Chapter

Visual Impairment Caused by Monovision Surgical Design

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Abstract

Neurophysiological anatomy of natural binocular vision shows the need to focus with both eyes to jointly produce the two corneas accommodation, correcting, in a compensatory way, the divergences inherent in the two different images, of the same visual field projected in the two distinct spaces, the two retinas. Corneal accommodation is part of the forced convection mechanism for the transfer of mobile mass in the cornea, trabecular meshwork and retina, to inhibit the accumulation of dehydrated intraocular metabolic residue, which can cause refractive errors in the cornea, obstruction of the trabecular meshwork and reduction of the amplitude of the signals produced by the phototransducers and sent to the brain. The IOL monovision surgical implantation technique differs from the physiology of natural binocular vision, which can cause after surgery disorders, described in this chapter, in that it imposes a different adaptation from the neurophysiological anatomy of human vision in addition to favoring the continuous progression of residue accumulation dehydrated intraocular metabolic and stimulate ocular.

Keywords: IOL monovision, binocular vision, corneal accommodation, corneal topography, forced convection, matabolic residue, stereoscopy

1. Introduction

This work is part of the research group "Mass transfer in flexible porous medium" certified by the Federal University of Pernambuco - UFPE at the National Council for Scientific and Technological Development – CNPq, of the Ministério da Ciência, Tecnologia e Inovações (Ministry of Science, Technology and Innovation), of the Federal Government of Brazil. Physically, a flexible porous medium can be a cleaning sponge but it can serve as a model to demonstrate the mass transfer movement by forced convection in the cornea, lens, trabecular meshwork and retina, as well as muscles.

In the research it was found that in the experiments carried out by the German astronomer and Jesuit Christoph Scheinerque, in 1619, *apud* [1], with holes in a card, when observing the same object through different holes, different distances are perceived, corresponding to the intraocular lenses formed by dehydrated metabolic residue droplets [2]. That is, the card selects the image to be viewed in an overlay of images, which may be the astigmatism cause, in addition to myopia or hyperopia [3].

The research group leader exercises his own eyes to solve his eye refraction problems and discusses with the researchers group the understanding of the intraocular process of dehydration and rehydration of metabolic residue.

In this chapter we will show that the implantation technique known as IOL monovision, should be performed only if the patient accepts the act, after being informed, in writing, of the possible negative consequences that may occur to his health following cataract surgery. The difficulties in living with the symptoms acquired by a patient submitted to this surgical technique are presented, as well as the preoperative exams. Before surgery the patient was authorized by the doctor to renew his driver's license to drive motor vehicles without the use of corrective lenses.

2. Binocular oculomotricity

Rectus muscles: Maintain the central fixation point, the intersection of the visual axes, projected in the respective central ocular fovea [2].

Superior oblique muscle: [2] Controls the cylindrical corneal dioptric power that is part of the moving mass transfer mechanism of the cornea and retina by forced convection and moves the trabecular meshwork to prevent obstructing the passage of aqueous humor [4]. The cerebral hemisphere adjusts the projected image on the contralateral eye nasal retina to the projected image on the ipsilateral eye temporal retina by contralateral eye superior oblique muscle contraction or relaxation, with the help of the other muscles to prevent torsional movement of the contralateral eye, so if the technician positions the corneal topography equipment without the contralateral eye occlusion then when turning off the light used for positioning the equipment the projected image on the contralateral eye temporal retina ceases to exist and can cause superior oblique muscle relaxation and repositioning of the eye under examination.

Inferior oblique muscle: Has antagonistic action to the torsional force of the superior oblique muscle to prevent cyclotorsional movement of the eye [2].

Ciliary muscle: controls the lens accommodation to select the depth of focus and moves its moving mass [2, 4].

Iris: Reduce the light diffusion in the projected image in the retina and prevents aqueous humor return when the pressure in the anterior chamber is greater than in the posterior one during the natural process of corneal cylindrical diopter power variation due to the images fusion [3–5].

Binocular visual field: It is the intersection of the visual fields of the two eyes. The person can focus on the tip of a pencil placed over the nasal root, this being the limit of near vision.

Retina: Its main function is to discretize the analog image projected on its photoreceptors, transduce it into neural signals and send them to the respective hemispheres.

3. Neurophysiological anatomy of natural binocular vision

3.1 Physioanatomy in the writing movement

To facilitate the explanation of the importance of the movement of the superior oblique muscle, the writing of a person covering a calligraphic text was chosen [2]. The superior oblique muscle, when accommodating the cornea, moves the forced intraocular convection mechanism, which keeps the mobile mass in

agitation to prevent the accumulation of dehydrated metabolic residue. Due to personal habits, the forced convection mechanism is impaired and the oculomotor system starts to accumulate dehydrated metabolic residue in droplet form [2], so the older the person, the greater the amount of droplets stored and the less visual acuity. This is the inducing reason why many believe in the link between age and visual degradation.

