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Trifocal and extended depth of focus intraocular lenses – comparative analysis

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ABSTRACT

Aim of the study: Comparative analysis of trifocal and extended depth of focus (EDoF) lenses, taking into account visual acuity (VA) at different distances, contrast sensitivity (CS), defocus curve, spectacle independence, reading speed and the presence of photic phenomena, and assessment of patient satisfaction.

Methodology: Review of scientific papers and articles on high technology lenses found in PubMed, American Academy of Ophthalmology, ESCRS databases and own observations.

Results: Regarding VA, the studies we analyzed showed significantly better uncorrected (UNVA) and corrected near visual acuity (CNVA) for trifocal than EDoF lenses, while the EDoFs showed slightly better results for uncorrected distance visual acuity (UDVA), uncorrected (UIVA) and corrected intermediated visual acuity (CIVA). CS in most of articles showed no significant differences, only a few presented a slightly better results in EDoF group. Analysis of defocus curve shows that trifocal lenses exhibit better close-range vision acuity compared to EDoF of intraocular lenses (IOLs). Most of authors summarize the patient-assessed incidence and severity of dysphotopsia as low and statistically insignificant in both groups of lenses (range is < 1% to 25%). Spectacle independence for near vision was observed for both types of lenses, but slightly better for trifocal IOLs than EDoF IOLs (87% vs. 79.83%). The differences in reading speed were not statistically significant. Patients' satisfaction was high for both lenses and all of them will choose the same lens again.

Conclusion: Visual function results are very good and comparable for both analyzed types of IOLs. However trifocal lenses presented better near vision, but EDoF IOLs had a slightly lower frequency and severity of dysphotopsia. The significant superiority of the EDoF lenses over the trifocals is not proven.

KEY WORDS: extended depth of focus intraocular lens, trifocal intraocular lens, cataract surgery, micromonovision.

INTRODUCTION

Cataract is the major cause of vision impairment on a global scale [1], therefore cataract surgery is constantly developing, both in the surgical technique and in the technology of intraocular lens production. Along with the development of civilization, we observe increasing expectations of patients related to the improvement of the quality of life and visual acuity at various distances without the use of corrective glasses [2-4].

Intraocular implants can be divided into so-called "Standard" monofocal and "Premium" lenses. Monofocal lenses are the most commonly implanted lenses in the world. They correct the spherical defect and provide very good visual acuity at one target distance, but for the remaining patients require the use of eyeglass correction [5-7]. The "Premium" group lenses also enable the correction of astigmatism (toric lenses) and presbyopia (multifocal lenses) [8].

In the recent past, the most commonly used multifocal intraocular lenses (IOLs) were the bifocal ones, which provide good and very good vision for near and distance [9]. Their disadvantage, especially in the day of common usage of smartphones and computers, is insufficient visual acuity at intermediate distance [10]. In recent years, trifocal lenses have become widely used, they also allow good or very good intermediate vision [11-15]. The common disadvantage of multifocal lenses, related to the division of light passing through the optical part of the lens into several foci, is the occurrence of undesirable optical phenomena (e.g. glare and halos) and a reduction in contrast sensitivity [16-20]. In order to reduce dysphotopsia while maintaining good quality of vision, extended depth of focus (EDoF) IOLs were introduced on the market. Their design and technology differs between the models of individual manufactures, they can use different principles: spherical aberrations, chromatic aberrations or "pinehole effect", but the main goal of the entire group is common – to achieve "pseudoaccommodation" [21, 22]. They are intended to ensure a very good distance and intermedi-

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ate visual acuity with an acceptable level of near vision and a low level of dysphotopsia, but the results obtained so far are varied and ambiguous in this regard.

The aim of this article is to present the results of available comparative studies after the implantation of trifocal lenses and lenses with extended depth of focus, taking into account visual acuity at different distances, contrast sensitivity, defocus curve, spectacle independence, reading speed and the presence of optical phenomena. We also analyzed the available previous reviews [23, 24], but our article takes into account the results of partially other authors and, additionally, the aspect of micromonovision in the context of the analyzed lenses.

