UNIVERSITY OF LATVIA
FACULTY OF PHYSICS, MATHEMATHICS AND OPTOMETRY
DEPARTMENT OF OPTOMETRY AND VISION SCIENCE

CHANGES IN CROSS AND UNCROSS STEREOACUITY AFTER LASIK EYE SURGERY

MASTER THESIS

Author: **Nigar Huseynova**
Student card number: nh18004
Supervisor: professor, Dr. phys. Gunta Krūmiņa

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ANOTĀCIJA

Maģistra darbs uzrakstīts angļu valodā uz 37 lappusēm. Tas satur 10 attēlus, 9 tabulas un darbam ir 49 atsauces uz literatūras avotiem.

Pētījuma mērķis bija novērtēt krustotās un nekrustotās disparitātes stereoredzes asumu pirms redzes refraktīvās operācijas, divus, četrus un sešus mēnešus pēc operācijas. Pētījumā piedalījās 102 acu klīnikas pacienti – 65 sievietes un 37 vīrieši vecumā no 19 līdz 45 gadiem. Visiem bija miopija vai miopija ar astigmatismu. Jaunais izveidotais izkliedēto punktu globālais stereoredzes datorizētais tests dod iespēju novērtēt abus disparitātes veidus. Rezultātu analīzē tika secināts, ka nav novērojamas statistiski būtiskas izmaiņas stereoredzes asumā pirms un pēc operācijas krustotās disparitātes gadījumā, savukārt nekrustotās disparitātes gadījumā ir novērota stereoredzes asuma uzlabošanās sešu mēnešu laikā pēc redzes refraktīvās operācijas.

Atslēgas vārdi: krustotā disparitāte, nekrustotā disparitāte, stereoredzes asums, refraktīvā ķirurģija

ABSTRACT

The Master thesis is written in English on 37 pages. It contains 10 figures, 9 tables and 49 references.

The master thesis aimed to evaluate crossed and uncrossed disparities stereoacuity before eye refractive surgery and after two, four, six months after surgery. One hundred two healthy adults participated in the study – 65 are females and 37 are males between ages 19 and 45. The study was focused on patients diagnosed with myopia and myopic astigmatism. The new global computerized stereotest provided RDS global stimuli, and there was used the psychophysical staircase method. It allowed to measure of both – cross and uncross disparity with individual approach to patients simultaneously. The statistical analysis stated that there were no difference before and after refractive surgery in group with crossed disparity. In group with uncrossed disparity we can see the improvement during the six months after the refractive surgery.

Keywords: crossed disparity, uncrossed disparity, stereovision acuity, refractive surgery

ABBREVIATIONS

CD – crossed disparity

UD – uncrossed disparity

ZD – zero disparity

RDS – random dot stereogram

TABLE OF CONTENTS

INTRODUCTION

Stereoacuity is one of the most important parameters which indicates quality of vision that at the same time means the quality of life. Unfortunately, the importance of maintaining and improving the level of stereoacuity after different ophthalmological interventions often does not attract the proper attention. Furthermore, the opportunity to measure existence or non-existence, type and level of stereoacuity for far distance with a standard optometric or ophthalmologic office equipment is usually restricted to Osterberg test, which provides information only about cross disparity. As a result, patients with low sensitivity towards the cross disparity are considered the stereoimpaired despite the fact of possibly high sensitivity to uncross disparity. That is why recommending to the practitioner a global digital psychometric method which calculates the real threshold for both cross and uncross disparities at the same time is seen as the best possible solution.

The new software can also be arranged according to the individual pupil distance which means more accurate and effective measurement, and which enhances the value of this method.

The aim of the study was to assess the crossed and uncrossed stereovision acuity before and after LASIK surgery using the new developed computerized random dot anaglyph global stereotest.

The objectives of the study are the following:

1. to assess the crossed and uncrossed stereovision acuity using the new developed computerized test in cases of refractive surgery for myopia and myopic astigmatism;
2. to compare results of the crossed and uncrossed disparity stereoacuity at the different points – before refractive surgery and two, four, and six months after refractive surgery;
3. to evaluate the correlation among ages, gender, anisometropia level, refraction, and type of previous correction and the crossed and uncrossed stereoacuity.

1. LITERATURE REVIEW

1.1. Different refractive surgical methods

Vision impairment is one of the biggest social problems in the world. The bulk of it consists of uncorrected refractive errors, numbers of which, unfortunately, are going to dramatically increase and become the second most common cause of worldwide blindness (*Naidoo et al.*, 2016).

A huge part of refractive errors is caused by myopia, which tends to infect teenagers with so high scores, that it threatens to turn into epidemy (*Dolgin*, 2015). In this situation the importance of productive treatment of refractive errors increases day by day. Among these are: prescribing eyeglasses, using contact lenses, performing visual training, and refractive surgery methods. Refractive surgery is an alternative method which is used if patients do not want to be dependent on eyeglasses or contact lenses, or can not to use them because of any of the following reasons -professional issue, high anisometropia, contact lens intolerance, after rhinoplasty, otoplasty surgery etc. Nowadays has known lots of surgical methods which are widely used by physicians in aim to improve visual acuity. The most prevalent ones can be divided into the following three groups: (*Garcia-Montero et al.*, 2019):

1. changes in corneal refraction- PRK (T-PRK, LASEK, epi-LASIK) and LASIK (Femto LASIK, SMILE);
2. improving vision by implantation of phakic lens (in anterior or posterior chambers);
3. manipulation with crystalline lens – a s clear lens ectomia with or without (in cases with high myopia) IOL implantation and if crystalline lens has opacifications – cataract surgery.

All these methods have their own medical reasons, contraindications, strengths and weaknesses and parameters. And only after collecting all information about a patient's lifestyle, occupation, medical history, and after full examination of eye parameters an ophthalmologist can decide which refractive method is better for a particular case.

1.1.1. Keratorefractive surgery

Improving visual acuity through changes in corneal refraction is the most preferred method among others, because of enabling improvements of a wide range of refractive errors, tightness, predictability, relatively easy procedure, and quickness of both processing and healing.

Keratorefractive surgery commonly has been implemented as LASIK, because of the prevailing predictability and efficacy, significantly shorter recovery time, and what is not the least – painless in comparison with PRK. And only rarely possible flap related complication and using more stromal tissue shows weak sides of LASIK compared with PRK (*Shortt et al.,* 2006a*; Shortt et al.,* 2013b).

Detailed preoperative examination with high attention to every small nuance is a half of the successful result in case of keratorefractive surgery. Mandatory for preoperative examination are:

1. Measurement refraction in cycloplegic condition for avoiding overcorrection in case of myopia or undercorrection in case of hyperopia;
2. Detailed peripheral retinal examination and if needed panretinal or local laser coagulation for prevention such a fearsome complication as retinal detachment;
3. Measurement a pupil diameter in both – high and low illumination to avoid such possible postoperative discomfort conditions as halos and glare, and even deny corneal refractive surgery in some cases if big pupil size in a low light condition is accompanied with high refractive errors, what can lead to significant problem for patient from impossibility to drive at evening up to difficulties for some persons in professional area (*Holladay et al*., 1999);
4. Waiting a few weeks after removing rigid contact lenses or approximately one week after removing soft contact lenses before doing corneal topography and other corneal examinations (*Wilson et al.*, 1990).

Best result (predictability and effectiveness) after keratorefractive surgery demonstrate patients with low and moderate myopia/myopic astigmatism in comparison with high myopia/myopic astigmatism patients. When looking at hyperopia- better results are achieved by the patients with refractive errors lower than 3.5 D. Regression is more common in groups of high refractive errors in cases of high myopia as well as for patients with high hyperopia (*Murray et al.*, 2017).

Patient's expectations and satisfaction are not always correlated with good uncorrected visual acuity. Sometimes they can be really upset because of possible problems in near distance visual acuity, vision at night, glare, and dryness. All these problems could be avoided if possible temporary discomfort or changes were explained before operation (*Tai & Sun,* 2019).

1.1.2. Improving vision by implantation phakic Lens (in anterior or posterior chambers)

Phakic lens implantation and crystalline lens changes both belong to the group of intraocular surgery. Which means that they have part of similar contraindications and a bigger number of more serious complications than when surgeon works on the surface, in the cornea. All this requires more responsibility, skills, and experience from the surgeons in order to achieve good results.

As known, keratorefractive surgery in cases of high refractive disruptions has its defined limits. Intraocular refractive surgery successfully fills in the gaps in cases of high refractive errors, which is out of reach of corneal refractive surgery. Also, it can be used as an alternative method if the patient has contraindication for corneal refractive surgery due to condition of cornea such as thickness or topography incompatibility (*Kamiya et al.*, 2008).

Range of possible refractive errors correction is huge – from 20 D of myopia till 8.0-9.0 D of hyperopia, and approximately up to 6.0D of astigmatism (*Garcıa-Montero et al*., 2019).