Figure 1a was created to explain the connection of the observed visual field and its relationship with the interpretation of the image. **Figure 1a** corresponds to one of the forms used by a right-handed person, with natural vision, when covering a calligraphic text. The visual axes of both eyes converge at the tip of the pencil, so the dashed vertical line which passes at the tip of the pencil divides the writer's visual field into the right and left visual fields. The right and left visual fields are projected inverted on the retinas of both eyes, **Figure 1b**, however, on the temporal retinas of their respective contralateral eye and on the nasal retinas of their respective ipsilateral eye. Optical discs are part of their respective nasal retina, that is, the projections on the two temporal retinas are more accurate than their respective projections on the nasal retinas.

The image projected onto the temporal retina, **Figure 1b**, is transduced to its respective ipsilateral cerebral hemisphere, **Figure 1c2**, and the image projected onto the nasal retina, **Figure 1b**, is transduced to its respective contralateral cerebral hemisphere, **Figure 1c2**.

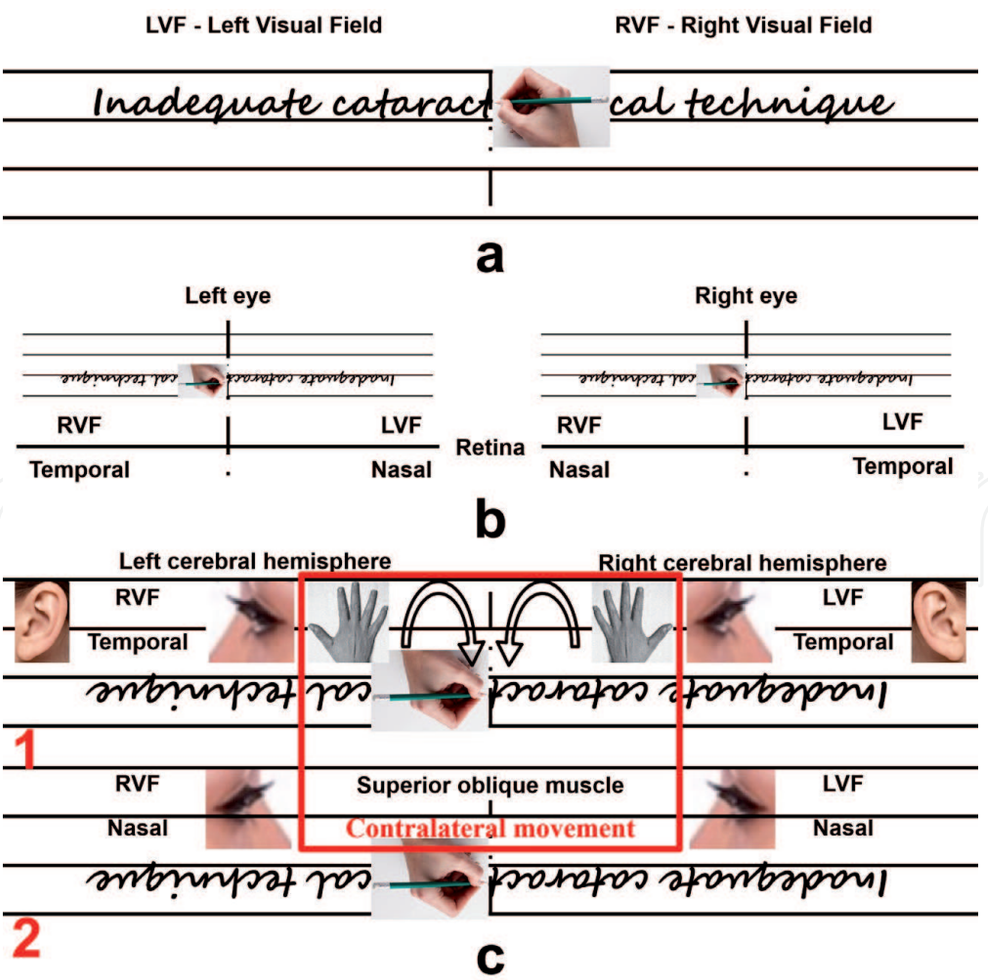

Figure 1.
Diagram showing the projection of the image on the retina and its transduction to the brain. (a) Visual fields, (b) projection into the human eye, (c) image sent to the brain, 1 - ipsilateral transduction, 2 - contralateral transduction.

Then, each cerebral hemisphere receives ipsilateral hearing and the projected image on the temporal retina of the ipsilateral eye, and, if it exists, includes the image of the contralateral hand, **Figure 1c1**, in addition to receiving the image projected on the nasal retina of the contralateral eye, and, if it exists, it includes the image of the ipslateral hand, **Figure 1c2**.

Each cerebral hemisphere controls, the contralateral superior oblique muscle, **Figure 1c2** and all other ipsilateral eye muscles (the rectus, inferior oblique, ciliary, iris, superior eyelid lift), control the movements of the contralateral hand and the rotating movement of the head in the contralateral direction **Figure 1c1**.