Trifocal intraocular lenses

Trifocal lenses provide good or very good quality of vision at all distances (Figure 1A). Technologically they are based on the principle of diffraction and they are composed by diffractive microstructures in concentric zones [4]. In some models, the principle of apodization is additionally used. The principle of apodization was based on the greater need for distance vision in condition of dim illumination (when pupils are large). In addition, a greater focus of light to the distant focal point reduces the defocused near light with its subsequent visual phenomena of glare and halos. This is achieved by a gradual reduction in diffractive step heights from center to periphery [3, 25, 26]. Since 2010 there are several models of these lenses available on the market, the most frequently described in the literature are presented in Table I [27-30].

Extended depth of focus intraocular lens

Extended depth of focus intraocular lenses (EDoF IOLs) are intended to provide a very good distance and intermediate vision acuity with an acceptable level of near vision. The construction and technology of the lenses differ from each other, depending on the individual company (Table II). They can use various of principle: spherical aberrations, chromatic aberrations or the “pinehole effect” [21, 22]. Based on the IOL technologies EDoF can be divided into two main categories: pure EDoF and hybrid EDoF. Pure EDoF IOLs employ solely spherical aberration-based optics or “pinehole” effect. Hybrid EDoF IOLs could be categorized as diffractive-EDoF, refractive-EDoF and diffractive-refractive-EDoF IOLs [21]. However, the basic principle of EDoF lenses is to create a single elongated focal point to enhance the depth of focus or range of vision (Figure 1B) [31]. A proprietary diffractive echelette design is used in EDoF IOLs and create their characteristic stepped structure. The height, spacing and profile of the echelettes are optimized to achieve a design in which the light from different zones of the lens mix, thus creating a new light diffraction pattern. In addition, proprietary achromatic technology and negative spherical aberration correction improve the image quality [32].

RESULTS

Characteristics of the included studies

The characteristic of the included studies are summarize in Table III [33-42]. These studies were conducted in different countries. All studies were published between 2017 and 2021. Our analysis included 967 eyes. The Tecnis Symfony IOL was implanted in the eyes included in the EDoF group, whereas PanOptix, FineVision Micro F and AT LISA tri 839 MP IOLs were implanted in the eyes included in the trifocal group. The follow-up duration of the studies ranged from 1 to 29 months.