The list of phakic lens implantation benefits includes fast recovery, stable vision condition, and what is crucial, especially for young patients – maintaining of accommodation. Of course, the possibility to remove or replace Phakic IOL, which makes this process reversible is an unfair advantage of their method if compared with others.

Size of pupil diameter and ability to change it, play a defining role in phakic IOL implantation procedure, because close neighbourhoods of IOL with iris and crystal lens and possible contact with them can lead to unwanted consequences. In the literature we can find reports which show the influence of phakic IOL to diameter, and amplitude of pupil constriction and dilatation after implantation (*Keuch et al.*, 2002).

Complications of phakic IOL implantation related to its contact with surrounding tissue and intervention to intraocular liquor flowing process. Among them are opalescence in the crystal lens, rising of IOP, loss of endothelial cells, pigment dispersion syndrome (*Sanders et al.*, 2003).

Literature survey majority shows high satisfaction levels among patients after Phakic IOL implantation, more than 90%, which makes this procedure favourable (*Tahzib et al.*, 2006). *Guell et al*. (2001) report about high myopia -patients group (-16.0 D -23.0 D) and crucial results after combined operation: first Phakic IOL implantation and then elimination of residual errors by keratorefractive surgery.

1.1.3. Refractive Clear Lens exchange and in case of opalescence in crystalline lens – cataract surgery

In both cases, no matter if there is crystalline lens opacification or not, goals, measurements, techniques, and all other procedures are the same. It can be mentioned only less comparable situations with possible corneal oedema after Clear Lens exchange procedures. Absence of opalescence means – crystalline lens is softer and use of both quantitative and qualitative energy are lower, procedure is quicker and as a result there less probability of corneal oedema.

Advantages of using these kinds of surgery in refractive aims are the high predictability and possibility to obtain the proper figure of refraction and relatively quick rehabilitation period (*Colin & Robinet,* 1994). Disadvantages of these procedures are basically the same as in all intraocular surgeries: CME, endophthalmitis, possible problem in corneal endothelial cells, risk of retinal detachment, especially in cases of high axial myopia. Difference with the other refractive procedures is the loss of accommodation in case of a patient being at young age (*Colin et al.,* 1998).

Currently, market provides the wide range of IOLs: aspheric, bifocal, accommodative, multifocal, suture fixated, anterior chamber, iris fixation, toric with yellow filters, etc. Surgeons can search the best choice for every individual case based on patients' preoperative data, lifestyle, and expectations (*Ruiz-Mesa et al.*, 2009; *Leyland & Pringle,* 2006). As mentioned above, high predictability of refractive results around 1.0 D fluctuation in 68-100% cases, as reported by the studies, leads to high UCVA in more than 70% (*Preetha et al.,* 2003).

1.2. Stereovision

1.2.1. Factors affecting the stereoacuity

Stereovision is the cherry on top of the visual system. It is the highest degree of binocularity, when two images from slightly different positions (disparate stimulation in retinas of two eyes) of one picture at the same time, helps the brain perceive depth, relative distance between objects, and create 3D dimension (*Ferrer-Blasco et al.,* 2009).

Despite the fact of receiving slightly similar pictures from both eyes, our brain can detect even a very small dissimilarity in aspects of the subject's orientation, their shadows, which can help the occipital cortex in formation of 3D vision. Fusion appears only if both our eyes can see the similar object, otherwise, instead of binocular single vision we will have such undesired effects as suppression, retinal rivalry, or superimposition.

Our daily life is filled with millions of tasks, and almost all of them need higher or lower levels of stereoacuity to implement. For some professions good level of stereoacuity is a prerequisite. Bottom line - stereoacuity shows the quality of vision. Existence and level of stereopsis can be measured by a few methods, based usually on anaglyph or vectogram principles. In practice, the most used tests are Randot, Titmus and Fly charts, Osterberg and pen tests, etc.

Factors which can reduce the stereoacuity are refractive errors, anisometropia, aniseikonia, heterophoria, age and others (*Ferrer-Blasco et al.,* 2009). Below, we will try to review some of them.

1.2.2. Stereoacuity and anisometropia

Anisometropia means difference in refraction of both eyes 1 dioptre or more *(Liu S et al.,*2003). At the same time anisometropia plays a huge role and has been the biggest cause of stereoacuity disrupting. Even if mild, it can lead to such undesired conditions as aniseikonia, amblyopia and misalignment. Anisometropia disturb the fusion process and reduce stereoacuity. According to some study: more than 2 dioptres in cases of spherical myopic anisometropia, more than 1 dioptre in cases of spherical hyperopic anisometropia, and more than 1.5 dioptres if there is myopic or hyperopic astigmatism – increasing probability of amblyopia and decreasing binocularity.

Interesting facts were stated in study by *Maciej Gawęcki (*2019):

1. Myopic anisometropia decreases stereoacuity at distance more, than at near. For near, this value was 3,0D for sphere and "against the rule astigmatism", and 4,0D for "with the rule astigmatism". For distance even 2,0D of spherical miopic anisometropia can significantly decrease stereoacuity.
2. "With the rule astigmatism'' disturbs stereoacuity for distance less (if 3.0 D or more), than "against the rule" (2.0 D or more). Linear relationship between rising amount of pure anisometropia and decrease of stereopsis was shown by *Levi* (2011). Total loss of binocularity if anisometropia 6.0 D or higher was described by *Chen et al.* (2013). To the opposite, timely treated amblyopia and well corrected anisometropia lead to increasing stereoacuity (*Weakley*, 2001).

1.2.3. Stereoacuity and refractive errors

Kulp et al. (2015*)* have checked 4040 children and spotted that hyperopia higher than +3.25 plays a huge role in development of amblyopia and strabismus, which in turn leads to impairment of stereovision. Even if there is no anisometropia and hypermetropia is bilateral – it also can lead to bilateral amblyopia, which means decreasing binocular vision.

Myopia and myopic astigmatism decrease stereoacuity less and show better results than hypermetropia groups if we compare cases with the same figures of refractive errors. Best result has been achieved in cases with high myopia in comparison with moderate or low (*Mortazavi et al.*, 2006).

1.2.4. Stereoacuity and visual acuity

As noted by *Lee & Isenberg* (2003), rising visual acuity is related to increasing near stereoacuity. *Jabbarvand et al.* (2016) analysed 180 patients after PRK and reported the greatest improvement in the group of high myopia in terms of near stereoacuity. Lowest result was achieved in a group without anisometropia, and with low myopia.

Sarkar et al. (2020) published less optimistic results – six months after refractive surgery in all 106 cases they observed worsening of both near and distance stereoacuity.

Wong et al. (2002) analysed patients with low refractive errors and good distance stereoacuity. Not in all cases the good distance stereoacuity was accompanied with the good near stereoacuity. Near stereoacuity is more sensible to inaccurate accommodative-convergence responses, which can negatively impact its results.

1.2.5. Stereoacuity and aniseikonia

Aniseikonia is the different perception of the subject's shape and size in the retina. The correlation between stereoacuity expressed in log and aniseikonia in percentage is a well-known fact (*Highman*, 1977).

Gobin et al. (2008) found that if aniseikonia after cataract surgery is 6% or more, it can significantly decrease stereoacuity. According to the "rule of thumb" 6% of aniseikonia is related to 3.0-4.0 D of anisometropia (*Ryan,* 1975).

Any refractive procedure firstly is aimed at enabling better quality of life due to improving visual and stereoacuity. The most successful in this is keratorefractive surgery, especially LASIK. In cases of moderate myopia results after Lasik surgery in terms of both distance and near stereoacuity was better than previous best spectacle correction (*Singh et al*., 2015). We can see better outcomes in improving stereoacuity when preoperative anisometropia is more than 2.5 D. Increase of stereoacuity after keratorefractive surgery is based on decreasing or eliminating preoperative anisometropia, and associated with it aniseikonia (*Huang & Lu,* 2009).

All this works if anisometropia is pure refractive. In cases when the cause of anisometropia is a different axial length or in the situation where we have a mixed refractive and axial anisometropia – the result can be not so impressive.

It can explain why the cases with astigmatism always show good results in terms of improving stereoacuity. Astigmatism is a purely refractive error and can be eliminated by refractive procedure with all associated aniseikonia (*Liu et al.*, 2003).

1.3. Stereoacuity and LASIK refractive surgery

Solomon et al. (2009) analysed 1581 articles dated from 1988-2008 and concluded that 95.4% of patients after Lasik surgery were satisfied. In the same analysis, we can see the statistics about 16 million LASIK procedures performed worldwide by that moment.

Taking into account the increasing amount of clinical research about LASIK, performed procedures and technological progress in the last 12 years after publication – we can place LASIK in one line with the safest, most effective and favourable procedures.

With the right approach to the procedure and in the capable hands, LASIK may significantly improve quality of life due to restored binocularity in some cases or increased level of stereoacuity in the others. All these changes for the better are possible through one or a few processes, depending on the individual patient's preoperative data base, hinge placement, size of optical zone, age, etc. (*Jimenez et al.*, 2008).