3.2 Eye exercises

The same interpretation of the oculomotor action of writing covering a calligraphic text, exposed through the diagram shown in **Figure 1**, is used in the analysis of the focus of a person's gaze, at the lateral limit of his binocular vision, the tip of the finger of his hand, very near to the nasal root, **Figure 2**, as children do in their initial oculomotor development. In **Figure 2a**, the right eye is diagrammed, positioning its visual axis tangent to the nasal root and intercepting the visual axis of the contralateral eye at a focus point common to both eyes, on the middle finger, of the contralateral hand, and on the **Figure 2b**, the left eye is diagrammed, positioning its visual axis tangent to the nasal root and intercepting the visual axis of the contralateral eye at a focus point common to both eyes, on the middle finger, of the contralateral hand. So:

- Ocular dominance, whether natural or pathological, fuses the images and alternates the dominant eye. As strabismus refers to eye misalignment [6], there can be no fusion of images or alternation in eye dominance, but surgical correction of strabismus is performed to restore or reconstruct normal eye alignment, to obtain normal visual acuity in each eye and be able to improve image fusion [6], then the patient can recover the alternating ocular dominance.

- The natural ocular dominance of the right eye, **Figure 2a**, and the left eye, **Figure 2b**, have their motor control image projected on the contralateral eye nasal retina, because in their ipsilateral temporal retina no image is projected. Thus, the contralateral cerebral hemisphere adjusts the greatest contraction of its superior oblique muscle, just as it adjusts the greatest contraction of the non-dominant eye natural lens, with its superior oblique muscle having the least contraction.

- By protecting newborns' nails with gloves to prevent injury these children miss the opportunity to adjust eye control.

- In the positions shown in **Figure 2**, the contraction of the twelve oculomotor muscles is constant, for any distance of focus, therefore, it is an extremely important position to adjust the refractive power of the non-dominant eye natural lens.

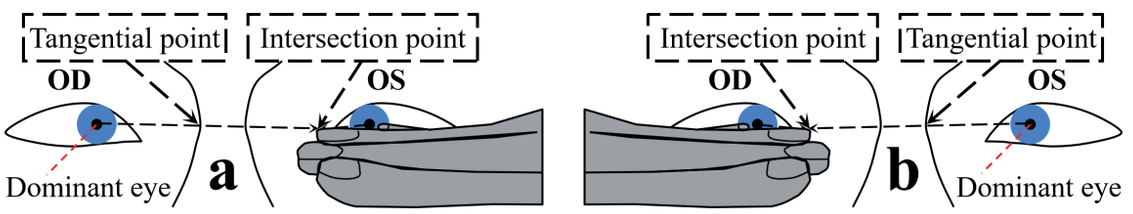

Figure 2.
Diagram showing the lateral limits of the binocular visual field. (a) left binocular limit, (b) right binocular limit.

4. Cataract surgery with monovision IOL

4.1 Etiopathogenesis of monovision

As [7] in monovision one eye (usually the dominant eye) is corrected for distance and the other eye is corrected for reading and according to [8] a lens set to far distances is implanted in your dominant eye, while a lens set to near distances is implanted in your non-dominant eye. It works because your brain automatically adjusts your visual system to achieve clear vision when you are focusing on near and distant objects [8].

This surgical technique uses pathological ocular dominance to maintain it and does not encourage its correction. In [2] it was demonstrated that in natural binocular vision, ocular dominance is alternated between the two eyes. But in [9] it says "If a strong degree of dominance is not apparent in a dominant eye test, it's more likely a person has mixed ocular dominance (*also called alternating ocular dominance*), where one eye is dominant for certain functions or tasks, and the other eye is dominant at different times", in addition to citing two criteria to determine ocular dominance, but under the hypothesis of alternating ocular dominance, that is, it identifies the natural ocular dominance acting alternately in both eyes.

In the work development, in the research group, it was found that in a simple frontal photo, a selfie, it is possible to perceive the result of pathological ocular dominance, but it is necessary to be sure that the photo is really frontal [10], see photo of **Figure 3**, because vicious ocular dominance can cause slight ocular deviation. Another way is to focus on the pencil tip that moves slowly to the nose root. The eye that keeps focusing on the pencil tip is the the dominant eye and the contralateral eye moves away quickly in its temporal direction, losing the focus point is the non-dominant eye, because who has natural binocular vision keeps both eyes focused on the pencil tip until it reaches the root of the nose effortlessly. The pathological ocular dominance is known as ocular dominance and in this chapter it is addressed only in its connections in planning and sequelae related to monovision surgery.