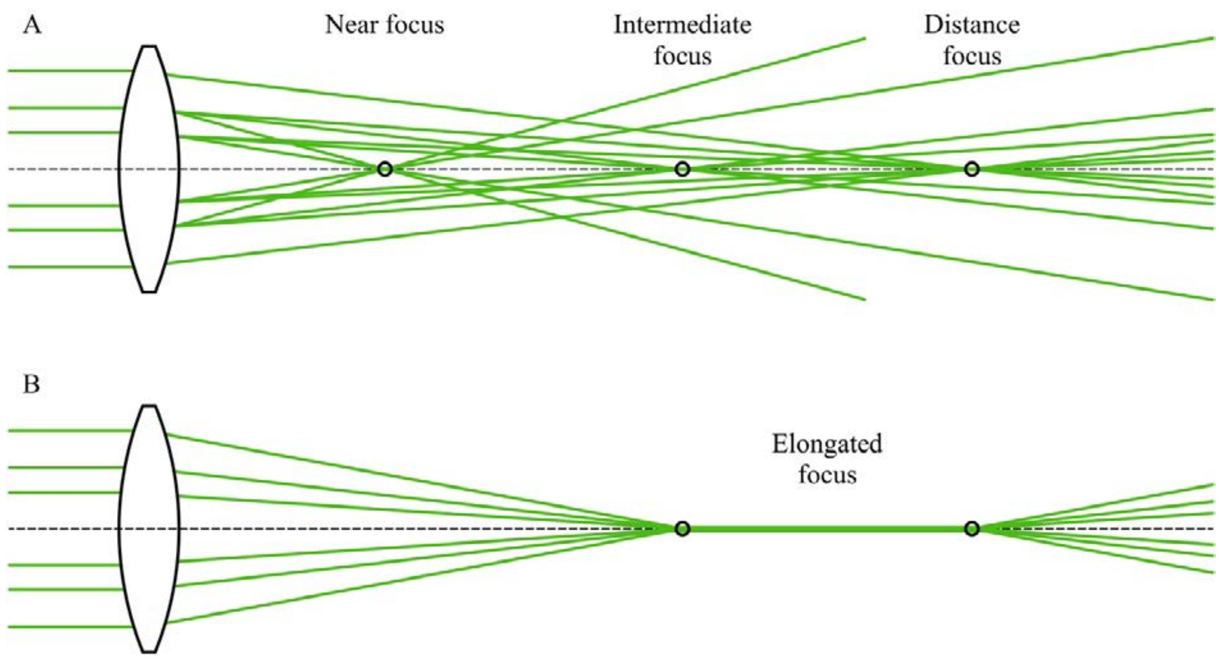

Figure 1. A) Trifocal IOL. **B**) Extended depth of focus IOL

Table I. Characteristics of commonly used trifocal intraocular lenses

IOLs	Type of optic	Pupil depends
PanOptix (Alcon)	Inner diffractive with outer refractive zone Non-apodized	Pupil independent up to 4.5 mm
At Lisa tri 839MP (Zeiss)	Diffractive Non-apodized	Pupil independent
FineVision Micro F (PhysIOL SA)	Diffractive Apodized	Pupil dependent
Versario MF 3F (Valeant Med)	Diffractive	Pupil dependent
RayOne trifocal (Rayner)	Diffractive Non-apodized	Less dependent on pupil size

Table II. EDoF Classification

EDoF Classification				
Pure EDoF IOL		Hybrid MF-EDoF IOL		
Spherical Aberration-Based EDoF IOLs	EDoF IOLs Utilizing the Pinhole Effect	Hybrid MF Diffractive/EDoF IOLs	Hybrid MF Refractive/EDoF IOLs	Hybrid MF Refractive-Diffractive/EDoF IOLs
Mini Well Ready (SIFI)	IC-8 (AcuFocus)	Tecnis Symfony ZXR00 (Johnson and Johnson Vision)	Lentis Mplus X (Oculentis GmbH)	InFo-Instant Focus IOL (Swiss Advanced Vision)
Wichterle Intraocular Lens-Continuous Focus (Medicem)	XtraFocus Pinhole Implant (Morcher)	At Lara 29 MP (CarlZeiss Meditec)	Acunex Vario AN6V	EDEN (Swiss Advanced Vision)
TECNIS Eyhance ICB00 (Johnson and Johnson Vision)			Lucidis (Swiss Advanced Vision)	Harmonis (Swiss Advanced Vision)
			Supraphob Infocus IOL (Appasamy Associates)	Synergy: ZFR00 (Johnson and Johnson Vision)

EDoF – extended depth of focus; MF – multifocal; IOL – intraocular lens

Visual Outcomes

The results of binocular visual acuity at different distances are presented in Table IV [33-42]. Visual acuity for distance was statistically significant in only one article, according to de Medeiros *et al.* patients with implanted EDoF IOLs achieved a better final UDVA and CDVA compared to patients with trifocal IOLs [39]. At 60 cm UIVA trifocal lenses was significantly better according to Lubiński *et al.* [40]. In the range of 66–70 cm de Medeiros *et al.* and Webers *et al.* achieved better results in patients EDoF lenses [39, 42], in Monaco's *et al.* and Lubiński's *et al.* study – with trifocal lenses [33, 40]. At 80 cm UIVA was better for trifocal lenses according to Lubiński *et al.* [40], while in the article of Mencucci *et al.* patients with EDoF lenses achieved better results, but only in mesopic condition, which was also confirmed in the CIVA study in 80 cm [38]. According to all studies, UNVA and CNVA unanimously fared better in the group of patients with trifocal lenses.