So, in most cases LASIK may:

1. to eliminate a wide range of ametropia (*Carones et al.*, 2003; *Sanchez-Pina et al.*, 2007);
2. to decrease anisometropia due to correcting the proper amount of ametropia. It is a well-known fact that anisometropia decreases stereoacuity. For spherical anisometropia the relationship is: 1D of anisometropia can diminish stereoacuity by 85-87 s/arc. For cylindrical anisometropia, 1.0 D can reduce 55 s/arc (*Brooks et al.*, 1996). Uncorrected visual acuity after refractive correction in comparison with corrected visual acuity before – it is a good indicator for understanding how to change stereoacuity after eliminating anisometropia;
3. to deal with aniseikonia due to eliminating minification or magnification effects of glasses, especially in cases with high refractive errors (*Liu et al.*, 2003). In cases of high ametropia patients can have small amounts of stereoacuity due to blurriness even with best glasses correction (*Brooks et al*., 1996). *Mravicic et al*. (2020) report about 98 patients in most cases improving level of stereoacuity and minimizing aniseikonia after LASIK. Number of patients with worsening stereoacuity is zero. But in cases where the cause of aniseikonia were mixed – axial and refractive anisometropia, or pure axial, the results were lower because LASIK surgery, being a keratorefractive procedure, cannot change axial parameters. To the opposite, minimizing aniseikonia from 10% till 3% takes place in cases with pure astigmatism. Also, a part of patients without any changes in stereoacuity, was from groups with low levels of refractive errors and without anisometropia;
4. to impact positively to phoria due to removing prismatic effects of glasses (*Razmjoo et al.*, 2008);
5. almost all cases in medical literature show improving or restoring in binocular function and stereoacuity due to all items above and because of increasing visual acuity (*Jabbarvand et al.*, 2016);

6. a huge role in increasing stereoacuity after LASIK surgery plays not a small percentage of cases with preoperative hypo or hypercorrection in glasses or contact lenses and of course patients who have never used any corrections before or use them infrequently (*Razmjoo et al*., 2008);

Inconsistent reporting about contrast sensitivity after keratorefractive surgery can be found in literature. One part of authors noted decrease or subtle changing in contrast sensitivity (*Zhao et al.,* 2010). Another part reports about improvement of contrast sensitivity (*Keir et al.,* 2009).

Singh et al. (2015) reported about better results in measurement of near stereoacuity after LASIK surgery, than distance in cases with myopia. In most cases myopia develops in the teenage period, which is a very important time for the formation of the visual system, of binocularity and stereopsis. Long period of time without any correction or hypocorrection can influence distance stereopsis formation due to distance blurriness, while near stereoscopy does not suffer because of pretty good near vision even without correction in cases with moderate and low myopia.

Most of the articles provide data about change of stereoacuity one, three and six months after Lasik surgery. *Jabbarvand et al*. (2016) mentioned possible impact to result from transient dry-eye syndrome, which can significantly decrease stereopsis in early postoperative periods.

Adaptation period of 3-6 months also affects the final result. *Karimian et al*. (2017) mentioned the importance of the long-term observation of stereoscopy data after LASIK surgery, because only after 3 months stabilization of the visual parameters start takes plays.

In population-based literature a wide range of studies report about changing in visual acuity after LASIK surgery. But most of them discuss only monocular visual acuity. Significantly less amount authors surveyed changing in binocular system, distance and near stereoacuity and factors impacting this process. Also, unfortunately, not everywhere stereoacuity measurement before and after correction was taken as an important parameter, demonstrating how successful keratorefractive surgery was. It should not be forgotten that the decrease of stereovision, even with higher postoperative visual acuity, can be a cause of patient's dissatisfaction and possible reduction of the life quality (*Wasserman*, 2007).

When we consider the results received by means of examination of stereoacuity as a statistical indicator among the group of patients, or as the data about change of stereoacuity after the surgical intervention, we should remember that in either case the outcome significantly depends on multiple contributing factors, including but not limited to: age indicator of the patients from the examined group (it is a well-known fact that the older is patient, the lower is his/her stereoacuity); what refraction errors had the patients from the examined group (the higher is the indicator of refractive errors, the better is the result); whether patients from the examined group had any anisometropia (patients with anisometropia achieve better results); whether patients from the examined group used any wearable correction (glasses or contact lenses) before; which methods are used for the conduct of the examination; what exactly is being examined – distance or near stereoacuity; etc.

Let's discuss below which groups of patients participated in the examinations and which methods of examination of stereoacuity were used by some authors whom we mentioned in the literature review:

For example, *Brooks et al.* (1996) conducted their assessment based on examination of the group of patients who were of the age range of 26-59 years old, were healthy and had good stereoacuity. The authors induced anisometropia using trial lenses, creating alternately unilateral myopia, hyperopia and astigmatism. Then they investigated how induced anisometropia affects the binocular vision and to what extent it negatively affects stereoacuity. They used the polarized Titmus stereotest (*Titmus Optical*) for examination of stereoacuity, while for binocularity measurement they used Worth four dot and Bagolini lenses at both 33 cm for near and 6 m for distance. The authors reached the conclusion that even not significant level of induced anisometropia still resulted in decrease of stereoacuity for all patients from this examined group. But it will be interesting measured the same patients after some adaptation period.

98 patients with the different refractive errors participated in the assessment by the other group of authors (*Mrawicic et al.*, 2019). Here, three parameters were examined: distance stereoacuity, near stereoacuity, and aniseikonia before and after refractive surgery (LASIK). The age range of the examined patients was 19-59 years old. Methods of examination used were as follows: near stereoacuity was measured by the Random dot Stereotest (*Precision Vision*) at 40 cm, distance stereoacuity was measured by means of Random dot Stereotest (*CSO, VisioChartCVCO3*) at 6 m, and aniseikonia was measured by means of the Awaya test. The outcome was as follows: almost all the 98 patients demonstrated improvements in stereoacuity levels. Especially this was noted about the patients from the groups with monocular myopia and anisometropia. These results confirm the investigations described above.

Jabbarvand et al. (2016) studied the effect of refractive procedure (PRK) on near stereoacuity levels. The examination was conducted with participation of 180 patients, which were divided into three groups: low myopia, high myopia, and hyperopia. The method for examination of near stereoacuity was the Random dot test at 40sm with corrective glasses before procedure and 1, 3 and 12 months after procedure. Having assessed the outcomes of the investigation, the authors reached the conclusion that no difference regarding sex or age was observed, and improvements in all groups of patients – especially in the groups of patients with high myopia and anisometropia – were observed.

Razmjoo et al. (2008) examined the group which consisted of 200 patients. Method of investigation was the Random dot test before and after refractive surgery (LASIK). Patients had myopia ranging from -0.5 D till -12.0 D. Results demonstrated the following: stereoacuity getting worse in 9.5% of patients; increase -32.5% of patients; and no change for 58% of patients. Best results were demonstrated by anisometropic patients without amblyopia after three months.

Singh et al. (2014) examined 40 patients with the following conditions: with mild and moderate myopia (-4.0-5.0 D); with low anisometropia (0.5-1.0 D); and with low astigmatism (0.5D-0.75D) before and after refractive surgery (LASIK). The Random dot test was the method for measurement of near and distance stereoacuity. The near stereoacuity was measured from the distance of 40 cm (Random dot, *Stereo Opticals Co Inc*) with polarized glasses. The distance stereoacuity was measured from the distance of 3 m (Distance Random dot Stereotest, *Stereo Opticals Co Inc*). The result was as follows: improvement was demonstrated by almost all patients, while the near stereoacuity measurements demonstrated better results than the distance stereoacuity measurements.

Karimian et al. (2017) studied the changes in stereoacuity of 49 patients of the age range of 23-32 and with myopia of 1.5-5.0 D, before and after refractive surgery (PRK). The measurements of the distance and near stereoacuity were taken by means of the following tests: TNO test (*Ootech*); Butterfly 40 cm (*Stereo Optical*); and stereoacuity test before and after two weeks, one month, and three months. This study reached the following conclusion: no statistical difference was caused by age or sex, TNO test better detects the stereoacuity improvements.

Situation gets worse when we try to collect data from studies about changes in uncross stereoacuity after LASIK or other corneal refractive surgeries. There is only one report – by *Jimenez et al.* (2008) describing upper disparity limit after LASIK. This research included 30 patients, all of whom had corrections by glasses or contact lenses before LASIK surgery. Range of anisometropia was small, average anisometropia was 0.92±0.13 D according to presurgical measurements. Authors arrived at the following result: after LASIK surgery the upper disparity limit decreased at the average of 26%. However, this research did not include groups of patients which, according to several studies, more often demonstrate better stereoacuity results after LASIK: patients with anisometropia of more than 2.5 D and patients without preoperative correction or without correction at all.