If a person, with one eye, sees the nearby objects well and with the contralateral eye sees the distant objects well, this situation was built through the convenience and personal habits, that is why, in this chapter, it is called ocular dominance, which is constructed involving eye shape and movement, in addition to the construction of neural communication, therefore, its surgical reproduction is impossible without the possibility of binocular vision. In this chapter, ocular dominance after monovision surgery is called dichotomous ocular dominance. Considering scientific knowledge, two surgical options are presented only for comparison with monovision surgery:

- **Bilateral monofocal intraocular lenses**: In this chapter it is considered that there are two monofocal lenses so that the eyes can focus on distant objects, although corrective lenses are required for reading. In this case, the distant focus is a known operational state of equilibrium, analogous to the state existing before surgery, and for reading, it is a state of temporary equilibrium, because of the use of corrective lenses, but both eyes focus simultaneously on same distance in both equilibrium states as well as images fusion.

- **Bilateral bifocal intraocular lenses**: In this chapter, it is considered that there are two lenses with two distinct optical powers so that the eyes can focus on far and near distant objects without the use of corrective lenses. In this case, the far focus and the near one are two well-known operational states of equilibrium, analogous to their corresponding states existing before the operation, because the two eyes simultaneously focus on common distances at different times.

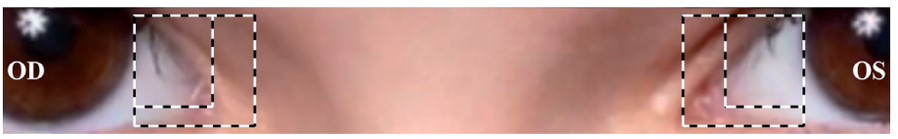

Figure 3.
The four rectangles are equal to two. Dominant left eye, greater nasal distance [10].

It is very important to point out that the eye projections are conical consequently the visual field perimeter for near focusing is much smaller than the visual field perimeter for distant focusing, therefore the cylindrical diopter due to the images fusion is greater for near focusing, as was verified in [11]. It should be noted that the opposite reactions in 5 cases mentioned can be explained by the probable differences in the distribution of accumulated metabolic residue as presented in [12]. It is important to consider this diopter variation when calculating the lens power for focusing at near distances. This dioptric variation is important for the forced convection mechanism in the cornea and retina, in addition to moving the trabecular meshwork, thus it is an important option to be chosen.

After monovision cataract surgery there is no balance state because it is impossible to fuse images at near or distant focusing distances, causing a complete dichotomy difficult to overcome.

4.2 Case report

A 69 years old female patient in Recife, Brazil, who underwent, in June 2019, cataract surgery in the left eye with implantation of the LW 625A lens power + 24.00 [13], with near focus. **Table 1** shows the corrective lenses used by the patient who, despite having a lens prescribed before the surgery, but that patient did not need corrective lenses to renew the national driver's license three months before the surgery and the **Figure 4** shows the chronology of the examinations performed. In November 2020 the situation came to a stable discomfort. There is no solution, through the patient's health plan, because all the professionals who examine her report that the surgeon's work was very good, there was good healing and the lens very well positioned, it seems to be describing a work of art, but at the being asked about headaches, the health plan ophthalmologists, inform that there is nothing to do with the surgery and that the patient must have another problem and should seek another specialist, such as a neurologist, to know the source of the pain, because the surgery is perfect.

Preoperative: The patient can choose between a national or imported prosthesis, for an additional fee, but did not inform the origin of the lens. The patient filled out a form informing social life and answering about the lifestyle after surgery, without any explanation of the result of the choice:

1. Do not wear glasses near.

2. Do not wear glasses neither far nor near (patient's choice).

3. It does not matter whether or not to wear glasses.

4. Do not wear glasses away.

Based on the patient's response, the surgeon defines the solution without informing the patient of the result found.

It is devoid of logic for someone to seek the help of a professional to obtain a lower quality of life. On the other hand, when there are several alternatives for cataract surgery with an IOL implant, the choice of treatment must be given to the patient, given that it is the patient who will live with the consequences of the surgery.

Note	Rx.	Spherical		Cylindrical		Axis	
		O.D.	O.S.	O.D.	O.S.	O.D.	O.S.
Before surgery	D.V.	+0.75	+1.50	−0.75	−0.25	123°	170°
	N.V.	+3.00		add		—	
After surgery	D.V.	0.00	−2.25	−0.25	−1.50	41°	118°
	N.V.	+3.00		add		—	
Currently	D.V.	−0.75	−3.00	—		—	
	N.V.	+3.00		add		—	

Table 1.
Lenses prescribed by doctors.