Contrast sensitivity

Eight articles [33-38, 40, 42] described contrast sensitivity (CS) (Table V), most of which showed no significant differences between groups [33-35, 37, 42]. In the work of Mencucci *et al.* EDoF lenses achieved better results in CS than trifocal lenses, both under photopic and mesopic conditions [38]. Escandon-Garcia *et al.* presented the results in which EDoF IOLs perform better under mesopic conditions but only at frequency of 1.5 cycles per degree (cpd) [36]. In our study from 2020, the results were as follows: under photopic conditions there were no differences at distance, at near to frequencies of 12 and 18 cpd, the better results were in the trifocal IOLs group; under mesopic conditions – for near there were no differences found, for distance – at the frequency of 18 cpd, EDoF lenses performed better [40].

Defocus curves

Eight articles used the defocus curve as the criterion [33-40, 42] (Table VI). Analysis of the results presented in the table shows that trifocal lenses exhibit better close-range vision acuity compared to EDoF IOLs [33, 34, 36, 37, 39, 40, 42, 43]. In contrast, in the case of distance and intermediate vision acuity, patients with EDoF lenses achieve better results [36, 39, 40, 43], except one work, Monaco *et al.*, in which trifocal lenses also performed better intermediate vision [33, 43]. Cochener *et al.* found no significant differences between the groups [35].

Table III. Characteristics of the included studies

Study author(s), year	Location	IOLs	Patients/Eyes	Age	Follow-up duration (months)
Monaco *et al.*, 2017	Italy	Tecnis Symfony (AMO)	20/40	67.0 ±8.5	4
		PanOptix (Alcon)	20/40	66.0 ±5.5	
Ruiz-Mesa *et al.*, 2017	Spain	Tecnis Symfony (AMO)	20/40	59.5 ±8.9	12
		FineVision Micfo F (PhysIOL SA)	20/40	54.5 ±7.2	
Cochener *et al.*, 2018	France	Tecnis Symfony (AMO)	20/40	69.2 ±8.4	6
		PanOptix (Alcon)	20/40	70.1 ±4.8	
		FineVision Micfo F (PhysIOL SA)	20/40	62.5 ±4.6	
Escandon-Garcia *et al.*, 2018	Portugal	Tecnis Symfony (AMO)	15/30	63.5 ±9.4	1-3
		PanOptix (Alcon)	7/14	62.3 ±9.0	
		FineVision Micfo F (PhysIOL SA)	23/46	62.6 ±8.0	
Mencucci *et al.*, 2018	Italy	Tecnis Symfony (AMO)	20/40	68.9 ±4.8	3
		PanOptix (Alcon)	20/40	70.1 ±4.8	
		AT LISA tri 839 MP (Zeiss)	20/40	71.6 ±4.4	
Ruiz-Mesa *et al.*, 2018	Spain	Tecnis Symfony (AMO)	14/28	63.1 ±10.0	9-29
		PanOptix (Alcon)	20/40	63.8 ±8.1	
de Medeiros *et al.*, 2019	Brazil	Tecnis Symfony (AMO)	14/28	NA	6-12
		PanOptix (Alcon)	13/26	NA	
Lubiński *et al.*, 2020	Poland	Tecnis Symfony (AMO)	20/40	62.4 ±7.9	12
		AT LISA tri 839 MP (Zeiss)	20/40	55.0 ±7.1	
Webers *et al.*, 2020	Netherlands	Tecnis Symfony (AMO)	14/28	67.57 ±12.21	3
		AT LISA tri 839 MP (Zeiss)	13/26	70.38 ±6.08	
Moshirfar *et al.*, 2021		Tecnis Symfony (AMO)	NA/108	62.8 ±11.0	1-3
		PanOptix (Alcon)	NA/113	63.5 ±11.8	

Photic phenomena

In most studies, the presence of photic phenomena was assessed subjectively by patients, without using standardized scales. For this reason, the results and conclusions presented by the authors may differ from each other. The occurrence of photic phenomena such as halo and glare has been discussed in 9 articles [33-35, 37-42] (Table VII). Most of authors summarize the patient-assessed incidence and severity of dysphotopsia as low in both groups of lenses, but the range is < 1% to 25% [33-35, 39-41]. In 2 articles, Mencucci *et al.* and Webers *et al.*, the evaluation of the presence of halo/glare was high – from 31% to 70% [38, 42]. Additionally, it can be seen that regardless of the type of implanted lens, halo is more common than glare is reported by patients.