Some details about crossed and uncrossed disparity: it is a well- known fact that in ideal conditions the range of stereoacuity is between 2-6 arcsec (*Howard et al.* 1995). Most of the studies demonstrated the stereoacuity level at 5.6 arcmin for the crossed and at 14.5 arc sec for the uncrossed disparity targets (*Grabowska*, 1983). *Yang & Blake* (1991) reached the conclusion that stereoscopic system consists of four spatial-frequency channels for both crossed and uncrossed stereo, two for each one. *Lasley et al.* (1984) reported the results of their investigation, leading to the conclusion that some patients can better reach crossed stereo rather than the uncrossed, whereas some other patients demonstrate completely opposite dynamics – better reaching uncrossed stereo rather than the crossed one. At the same time, the authors noted that in certain conditions some patients can detect only crossed disparity, while others – only uncross disparity.

Jaschinski et al. (2009) reported about cross and uncross stereoacuity examination cases of 11 patients with good stereoacuity and healthy eyes. Three of them demonstrated significant differences between crossed and uncrossed disparities. The proportion of crossed and uncrossed disparities among the population with dysphoria was illustrated in the studies of *Lam et al.* (2002). For patients with orthophoria the mean stereoacuity was measured at 5.31 arc sec, in cases of patients with exophoria – at 6.02 arc sec and in cases of patients with esophoria – at 8.91 arc sec.

The figures for mean crossed stereoacuity indicated 4.8 arc sec, and for the uncrossed stereoacuity – 7.2 arc sec. As a result, we can observe better outcomes in measurement of crossed stereoacuity than in measurement of the uncrossed one in all three variations of phoria, with significant difference only for the exophoria. Of course, patients with orthophoria had better stereoacuity results than the other patients. Also, patients with exophoria had better crossed stereoacuity than the uncrossed stereoacuity. Measurements were taken at the 6 m distance, using a three-rod apparatus.

To our knowledge, the relationship between cross and uncross stereoacuity and its change after LASIK surgery was not properly identified before.

2. DATA AND METHODS

2.1 Subjects

The present study was performed as a before-after excimer laser refractive surgery between February 2020 and January 2021. One hundred two healthy adults participated in this research. Refractive surgery was performed for both eyes. Among them, 65 are females, 37 are males, aging from 19 to 45, with an average age being 27 (standard deviation ± 6 years). All principles of the Declaration of Helsinki applied to the study. Hence, before signing the consent, patients received extensive detail about the procedure they had to go through since they have never been part of any similar studies before. The study focused on patients diagnosed with myopia and myopic astigmatism who were referred to our hospital for excimer refractive treatment with the goal of correcting refractive errors, achieve better visual acuity, and improve binocular and stereovision. The exclusion criteria were:

- hyperopia, hyperopic or mixed astigmatism
- prior refractive surgery
- strabismus, history of strabismus surgery
- general health problem, systemic disease, autoimmune disorders
- history of eye or head trauma
- colour vision defect
- amblyopia

Through a vision test within the last six months, we ensured that subjects have stable vision. Before doing the special stereotest (basement of this study), each participant went through a standard vision examination including objective and subjective refraction (manifest and cycloplegic), determination of BCVA (best corrected visual acuity) with a digital chart projector (*CCP-3100 Huvitz*), biomicroscopy, ophthalmoscopy, pneumotonometry, binocular function measurements for far and near distances, evaluation of accommodation, objective far and near phoria measurement with prism bar and checking of a stereo vision. The stereo vision test was performed with the best eyeglasses correction one week before refractive surgery. Only in cases with anisometropia higher than 2.5 dioptres (7 patients) for the correction we have used contact lenses (see Fig.2.1).

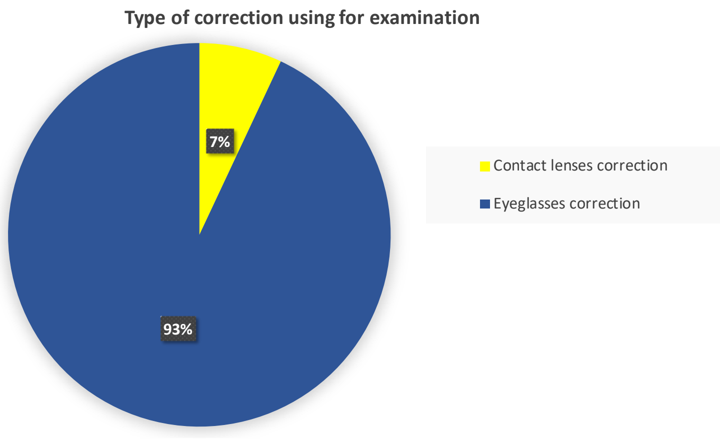

Fig. 2.1 Type of correction for stereotest.

All pre-and postoperative examinations were performed by one optometrist (N.H.). Repeating tests were conducted two, four, and six months after the LASIK refractive surgery**.** Testing after the surgery were performed without correction. Furthermore, patients who has a residual refractive error more than 0.75 D after surgery during all six months of the study were excluded. In addition to them were excluded all patients who had visual acuity lower than 100% in both eyes.

As mentioned above (see page 13), 65 females and 37 males, in other words, 204 eyes, were examined during this study. The mean preoperative spherical refractive error in patients was measured as -4.44±2.0 D, ranging from -1.12 to -8.75 D (see Fig.2.2).

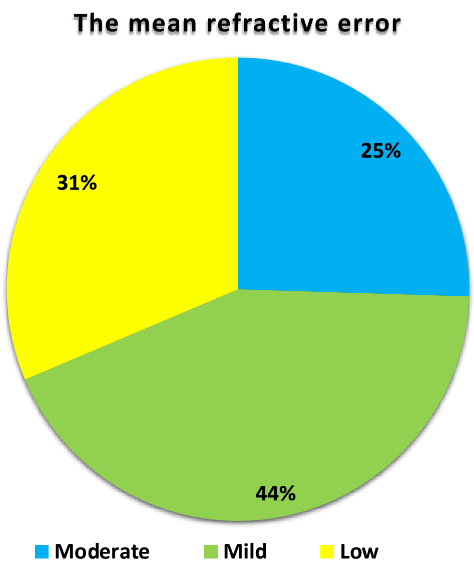

Fig. 2.2 The mean refractive error.

Before the surgery, 14 patients wore contact lenses, and 22 patients wore eyeglasses daily. The 26 participants used to wear eyeglasses or lenses occasionally, and 40 people did not use any correction (see Fig.2.3).

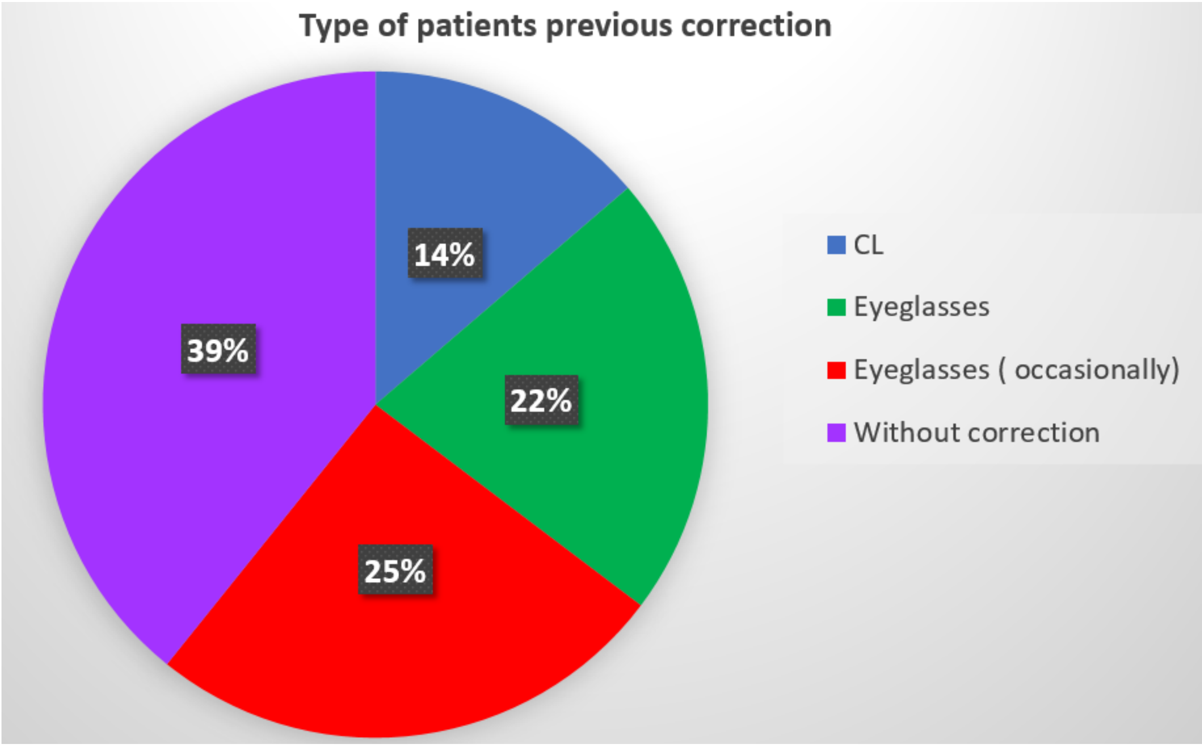

Fig. 2.3 Type of patient previous correction.

