its effects on the cornea need to be looked, at closely.

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