Spectacle independence and reading speed

Six studies provided data for spectacle independence of far, intermediate and near distance [33-35, 38, 40, 42] (Table VII). To distance and intermediate distances, independence from glasses was achieved in 100% of patients in most of analyzed studies [34, 35, 38, 40, 42]. However, according to Monaco *et al.* 2 patients from the EDoF group and 3 patients from the trifocal lens group declared that they sometimes need distance glasses [33]. For near vision scores were high for both lenses, but the trifocal lens fared slightly better here – an average of 79.83% of patients with EDoF lenses and 87.0% of patients with trifocal lenses achieved independence from glasses.

Reading speed after implantation of both lenses was reported in 2 studies, none of which showed any significant differences [38, 42].

Patient satisfaction

Patient satisfaction after intraocular lens implantation was assessed using various questionnaires. Despite the different methods, the results of the articles are similar. Patients regardless of their implanted lens rate their degree of satisfaction as high and would choose the same lens again [33-35, 38-42] (Table VII).

Micromonovision

A new strategy for EDoF IOLs, called micromonovision, has recently been proposed. It is reported to provide significantly better intermediate and near visual acuity than after implantation of EDoF IOLs targeted for non-monovision [44].

Table IV. Visual activity outcomes

Study author(s), year	IOLs	UDVA	CDVA	UIVA			CIVA			UNVA	CNVA
				60 cm	66-70 cm	80 cm	60 cm	66-70 cm	80 cm		
Monaco *et al.*, 2017	Tecnis Symfony (AMO)	0.03 ±0.05	–0.01 ±0.02	–	0.27 ±0.08	–	0.16 ±0.07	–	–	0.07 ±0.08	0.07 ±0.07
	PanOptix (Alcon)	0.00 ±0.04	–0.01 ±0.01	–	0.23 ±0.07*	–	0.13 ±0.07	–	–	0.02 ±0.06*	0.01 ±0.04*
Ruiz-Mesa *et al.*, 2017	Tecnis Symfony (AMO)	0.01 ±0.02	–	0.09 ±0.08	–	–		–	–	0.17 ±0.06	–
	FineVision Micfo F (PhysIOL SA)	0.01 ±0.03	–	0.11 ±0.08	–	–		–	–	0.06 ±0.07*	–
Cochener *et al.*, 2018	Tecnis Symfony (AMO)	0.009 ±0.06	–	0.214 ±0.174	–	–		–	–	0.244 ±0.15	–
	PanOptix (Alcon)	0.011 ±0.139	–	0.260 ±0.123	–	–		–	–	0.180 ±0.00*	–
	FineVision Micfo F (PhysIOL SA)	0.017 ±0.100	–	0.241 ±0.203	–	–	–	–	–	0.194 ±0.07*	–
Escandon-Garcia *et al.*, 2018	Tecnis Symfony (AMO)	0.08 ±0.10	–0.10 ±0.19	–	–	–	–	–	–	–	–
	PanOptix (Alcon)	0.07 ±0.10	–0.07 ±0.19	–	–	–	–	–	–	–	–
	FineVision Micfo F (PhysIOL SA)	0.08 ±0.09	–0.24 ±0.14	–	–	–	–	–	–	–	–
Mencucci *et al.*, 2018	Tecnis Symfony (AMO)	–0.04 ±0.05	–0.05 ±0.05	–	–	0.07 ±0.07**	–	–	0.06 ±0.07**	0.25 ±0.08	0.20 ±0.10
	PanOptix (Alcon)	–0.02 ±0.08	–0.03 ±0.08	0.07 ±0.04	–	0.16 ±0.06	0.06 ±0.05	–	0.14 ±0.08	0.15 ±0.05*	0.12 ±0.04*
	AT LISA tri 839 MP (Zeiss)	0.00 ±0.02	–0.01 ±0.02	–	–	0.11 ±0.07		–	0.06 ±0.04	0.18 ±0.05*	0.13 ±0.04*
Ruiz-Mesa *et al.*, 2018	Tecnis Symfony (AMO)	0.05 ±0.12	–0.02 ±0.03	–	–	–	0.05 ±0.04	–	0.06 ±0.04		0.20±0.06
	PanOptix (Alcon)	0.00 ±0.03	–0.03 ±0.03	–	–	–	0.06 ±0.04	–	0.06 ±0.06		0.04 ±0.06*
De Medeiros *et al.*, 2019	Tecnis Symfony (AMO)	–0.00 ±0.05*	–0.02 ±0.05*	–	0.20 ±0.04*	–	–	–	–	0.16 ±0.08	
	PanOptix (Alcon)	0.09 ±0.10	0.06 ±0.12	–	0.39 ±0.09	–	–	–	–	–0.01 ±0.08*	
Lubiński *et al.*, 2020	Tecnis Symfony (AMO)	0.08 ±0.08	–	0.09 ±0.09	0.11 ±0.08	0.15 ±0.08	–	–	–	0.21 ±0.15	
	AT LISA tri 839 MP (Zeiss)	–0.12 ±0.10	–	–0.01 ±0.04*	–0.05 ±0.06*	–0.01 ±0.06*	–	–	–	–0.01 ±0.04*	
Webers *et al.*, 2020	Tecnis Symfony (AMO)	0.01 ±0.12	–	–	–0.02 ±0.03*	–	–	–	–	0.09 ±0.05	
	AT LISA tri 839 MP (Zeiss)	0.05 ±0.07	–	–	0.01 ±0.09	–	–	–	–	0.04 ±0.07	
Moshirfar *et al.*, 2021	Tecnis Symfony (AMO)	0.13 ±0.17	0.02 ±0.05	–	–	–	–	–	–	0.21 ±0.17	
	PanOptix (Alcon)	0.12 ±0.09	0.02 ±0.06	–	–	–	–	–	–	0.16 ±0.12	