Among the patients with correction only 5-7 of them used proper vision correction. In most cases, participants wore eyeglasses with significantly lower numbers than needed or used contact lenses with same dioptre for both eyes, which required to be different. According to some patients, it was easier to buy a box of lenses with equal dioptre for both eyes. Some did not have enough time to visit a specialist when their earlier eye correction unit became uncomfortable to use. Instead, they decided to buy a new pair of eyeglasses on their own.

For every patient, the anisometropia was calculated as the difference between the spherical equivalents of each eye. The average anisometropia was 0.98 D ranging from 0 to 4.0 D. We divided patients into two groups based on their anisometropia. In Group 1, 91 participants had 0-2 dioptres anisometropia and in Group 2, 11 patients had more than 2 dioptres anisometropia.

2.2 Stimuli and equipment

Stereoacuity measurements were performed by author before and after surgery, and the results were compared. The new stereo test stimuli were generated using a graphics workstation on an iMac with Microsoft Windows 8 installed in. The computer has Intel Core i5 dual-core processor with a 2.3 GHz (*Turbo Boost 3.6 GHz*) clock speed, 8GB DDR4 RAM with 2133 MHz memory speed, and Intel Plus Graphics 640 processor graphics card. We used an external screen connected via HDMI cable at a fixed 4 m distance from the observer during the experiment. The resolution of the display was set to 1920x1080 pixels, where 1 pixel corresponds to 0.167 mm.

Throughout all testing processes for each patient, the screen was configured to maximum brightness. The room illumination level was set to 100 lux during all tests, and the window blind was used to help block the light from outside to reach proper light levels. A patient was seated on an optometric studio chair. Each patient's height was adjusted to the level where eyes can have a perpendicular view at the centre of the screen. No chinrest nor a headrest was necessary for the observer because this digital text did not have any motion parallax clues. The stimuli were generated considering the use of anaglyphs for the subject placing a red (Wratten 29) filter in front of the right eye and a green one (Wratten 58) in front of the left eye to obtain a dichoptic presentation.

To assess stereovision, we applied a new computerized approach initiated by Professor Dr.phys. Gunta Krūmiņa of the University of Latvia, Faculty of Physics, Mathematics and Optometry and developed by Dr.Eng. Vsevolod Liakhovetskii of the Russian Academy of Sciences, Pavlov Institute of Physiology. The initiation file (.ini) was modified to customize the main settings of the software. Internal variables were personalized as following: the distance between the stimuli and the subject – 4m; the dimension of the pixel size according to the display in use – 0.167 mm; the dimension and size of the two kinds of random "dot" stimuli in rectangular shape 41×41 and 36×30 pixels; the maximum exposure time: 1000 ms, three correct answers for decreasing disparity and two incorrect answer for increasing disparity.

Following personal data of each subject was inputted into the software:

1. full name or reference code;
2. age;
3. interpupillary distance (PD) in mm.

The stereopsis of each participant was evaluated individually. The response device was a customized wired keypad with numeric signs, where study participants could select vertically aligned 2, 5, 8 for crossed, zero, and uncrossed disparity, respectively. If it was impossible to detect the spatial position of the stimuli, then button 5 was also allowed to be used in this case.

The desktop computer keyboard was modified by covering and disabling buttons other than those mentioned above (see Fig. 2.4). The main purpose behind such modification is to ease participant's response selection experience by limiting the number of buttons and their locations to remember.

Fig. 2.4 Customized USB wired desktop computer keyboard.

We only tested a single level of stereoscopic ability, global motion perception. A suprathreshold was included in the stereo test. The suprathreshold hyperacuity stimulus was formed in a horizontally divided field and it served as a front parallel plane of dynamic random dots. As each trial being assessed individually, the upper part of the field indicates a zero-disparity reference of 0% decorrelation. The bottom part of this field is mostly recognized as the randomly varying magnitude and the condition of disparity. Due to intrinsic dimensions dots in rectangular shape could be generated as decorrelated residuals in the bottom part of the screen since their random positioning was overlapped in some cases. In this new stereo test, the stimulus was observed for 1000 milliseconds by a liquid crystal optical shutter which aligns with the monitor's frame rate. We experienced the bottom half of the screen with different decorrelations at each training session. Two dots in rectangular shape were positioned randomly that form the image. The sizes of dots were 41 by 41 pixels and 36 by 30 pixels. The black background was the only part that was not covered by these rectangular-shaped dots. When observed from a 4 meter distance the bigger shape had an angular size of 8 arcmin and 14 arc sec, where the other shape 4 arc min and 52 arc sec. The space covered by the rectangular dots and the background is called the average density of the RDS. It was the same as the global stimulus, approximately 18%.

Close-up imagery of the Anaglyphic technique is conducted to have the same crossed disparity positioning of various dots in a rectangular shape in stimuli.

Observers were asked to note the position of the bottom part of RDS in respect to the upper part. In the upper part of the screen, almost half of the dots reflect the same red and green pattern tilted horizontally (see Fig. 2.5). And the other half reflected a monochrome pattern which can be seen with the help of anaglyph goggles. The software enabled an observer to notice the same colour from all dots reflected on the screen.

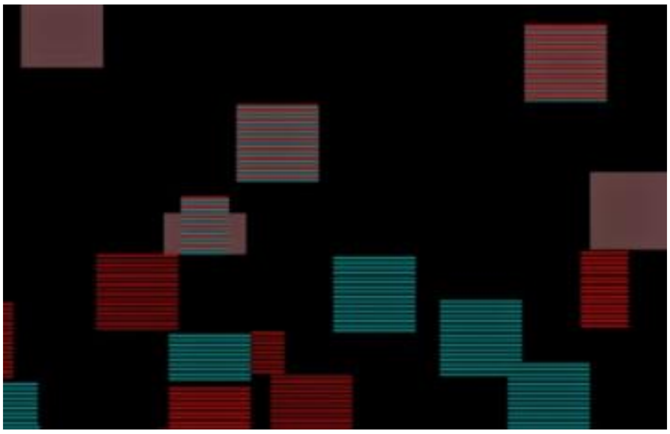

Fig. 2.5 The dot reflect the same red and green pattern tilted horizontally.

By moving lines of a particular colour in a certain magnitude and direction horizontally we could see the horizontal disparities at the bottom part of the screen. In the CD and the UD this horizontal disparity ranged between 1 to 120 pixels. For each trial, we set random positioning for dots on the whole screen.

Close up scene of the screen with dots in red and green colours on the bottom part and monochrome dots on the top. As per participant's responses to the psychophysical exam included in the study, each session needed multiple trials, and observers were conducted in at least 31 tasks but no more than 137. The central white cross with 30-pixel arms and 2-pixel thickness shown in the new stereo test software. The average time of the display was 1000 milliseconds that used a black background. Next, the same amount of time interval was used to display the hyperacuity RDS stimulus. The response interval started with displaying the stimulus and ended 3000 milliseconds after the stimulus disappeared. An accepted staircase method for psychometric function triggered a diverse magnitude and sign for the stimuli. The software also recorded the time elapsed in between the appearance and disappearance of stereoscopic stimuli. For each trial, response time was calculated and accounted as the total perception time including time spent for the manual response made through the answering device. Patients were trained to use the answering device precisely so that the observer can have a clear understanding of the test. It would also allow us to be sure of the accuracy of the answering process. Patients were also tested to identify the position of the bottom part of the screen compared to the upper part in a trial mode. Response details were instantly saved in a .txt file along with the general outcomes (see Table 2.6).

Table 2.6

Output data in new digital stereotest. CD-cross disparity, UD- uncross disparity

Variable	**Unit of measure**
Mean UD	pixel
Mean UD	arc sec
Mean CD	pixel
Mean CD	arc sec
Mean Times correct CD	millisecond
Mean Times incorrect UD	millisecond
Mean Times correct UD	millisecond

2.2.1 Calculation method of the stereo threshold in the new digital stereotest

Perceptual psychology research has created explicit psychophysical methodologies to change the force of the improvements in a connected percept.

Ideally, an observer can identify the occurrence of stimulus by observing the threshold point. To eliminate the human error the probabilistic term is applied to define the threshold. Providing the observer's stereo threshold in a rapid and valid approach required to involve the new digital stereo test with a particular staircase method. Such a compatible method adjusts the direction and amount of the stimulus intensity. It is accomplished by bearing on priorly acknowledged guidelines and the subject's performances. Variable data such as the early stimulus level, the dimension of the ascending and descending steps, the number of reversals required to stop the procedure, and the condition that modifies the series determine the threshold assessment.

The 2 up - 3 down rule is when three correct answers are needed to decrease the angle disparity and two false answers to increase. The staircase method included in the new stereo test software functions based on this rule. Reversal points for each staircase are considered being flexions.