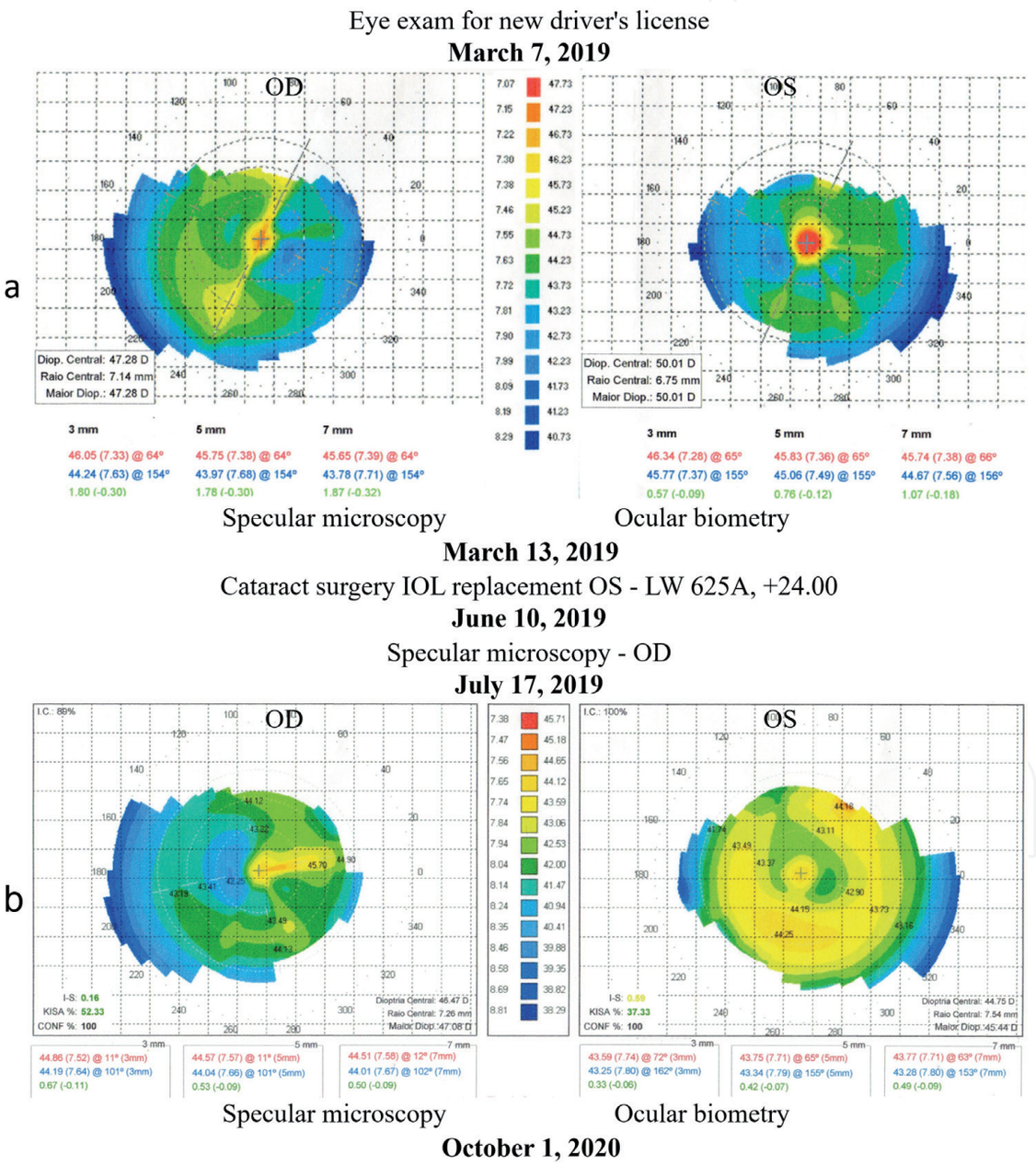

Figure 4.
History of exams performed by the patient. (a) before surgery, (b) after surgery.

Figure 4 shows the chronology of the surgery and exams, in addition to simulated keratometry of the corneas before, **Figure 4a**, and after, **Figure 4b**, surgery. The anterior corneal surface of the left eye, after surgery, is more regular