IOL – intraocular lens; UDVA – uncorrected distance visual acuity; CDVA – corrected distance visual acuity; UIVA – uncorrected intermediated visual acuity; CIVA – corrected intermediated visual acuity; UNVA – uncorrected near visual acuity; CNVA – corrected near visual acuity

** Statistically significant.*

*** Statistically significant in mesopic conditions.*

Table V. Contrast sensitivity (CS)

Study author(s), year	IOLs	CS: under photopic conditions	CS: under mesopic conditions
Monaco *et al*., 2017	Tecnis Symfony (AMO)	NSD	NSD
	PanOptix (Alcon)		
Ruiz-Mesa *et al*., 2017	Tecnis Symfony (AMO)	NSD	NSD
	FineVision Micfo F (PhysIOL SA)		
Cochener *et al*., 2018	Tecnis Symfony (AMO)	NSD	NSD
	PanOptix (Alcon)		
	FineVision Micfo F (PhysIOL SA)		
Escandon-Garcia *et al*., 2018	Tecnis Symfony (AMO)	NSD	For 1.5 cpd better in EDoF IOLs group
	PanOptix (Alcon)		
	FineVision Micfo F (PhysIOL SA)		
Mencucci *et al*., 2018	Tecnis Symfony (AMO)	Better in EDoF IOLs group	Better in EDoF IOLs group
	PanOptix (Alcon)		
	AT LISA tri 839 MP (Zeiss)		
Ruiz-Mesa *et al*., 2018	Tecnis Symfony (AMO)	NSD	NSD
	PanOptix (Alcon)		
Lubiński *et al*., 2020	Tecnis Symfony (AMO)	NSD in distance vision For 12 and 18 cpd better in trifocal IOLs group in near vision	For 18 cpd better in EDoF IOLs group in distance vision NSD in near vision
	AT LISA tri 839 MP (Zeiss)		
Webers *et al*., 2020	Tecnis Symfony (AMO)	NSD	NSD
	AT LISA tri 839 MP (Zeiss)		