In the ascending staircase, the following step is half of the previously taken step in the absolute term. However, in the descending staircase, the next level downwards is half the actual level (see Fig. 2.7).

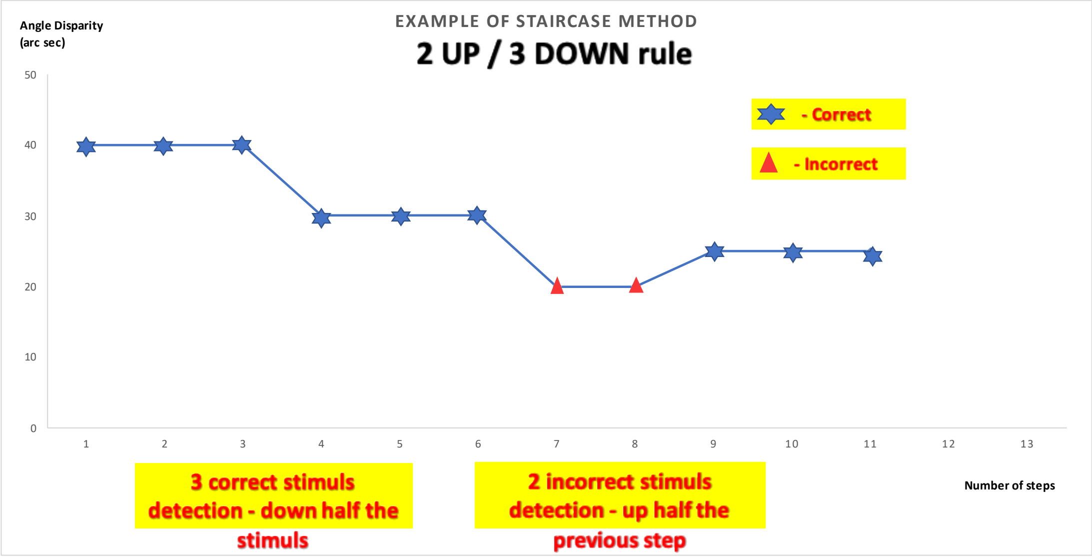

Fig. 2.7 Example of staircase method.

The step could not be higher than the previous one in the second upward jump. In this case, the observer was right, where the threshold for the staircase stopped at the level where the second jump occurred. Although it had reached the threshold this staircase remained at the same level until the next staircase reached the threshold.

The limit for the staircase of the lower threshold in the software was set to 1-pixel and the limit for the staircase of the upper threshold was set to the 120-pixel disparity. The upper threshold corresponded to a 1-degree disparity at the observation point, therefore its limit was set to a fixed value. The main purpose in conducting this research was to examine the stereo threshold rather than the upper limit of stereopsis.

By merging two staircase series the new software for stereo test enabled us to exam the CD and UD thresholds at the same time. On the other hand, we randomly tested ZD to record correct and incorrect perceptions, as well as the average time of responses.

2.3 Surgical technique and postoperative care

All Lasik surgeries in this study (total 204 eyes) were performed by the same ophthalmologist (N.H.), using Allegretto Wave Eye-Q 400 Hz (Alcon) laser machine with a pulse duration of 12 ns. A corneal flap was cut by using Moria microkeratome under topical anaesthesia. The mean optical zone of the treatment was between 6-6.5 mm. In all cases predetermined flap thickness was 90 microns. The hinge position of the corneal flap trephine was nasal in all eyes. The patient was asked to fixate on a helium-neon light, then ablations cantered on corneal vertex. The built-in eye tracker was used to compensate eye movements in the ablation process. After delivering ablation to the stroma and irrigating treatment zone with balanced salt solution the flap is repositioned on its place. After Lasik surgery patients wore bandage contact lens for 1 day. All patients in this research had unremarkable LASIK treatment procedure. Postoperative therapy consists of topical antibiotic, steroid drops, and artificial tears.

3. RESULTS

The analysis of collected data shows- crossed (CD) and uncrossed (UD) disparity are different in all subjects and all cases: before, two months, four months, and six months after. Only 29 participants were sensitive to both CD and UD in all our testing. In contrast, 20 patients showed an absence of stereoacuity to both CD and UD in the test. The rest 53 patients showed variable results depending on the type of disparity and testing time (see Fig 3.1).

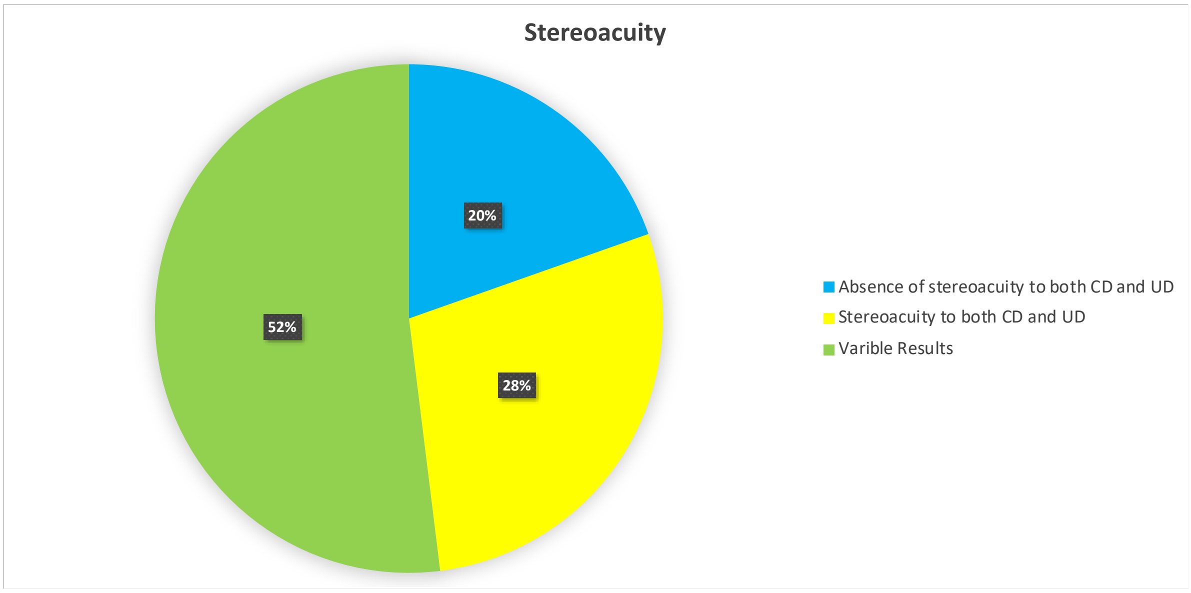

Fig 3.1 Stereoacuity during the testing time.

The five ranges of stereoacuity classified based on stereoacuity level, as commonly used in the literature, are:

1. 0-50 arcsec – high stereoacuity
2. 50-110 arcsec – stereo normal
3. 110-300 arcsec – mildly stereo impaired
4. 300-1000 arcsec – moderate stereo impaired
5. More than 1000 arcsec markedly stereo impaired

Twenty-nine participants had high stereoacuity to both CD and UD before the surgery. Results are noted in Table 3.2. Only two patients had high stereoacuity in CD and four of them were stereo normal. Out of the remaining 23 patients, 14 were mildly and 9 were moderately stereo impaired. However, in the UD group, 2 patients had high stereoacuity and none of them were stereo normal. 22 of them were markedly impaired, 3 were moderate, 2 were mildly.

Table 3.2

Type of CD&UD stereoacuity before operation

Before		
Cross disparity	**Uncross disparity**	
Mildly stereoimpaired	Markedly stereoimpaired	9
Mildly stereoimpaired	Mildly stereoimpaired	2
Mildly stereoimpaired	Moderate stereoimpaired	2
Mildly stereoimpaired	High stereoacuity	1
Moderate stereoimpaired	Markedly stereoimpaired	8
Moderate stereoimpaired	Moderate stereoimpaired	1
Stereo normal	Markedly stereoimpaired	3
Stereo normal	High stereoacuity	1
High stereoacuity	Markedly stereoimpaired	2

Six months after operation we can see follow picture (see Table 3.3).

Table 3.3

Type of CD&UD stereoacuity 6 months after operation

Before		
Cross disparity	**Uncross disparity**	
Mildly stereoimpaired	Markedly stereoimpaired	9
Mildly stereoimpaired	Mildly stereoimpaired	2
Mildly stereoimpaired	Moderate stereoimpaired	2
Mildly stereoimpaired	High stereoacuity	1
Moderate stereoimpaired	Markedly stereoimpaired	8
Moderate stereoimpaired	Moderate stereoimpaired	1
Stereo normal	Markedly stereoimpaired	3
Stereo normal	High stereoacuity	1
High stereoacuity	Markedly stereoimpaired	2

Results of comparing dates before/after in CD in Figure 3.4.