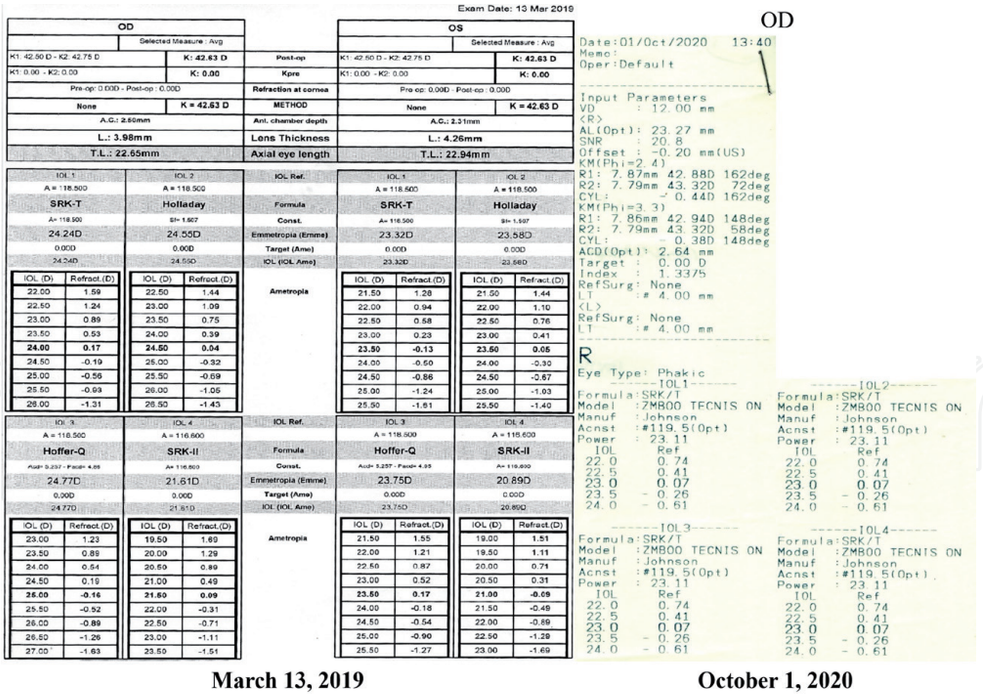

Figure 5.
Biometry before and after surgery.

than before the surgery and also in relation to the contralateral eye. The anterior surface of the cornea became more regular, As already explained in several studies [12, 14–16], the intraocular metabolic residue is dehydrated and stored, making a volume with high viscosity. To eliminate this viscous volume, it is necessary, first, to rehydrate it in order to reduce the viscosity and homogenize its concentration in the mobile mass, however, the only intraocular natural rehydration process available is the agitation performed through corneal flexion [14] using images fusion. In the 69-year-old patient case, the surgery made impossible for her to fuse the images, so there is no way to eliminate the metabolic residues from the cornea significantly. **Figure 5** shows the ocular biometry before and after surgery and **Figure 6** shows the specular microscopy before and after surgery, to better understand the patient's before and after operative conditions.

5. Conclusion

This chapter aims to show that there is no scientific reason for the use of the called monovision surgical technique, as well as to show that there are at least two scientific surgical alternatives. Two ways of ocular dominance are described, natural and pathological. Natural ocular dominance occurs according to the ocular system neurophysiological anatomy. Pathological ocular dominance is described in two forms, acquired and dichotomous. Acquired ocular dominance is known as ocular dominance and dichotomous ocular dominance, as referred to in this chapter, is characterized by surgical imposition. The three ocular dominances are described by their main functional characteristics and their consequences.

1. **Etiology of natural ocular dominance** - This ocular dominance is alternated between the eyes, so the dominate eye is the contralateral to the direction of the eye movement in relation to the head, its fixation, to reach an objective or to remain focused on a known objective, right after that, the dominant eye will be its contralateral one. This alternation of domination stimulates mainly the