NSD – no significant difference

Table VI. Defocus curves

Study author(s), year	IOLs	Results of defocus curve
Monaco *et al*., 2017	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near and intermediate vision
	PanOptix (Alcon)	
Ruiz-Mesa *et al*., 2017	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near vision
	FineVision Micfo F (PhysIOL SA)	
Cochener *et al*., 2018	Tecnis Symfony (AMO)	NSD
	PanOptix (Alcon)	
	FineVision Micfo F (PhysIOL SA)	
Escandon-Garcia *et al*., 2018	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near vision EDoF IOL better than trifocal in intermediate vision
	PanOptix (Alcon)	
	FineVision Micfo F (PhysIOL SA)	
Ruiz-Mesa *et al*., 2018	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near vision
	PanOptix (Alcon)	
de Medeiros *et al*., 2019	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near vision EDoF IOL better than trifocal in distance and intermediate vision
	PanOptix (Alcon)	
Lubiński *et al*., 2020	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near vision EDoF IOL better than trifocal in distance and intermediate vision
	AT LISA tri 839 MP (Zeiss)	
Webers *et al*., 2020	Tecnis Symfony (AMO)	Trifocal IOL better than EDoF in near vision
	AT LISA tri 839 MP (Zeiss)	

Range of vision: from –4.0 D to –2.0 D – near vision; from –2.0 D to –0.5 D – intermediate vision; from –0.5 D to +0.5 D – distance vision [43]

Table VII. Photic phenomena, spectacle independence, reading speed and patient satisfaction

Study author(s), year	IOLs	Spectacle independence	Reading speed	Halo/Glare	Patient Sasisfaction
Monaco *et al.*, 2017	Tecnis Symfony (AMO)	High (70%)	–	Low (25%)	High
	PanOptix (Alcon)	High (85%)		Low (15%)	High
Ruiz-Mesa *et al.*, 2017	Tecnis Symfony (AMO)	High (90%)	–	Low	High
	FineVision Micfo F (PhysIOL SA)	High (95%)		Low	High
Cochener *et al.*, 2018	Tecnis Symfony (AMO)	High (90%)	–	Low (< 1%)	High
	PanOptix (Alcon)/ FineVision Micfo F (PhysIOL SA)				High
Mencucci *et al.*, 2018	Tecnis Symfony (AMO)	High (60%)	NSD	High (halo – 70%, glare – 50%)	High
	PanOptix (Alcon)/AT LISA tri 839 MP (Zeiss)	High (67%)			High
Ruiz-Mesa *et al.*, 2018	Tecnis Symfony (AMO)	–	–	NSD	–
	PanOptix (Alcon)				
de Medeiros *et al.*, 2019	Tecnis Symfony (AMO)	–	–	Low (< 1%)	High
	PanOptix (Alcon)				High
Lubiński *et al.*, 2020	Tecnis Symfony (AMO)	High (90%)	–	Low (5%)	High
	AT LISA tri 839 MP (Zeiss)	High (100%)		Low (20%)	High
Webers *et al.*, 2020	Tecnis Symfony (AMO)	79%	NSD	High (halo – 57%, glare – 50%)	High
	AT LISA tri 839 MP (Zeiss)	85%		High (halo – 85%, glare – 31%)	High
Moshirfar *et al.*, 2021	Tecnis Symfony (AMO)	–	–	Low (5%)	High
	PanOptix (Alcon)				High

In Cochener *et al.* study (35) both trifocal IOLs were targeted for emmetropia and the EDoF lens was targeted for micromonovision (< –0.25 D) or emmetropia. Their results showed that UNVA was statistically better for both trifocal lenses as compared to EDoF IOL. Nevertheless, near vision with the EDoF lens was good, however authors suggested this is only the case if targeting slight monovision.

In the article published by Webers *et al.* [42] the trifocal group was targeted for emmetropia as a postoperative mean refractive spherical equivalent and the EDoF group was targeted for micromonovision (–0.5 D) in nondominant eye and emmetropia in dominant eye. No significant differences were found in the UDVA and UNVA in photopic conditions. A small significant difference was found in UIVA between both groups in favor of the EDoF group. No differences in visual acuity at all distances were seen between groups under mesopic conditions.

Tan *et al.*'s [45] patients were divided into two groups: the monovision group and the control group (non-monovision group). In the monovision group, Tecnis Symfony IOL power calculations were performed using a micromonovision approach aiming for minimal residual myopia (≈ –0.50 D) in the nondominant eye and emmetropia in the dominant eye. In the control group, emmetropia was considered as the target refraction for both eyes. There was no statistically significant difference in binocular UDVA between the groups. In contrast, binocular intermediate and near visual acuity was statistically significantly better in the monovision group compared to the control group.