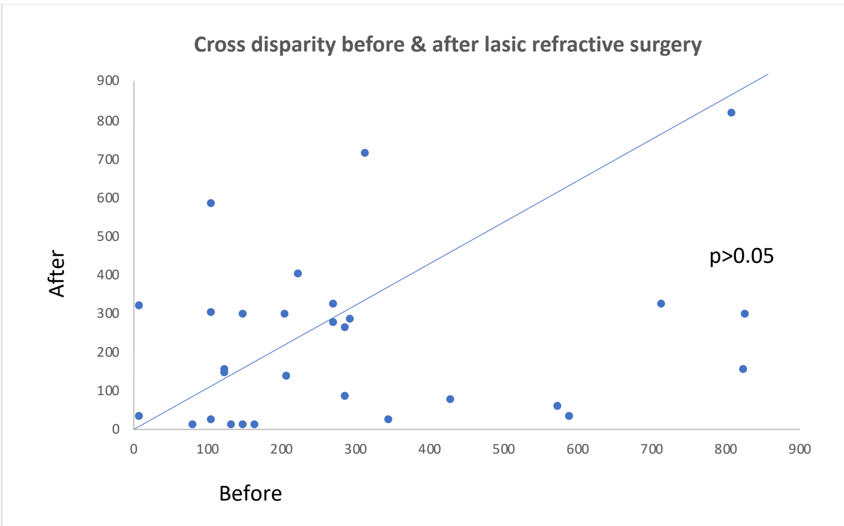

Fig 3.4 Changes in cross stereoacuity 6 months later

Improve	41.4%
Doesn't change	41.4%
Worse	17.2%

Six months after the surgery, approximately in 41.4% of cases, the stereoacuity was improved, in 41.4% cases, it did not change at all, and in 17.2% cases, it got worse. The comparative UD results based on dates are stated in Figure 3.5.

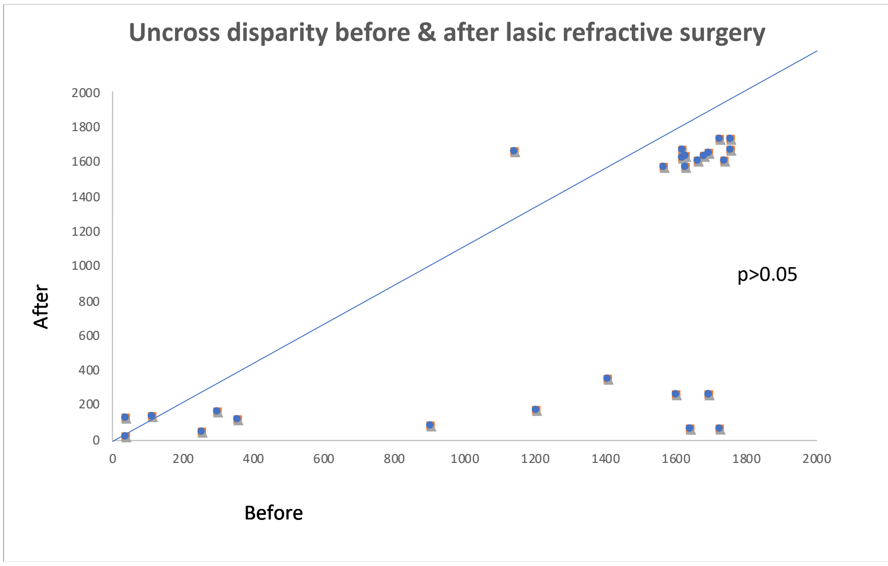

Fig 3.5 Changes in uncross stereoacuity 6 months later.

Improve	41.4%
Doesn't change	55.2%
Worse	3.4%

Six months after the surgery, in the UD group, approximately in 41.4% of cases, the stereoacuity was improved, in 55.2 % cases, it did not change at all, and in 3.4% cases, it got worse.

3.1 Relation between CD and UD in the same patients

As mentioned above, 29 patients showed stereoacuity in both CD and UD cases, but it is clearly shown in Table 3.6 responses to CD and UD are not identical. A patient can be stereo sensitive to CD but at the same time be markedly impaired to UD and vice versa.

For example, before the surgery, 35th, 50th, 67th, 74th, 90th, 101st patients recorded to have high stereoacuity in CD, but only 67th patient was sensitive to UD as well (see Table 3.6), the rest had low stereoacuity to UD. Before the surgery, two participants were stereo sensitive to

UD. One of them had good stereoacuity to CD, where the other one was mildly stereo impaired to CD.

After the LASIEK surgery, 11 participants had better results regarding stereoacuity to CD. Ten of these participants had low acuity to UD. Only one out of 11 had higher acuity to both UD as well as CD.

On the other hand, six patients had a better stereoacuity to UD 6 months after the Excimer laser refractive surgery. Out of six, only one patient had high stereoacuity to CD, and five patients demonstrated low sensitivities to CD (see Table 3.6).

Table 3.6

Correlation between CD and UD

ARCSEC	UD<50	51<UD<109	110<UD<299	300<UD<1000	UD>1000
CD<50	1	0	3	1	3
51<CD<109	0	0	0	0	3
110<CD<299	1	2	4	0	4
300<CD<1000	2	0	1	0	4
CD>1000	0	0	0	0	0

Analysed 29 participants where are all necessary data- individual improvement in stereoacuity is seen (ANOVA, p-value=0.0001, $p<0.05$).

3.2 Relation between stereoacuity and type of vision correction

We were curious to find a possible correlation between stereoacuity and correction type. Before the surgery, all six participants with high acuity to CD wore correction daily. Four of them use contact lenses where two of them use eyeglasses. The same results occurred regarding the UD. Two participants with high stereoacuity wore correction all the time; one of them used eyeglasses and another used contact lenses. But in all mentioned cases correction were significantly lower numbers than needed.

Six months after the surgery, we could not find any correlation between the type of the correction and changes in stereoacuity. Results are recorded in the table below (see Table 3.7).

Table 3.7

Relation between stereoacuity and type of vision correction, (green- improvement, yellow does not change, red- getting worse)

Relation between stereoacuity and type of vision correction						
Type of vision correction	**CD**			**UD**		
Spectacles (daily)	4 (58%)	3 (42%)	0 (0%)	1 (14%)	6 (86%)	0 (0%)
Spectacles (not daily)	4 (44%)	1 (12%)	4 (44%)	5 (56%)	4 (44%)	0 (0%)
Contact lenses	5 (38%)	4 (31%)	4 (31%)	6 (46%)	6 (46%)	1 (8%)

3.3 Relation between stereoacuity and type of refraction

We created three groups out of 29 participants sensitive to both CD and UD based on eye refraction. The first group had average refraction between 0 - 3,0 dptr, the second group had 3,25 - 6,0 dptr, and the third group had 6,25 - 9,0 dptr. Six months after the surgery two groups (high and low myopia) had improvement in the CD- 63% of patients in the group with lower myopia and 50% of patients in the group with high myopia. Results for patients with medium myopia mostly remained unchanged (53%).

Results for a group of patients with high acuity to UD and stereoacuity, medium myopia usually stayed the same (67%). Another two groups (low and high myopia) were almost equally divided (Table 3.8).

Table 3.8

Relation between stereoacuity and type of refraction (green- improvement, yellow does not change, red- getting worse).

Patients with stereoacuity to both CD&UD (29)						
Average ref (dptr)	**CD**			**UD**		
0-3	5(63%)	2(25%)	1(13%)	3(38%)	3(38%)	2(25%)
3,25-6	4(27%)	8(53%)	3(20%)	4(27%)	10(67%)	1(7%)
6,25-9	3(50%)	2(33%)	1(17%)	2(33%)	2(33%)	2(33%)

3.4 Relation between stereoacuity and anisometropia level

In eighty nine percent of participant anisometropia level was between 0-2 dptr and 11% of participants' anisometropia level was between 2.25 - 4 dptr.

Six months after the excimer laser treatment, patients with 0-2 levels of anisometropia had 48% improvement regarding CD and 32% improvement regarding UD.

Regarding CD or UD, patients with anisometropia level of 2.25-4 did not record any changes in half of the cases (see Table 3.9).

Table 3.9

Changes in cases with anisometropia (2.25-4 dptr), (green- improvement, yellow does not change, red- getting worse).

Patients with stereoacuity to both CD&UD (29)						
Anisometropia (level)	**CD**			**UD**		
0-2 (dptr)	12(48%)	10(40%)	3(12&)	8(32%)	13(52%)	4(16%)
2,25-4 (dptr)	0(0%)	2(50%)	2(50%)	1(25%)	2(50%)	1(25%)

Patient's serial numb	Anisometropia (0-	CD	UD
10	0.25	↑	→
13	0.5	↑	→
15	1.75	↑	↓
20	0.5	→	→
23	1.75	→	↑
35	0.25	↑	→
45	1	↑	↓
46	1	↑	↑
50	0.5	↓	↑
52	1.75	→	↑
55	1	↑	→
63	0.5	↑	↑
65	0.25	↑	↑
66	1.5	→	↑
67	1	↑	↓
74	1	→	→
77	0.25	→	→
79	2	→	→
83	0.5	→	↑
84	0	↓	↓
87	0	↑	→
88	0.25	→	→
90	0	↓	→
91	0.25	→	→
94	1.5	↑	→

3.5 Relation between stereoacuity and gender

As we can see from Table 3.10, males had better improvement regarding the CD, 44% compared to 40% in females. On the other hand, females had better improvement regarding UD, 35% compared to 22% in males.