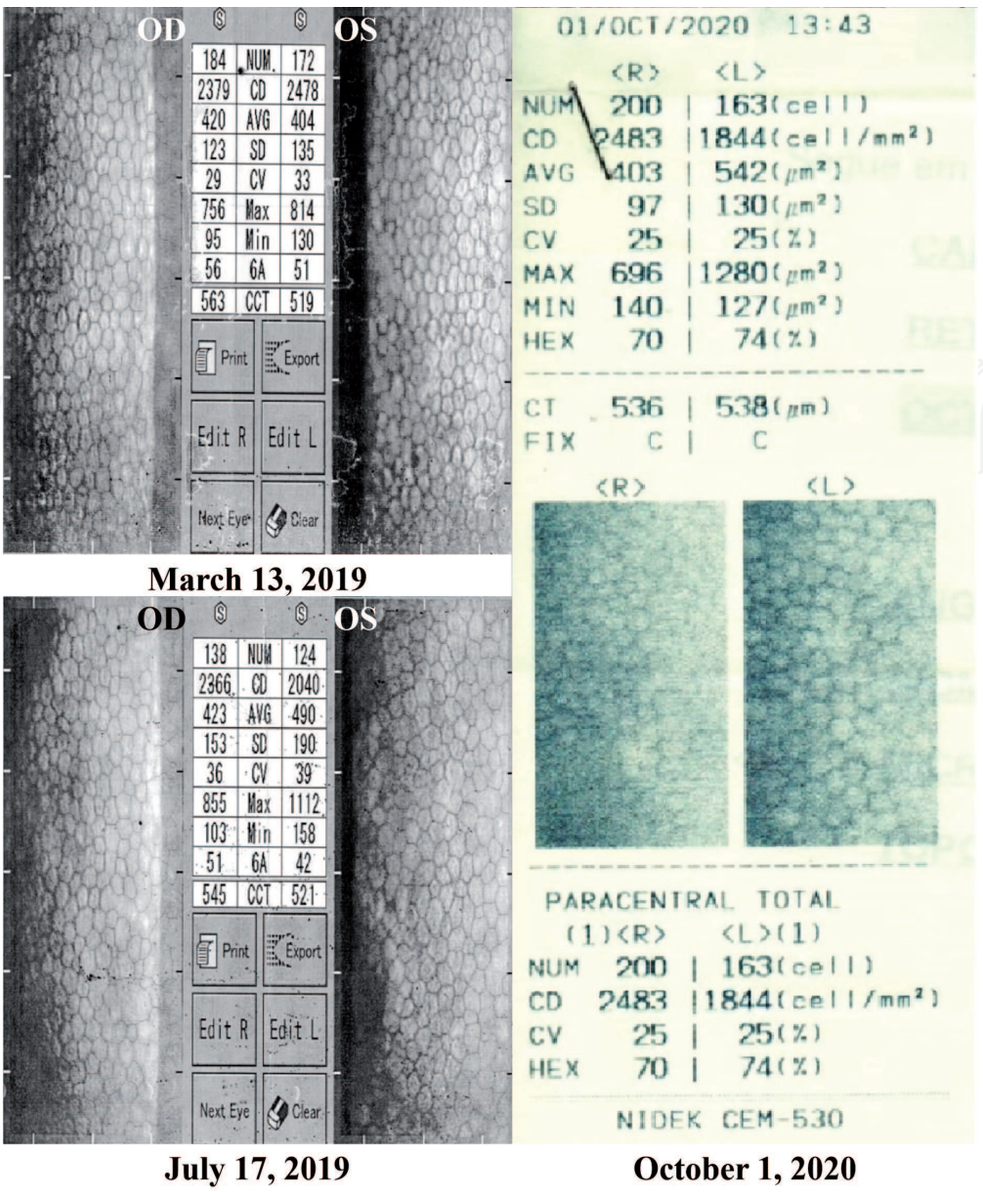

Figure 6.
Specular microscopy before and after surgery.

physiological process characteristic of the action of the two superior oblique muscles. The superior oblique muscle action changes the corneal cylindrical dioptric power and sustains the sclera in opposition to the consequent variation in intraocular pressure. Then, the cornea shape change is part of the mass movement forced convection mechanism in the cornea and retina, in addition to moving the trabecular meshwork, to avoid obstructing the passage of aqueous humor. Forced convection in the cornea and retina prevents the accumulation of metabolic residue that causes refractive error in the cornea and stiffens the retina. The ocular domain alternation is a fast process and makes small changes in the natural lens dioptric power that is part of its own forced convection mechanism to prevents the metabolic residues accumulation that cause refractive error and consequent opacity.

2. **Etiopathogenesis of ocular dominance** - This ocular dominance is the result of habits that are harmful to the intraocular forced convection mechanism. Then, the refractive error caused by the dehydrated metabolic residues accumulated in the cornea, retina and lens resist the natural movement of the eyes and create vicious pathological movements, such as the saccadic movement

[17] and the cyclotorsion movement mentioned in [18]. Dominance may not be full, as mentioned in [9], dominance depends on the evaluation criteria and usually for a specific activity.

3. **Etiopathogenesis of dichotomous ocular dominance** - This ocular dominance is the surgical result of imposing a lens set to far distances is implanted in your dominant eye, while a lens set to near distances is implanted in your non-dominant eye [8]. Thus, the patient is obliged to use corrective lenses in order to take advantage of his precarious intraocular force convection mechanism, before operative, however, upon waking up or when opening the eye during sleep, it causes an important impact, as it is not common to sleep with glasses, that is, the patient's brain spent 69 years adopting the direction of eye movement in relation to the head as a criterion for alternating ocular dominance and, due to the imposition of monovision surgery, in a "magic step", the focusing distance became the criterion for alternating ocular dominance without causing any disturbance for the patient. It is an alternative that should only be adopted with the permission given by the patient, after all, it is the patient who will be responsible for the administration of the after operative problems. In the case of the patient in focus, ocular dominance was imposed by the professional without the patient's knowledge, causing visual losses in precision, sharpness, agility, expansion, among others.

    - **Precision**: In [8] it is written that the patient may still need a pair of glasses to read small print for a few hours or to thread the needle. In the binocular view, each cerebral hemisphere receives the image projected on the temporal retina of the ipsilateral eye and simultaneously receives the image projected on the nasal retina of the contralateral eye, that is, for the more precise region of the retina, both eyes transmit neural signals twice as much to the brain, then, binocular vision is more than twice as accurate as monocular vision, with occlusion of one eye, since, in addition to having twice as many points, they are adjusted together, by the action of the superior oblique muscles, **Figure 1c**. This description combines with human perception, two eyes see better than one eye. The lack of precision is analogous to the sportsman using the sight out of alignment.
      The use of bilateral monofocal lenses maintains visual accuracy before surgery however one may need glasses for some activities.