In Cochener's article for the Concerto Study Group [44] the mean binocular decimal UDVA after bilateral EDoF IOLs (Tecnis Symfony) implantation was comparable in the entire cohort – the monovision group (target refraction between –0.5 D and –0.75 D), and the non-monovision group (target refraction – emmetropia). The monovision group had significantly better UIVA and UNVA than the non-monovision group. Corresponding to these visual outcomes, the level of spectacle independence reported by patients was high, with most eyes not requiring spectacles for distance vision, intermediate vision, or near vision activity. Spectacle independence for near activities was better in the monovision group.

Ganesh *et al.*'s [46] results were consistent with those of the recently published multicentric study by the Concerto Group, in which bilateral implantation of the EDoF IOL (Tecnis Symfony) with micromonovision provided significantly better uncorrected intermediate and near visual acuity compared to that with the non-monovision group. Their conclusion was that the preliminary results with relatively small number of enrolled eyes suggest that micromonovision with the EDoF IOL was well tolerated and led to excellent outcomes for most activities at all distances. However, further research involving a larger sample size is required to verify these results.

DISCUSSION

In recent years, newer IOL technology has revolutionized cataract surgery to meet patients' growing expectations for excellent distance, intermediate and near vision [47]. Our article is an up-to-date comparative analysis of the results after implantation of trifocal and extended depth of focus IOLs, which may provide important information in choosing the proper lenses for patients. Regarding visual acuity, the studies results which were analyzed showed significantly better UNVA and CNVA for trifocal than EDoF lenses, while the EDoF group showed slightly better results for UDVA, UIVA and CIVA (Table IV), what was confirmed by the defocus curve (Table VI). In addition, a trifocal lens is more likely to be spectacle independent, but also has a slightly higher potential to induce halo or glare (Table VII).

All studies in this analysis involved bilateral implantation of the same IOLs [33-42]. Most authors declare the preoperative assumption of emmetropia [33, 36, 38, 40, 41]. In articles published by Cochener *et al.* and Webers *et al.*, patients with trifocal lenses were achieved target emmetropia, and the EDoF group – emmetropia or micromonovision [35, 42].

The insertion of EDoF lenses compared to trifocal lenses did not fully meet the expectations of patients. In principle, they were supposed to improve the contrast sensitivity, reduce the frequency and intensity of photic phenomena such as glare and halo, while maintaining very good visual acuity in the range from intermediate to the far distances. Our analysis shows that the definitive advantage of EDoF lenses in these categories has not been achieved, so we are waiting for new lens technologies or improvement of the current ones to obtain a lens with good visual acuity at all distances with no or minimal dysphotopsia.

Hence, in order to achieve satisfactory outcomes for near vision, the time-tested concept of micromonovision following the bilateral implantation of this lens may be attempted [48]. Nevertheless, the weak point of micromonovision is the possibility of calculation mistakes, even when using modern calculation formulas.

Despite of all authors adopted similar inclusion and exclusion criteria for the studies, the limitation of our analysis is the differences in the research carried out, such as follow-up time, various methods and conditions for testing e.g., contrast sensitivity or different types of questionnaires assessing the subjective feelings of the patients.

In conclusion, visual function results are very good and comparable for both analyzed types of IOLs. Trifocal lenses presented better near vision, but EDoF IOLs had a slightly lower frequency and severity of photic phenomena. Based on data from the literature, we have not demonstrated a significant superiority of one lens over the other. In clinical practice, still, in addition to the characteristics of the IOL, the patient's personality, expectations, preoperative status and economic status should also be considered. Also, it makes sense to introduce micromonovision as a refraction target for patients planning to implant EDoF lenses to increase their postoperative satisfaction with vision at intermediate and near distances. In the future, next studies on a larger group of patients with longer follow-up are necessary to demonstrate the superiority of EDoF lenses over trifocals.

DISCLOSURE

The authors declare no conflict of interest.

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