Six months after the excimer laser surgery, there was no change among most male patients (56%) regarding CD and UD.

Meanwhile, half of the female patients (50%) did not show any change regarding UD, where 40 % had an improvement regarding CD (Table 3.10).

Table 3.10

Relation between stereoacuity and gender (green- improvement, yellow does not change, red- getting worse).

Gender	Total number	Patients with stereoacuity to both CD&UD (29)	CD			UD		
m	37	9 / 24%	4(44%)	5(56%)	0(0%)	2(22%)	5(56%)	2(22%)
f	65	20 / 31%	8(40%)	7(35%)	5(25%)	7(35%)	10(50%)	3(15%)

Patient's serial numb	Gende	CD	UD
63	f	1	1
84	f	-1	-1
15	f	1	-1
87	m	1	0
35	m	1	0
79	f	0	0
52	m	0	1
65	f	1	1
10	m	1	0
90	f	-1	0
94	f	1	0
23	f	0	1
46	f	1	1
66	f	0	1
74	m	0	0
20	f	0	0
91	f	0	0
88	m	0	0
50	f	-1	1
55	f	1	0
77	f	0	0
83	f	0	1
13	f	1	0
67	f	1	-1
45	m	1	-1
92	m	0	-1
70	f	-1	0
101	f	-1	0
47	m	0	1

3.6 Relation between stereoacuity and age

We tried to display how age affected the change in stereoacuity 6 months after excimer laser correction (see Fig. 3.11).

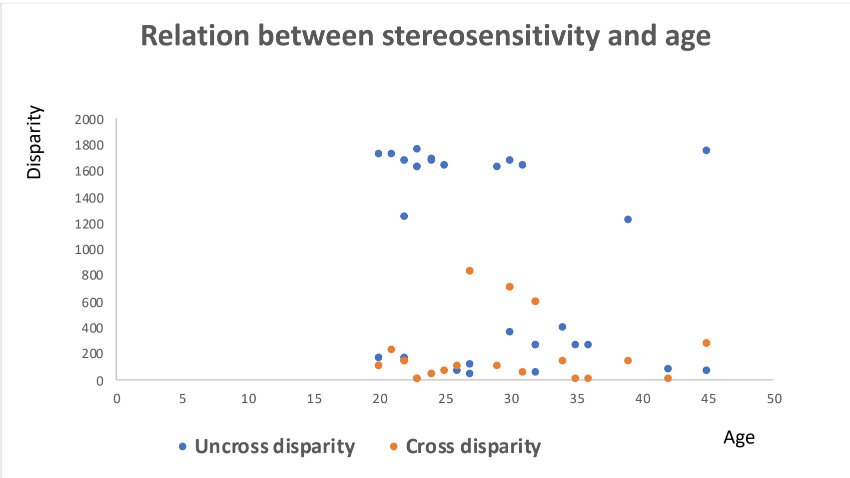

Fig. 3.11 CD and UD stereo thresholds (arcsec) at different ages.

The average age of participants with better improvement regarding CD was 26.9 years. The mean age of participants with lacking results was around 34.2 years. The average age of participants with better improvement regarding UD was 31.2 years. The mean age of participants with lacking results was around 30.4 years (see Table 3.12).

Table 3.12

Relation between stereoacuity and age (green- improvement, yellow does not change, red- getting worse).

Patients with stereoacuity to both CD&UD (29)					
CD			UD		
31.2	27.2	30.4	26.9	28.9	34.2

4. DISCUSSION

Studies based on the stereoscopic disparity thresholds are increasing interest rates. One of the major contributing factors in this study is the number of refractive surgeries increasing day by day. The results found in the literary pieces were usually quite different depending on the choice of the methodology and the selection of the different groups of participants. As we know, lots of factors like age, visual acuity, level of anisometropia, refraction and others can influence on the result of stereoacuity. We have analysed stereo sensitivities using a new digital stereotest in both direction CD and UD, at a far distance of 4m, for 102 participants of nonexpert one week before and two, four, six months after LASIK refractive correction.

25% of the participants in our study wore eyeglasses occasionally while 39% did not use any correction at all. The other 36% despite of wearing eyeglasses and/or contact lenses on daily basis in almost all of cases used wrong correction number (lower than required), which undoubtedly positively influenced the results after LASIK correction and support finding (*Razmjoo et al.*, 2008).

We excluded all cases with visual acuity less than 1.0. Due to increasing of visual acuity in almost all cases (*Jabbarvand et al.,* 2016) medical literature shows improvement or restoration in stereoacuity. Despite that fact we found improvement only in 41,4% of cases toward the CD, equal number of participants' (41.4%) results have not changed, and 17.2% even show worse stereoacuity. Toward the UD we have following figures: 41.4% improvement, 55.2% no changes and 3.4% show deterioration result.

Fascinating differences in results were found between patients with moderate, mild, and low refractive errors. Among the patients showing the improvement of stereoacuity in CD we can see groups with low (63%) as well as with high (50%) myopia. Results of the group with medium myopia mostly do not change (53%). The results of the group sensitive to UD- stereo acuity of patients with medium myopia prevalently does not change (67%). Another two group (low and high myopia) are almost equally divided. Therefore, this is not support finding *Mravicic et al*. (2020) where the number of patients with worsening stereoacuity after excimerlaser is equal to zero. Probably the difference in results depends on the multitude of factors; one of them- the aniseikonia especially in cases with high refractive errors (*Liu et al.*, 2003). Also, removing prismatic effects of glasses can positively impact the phoria in group with high ametropia (*Razmjoo et al.*, 2008).

89% participants in the study were with 0-2 dioptres anisometropia. They show the improvement in 48% toward to CD and 32% toward to UD. The rest (11%) that had more tha 2 dioptres anisometropia toward to both CD and UD in half of cases hasn't change. It does not match with *Mravicic et al*. (2020).

Between the multitude factors affecting the stereoacuity level after excimer laser surgery the possible impact of dry-eye syndrome occurs, which can significantly decrease stereopsis *Jabbarvand et al*. (2016)

We did not find any relationship between age and change in stereoacuity in our research as well as *Karimian et al.* (2017) after PRK refractive surgery.

Unfortunately, the measurement of stereoacuity in both direction CD and UD before and after the correction was not taken as an important parameter everywhere, demonstrating how successful keratorefractive surgery was. We should remember that the decrease of stereovision, even with higher postoperative visual acuity after refractive surgery, can be a cause of patients' dissatisfaction and possible reduction of the life quality (*Wasserman*, 2007).

In addition to that the standard optical equipment did not include stereotest for far in the way to uncross disparity, but only for the cross disparity (Osterberg). As we have seen from the result of our research approximately 9-10% of the participants were highly sensitive to UD and at the same time impaired to CD, which in cases of impossible measurement of UD could lead to the wrong conclusion about the absence or the lack of stereoacuity. Digital test used in this study gives possibility of easy, quick, and accurate check of stereo disparity in both way cross and uncross disparity simultaneously.

CONCLUSIONS

1. The crossed and uncrossed stereoacuity were assessed before and after LASIK eye refractive surgery using the new developed random dot anaglyph global stereotest. The study participants with myopia and myopic astigmatism had 302±244 arc sec crossed- and 1293±610 arc sec uncrossed-disparity stereoacuity before refractive surgery, and 219±210 arc sec crossed- and 862±764 arc sec uncrossed-disparity stereoacuity six months after refractive surgery.

2. Comparing results of the crossed and uncrossed disparity stereoacuity at the different points – before the refractive surgery and two, four, and six months after the refractive surgery – the data were not statistically significantly different in the crossed disparity (ANOVA, $p=0.411$). However, the uncrossed disparity data presented the statistically significant improvement during six months after refractive surgery (ANOVA, $p=0.00004$).

3. We did not find any marked correlation among ages, gender, refraction, and correction type of previous correction and changes in the crossed and uncrossed disparity stereoacuity results before and after six months after refractive surgery.

4. The study results shown that subjects with low anisometropia (1.0 to 2.0 D) had more improvements in the crossed disparity stereoacuity, while subjects with high anisometropia (more than 2.0 D) had improvement in uncrossed disparity stereoacuity during six months after the surgery.

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I certify with my signature that the research has been conducted independently, all information sources used in the thesis have been mentioned in the reference list, and the submitted electronical copy of the thesis corresponds to the printed version.

Author: ___________ Nigar Huseynova, student card no. nh18004 ___________
(signature) (date)

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