    - **Sharpness**: In [8] it is written that the patient may still need a pair of glasses for nighttime driving. Analyzing **Figure 1c**, the monovision, without occlusion of the contralateral eye, is less clear, because a cerebral hemisphere receives the focused image projected on the temporal retina of the ipsilateral eye adding, as noise, without focusing, the image projected on the nasal retina of the contralateral eye and the contralateral cerebral hemisphere, receives, in focus, the image projected on the nasal retina of the contralateral eye to this cerebral hemisphere, without the region projected on its optic disc, adding, as noise, without focusing, the image projected on the temporal retina of the ipsilateral eye, that is, the patient's brain starts to receive the image focused by one eye with the addition of the defocused image of the contralateral eye. This is a form of stimulus for night blindness. The lack of sharpness is analogous to the sportsman who uses the target in smoke.
      The use of bilateral monofocal lenses can superimpose images with the same dimensions increasing the neural energy transmitted to the brain however one may need glasses for some activities.

- **Agility**: It is misleading to admit that the depth is given by binocular vision. If the depth depended on the simultaneous vision of the two eyes, the chicken would not be able to choose the grain of corn it eats. Animals that see their goal simultaneously with both eyes have greater agility of depth distance. The perception of distance depends on movement so astronomers are able to observe and analyze the universe with a telescope because there are movements. Those who have a natural binocular vision cannot visualize movements in static images nor can they view the stereoscopic image from photographs taken at two different points, they see two planes of images. When fixing an observation point, the alternation speed of the domain between the eyes produces dioptric powers changes in the crystallines for the rapid perception of depth but this visualization of depth is only possible up to a certain distance, from which, the brain makes use of the corneas diopter variation and for greater distances the person makes use of the head movement. After the monocular surgery there is no adjustment movement between the eyes and this may have been one of the causes of the 69 year patient's suffering. The substitution of the corneal movements for the movement of the head for depth perception the patient loses in agility because the corneas are more agile that the head, so the patient can be deprived of practicing activities that depend on agility and in transit may even cause an accident [19]. With dichotomous ocular dominance the patient may have difficulty to drive a motor vehicle, ride a bicycle and practice many sports such as tennis, ping pong, since in addition to the loss of agility, the brain receives the blurred image [20] of the contralateral eye. The lack of agility is analogous to that of sportsman with heavier equipment. An easy way to perceive the severity of the distance change problem is to use the basic principle observed by Scheinerque, in 1619, apud [1] through the using of pinhole glass [21] playing ping pong. One must be very careful when testing. The use of bilateral monofocal lenses maintains the mechanism of forced convection in the cornea, in the retina and the movement of the trabecular meshwork, fundamental for eye health, in addition to contributing to the perception of depth and has a much better result than that obtained with monovision surgery, however it may be necessary to wear glasses for some activities.

- **Dimension**: The monocular visual field has less visual space than the visual field with both eyes. No explanation is necessary but the monocular visual field blinds part of the contralateral eye's temporal visual field. The reduction of visual space is analogous to the sportsman located on the side of the wall.
  The use of bilateral monofocal lenses maintains the same dimensions of the visual field before surgery, however, one may need glasses for some activities.

To enable alternating ocular dominance if the surgery is bilateral bifocal the patient does not need corrective lenses and if the surgery is bilateral monofocal the patient must use near corrective lenses and if the surgery is monovision the patient must use two distinct optical powers of lenses.

The vision has many secrets as nobody knows how the other sees besides nobody can compare alternatives to intraocular lenses therefore if the patient is in a very adverse situation in his vision many of the basic movements he has already lost then any improvement is profit. This was not the 69 years old patient's situation before surgery. Monovision surgery only serves to prove the human being's adaptive power to stay alive.

After monofocal surgery, the patient cannot, without the use of corrective lenses, drive her vehicle or walk on the street safely [19, 20], in addition to losing the image fusion, blurred image [20] and, consequently, exposing herself to macular degeneration [15, 16], the increase in intraocular pressure (glaucoma) [2, 5, 10, 12] and, with corrective lenses, the 69-year-old patient suffers discomfort for read and headaches, today she prefers to abstain of read because of the great visual discomforts.

Monovision surgery and bilateral monofocus surgery do not interfere in the surgeon's fees or in the surgical costs of the clinic or health plan, in addition to not interfering in the values negotiated by the implanted lenses, so monovision surgery does not bring any financial advantage and can bring unrecoverable damage to the patient, why, in secret for the patient, use monovision surgery without any scientific basis?

Acknowledgements

To God for having helped the first author, in troubles during many years of suffering that led him to become an analytical observer of events in his own body, because of his mother, under the doctor's permission, 15 days before the birth of the first author, traveled by plane. In addition, by helping us to live, long ago, with the hardships as a result of internal political and economic decisions. For Marcos, first and third authors' brother, who saw in 1999 in a self-help book the importance of oculomotor muscle relaxation for eyesight treatment. To colleagues of the first author ANDES-SN Sindicato Nacional members and its Seção Sindical ADUFEPE members who during the intervals of same these organizations' meetings, provided important scientific information for the study. To those who were interviewed, friends, colleagues and family members who directly or indirectly have contributed to this work. To the engineer Florisnaldo Hermínio da Fonseca for the financial help in publishing this chapter. The authors agree with the individual mentions.

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