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**Kvalita nočního vidění u pacientů v závislosti na druhu implantované nitrooční
čočky (IOL)**

**Quality of night vision in patients depending on type of implanted intraocular lens
(IOL)**

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Hradec Králové 2025

Prohlášení autora

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Souhrn

Předkládám soubor komentovaných publikací, na základě našich studií, které jsme provedli na Ústavu leteckého zdravotnictví Praha od roku 2016. Naším primárním úkolem je pečovat a posuzovat zrak leteckého personálu, vydávat licence v několika kvalifikačních třídách. Od hobby létání, přes civilní komerční letectví, až po vojenské nadzvukové letectvo. Přirozeným předpokladem je dobrá kvalita zraku a to za všech okolností, zvláště světelných podmínkách (denní, soumravné a noční). HD analýza nám poskytuje cenné informace kvality optického systému oka (KOSO), kdy přístroj měří rozptyl světelného toku vcházející do oka a zpět, dopadající na detektor. Stanovením indexu rozptylu světelného bodu OSI odvozujeme další funkce rozptylu bodu PSF a kvality kontrastu MTF. Dle šíře vstupní apertury a zornice za denních nebo nočních světelných podmínek. Měřili jsme KOSO u očí po operaci katarakty s různými implantovanými nitroočními čočkami (IOL). Monofokálními (IOL), monofokálními torickými (TIOL) a multifokálními a multifokálními torickými (MF IOL, MF TIOL). Prokázali jsme, že KOSO u všech typů IOL je na vysoké úrovni jak za denních, tak nočních světelných podmínek ve srovnání s KOSO očí s kataraktou. Nejvíce pacienti oceňovali korekci astigmatismu pomocí torických variant IOL za nízkých světelných podmínek s předoperačním stavem. Nicméně u MF IOL uváděli, kromě výrazného benefitu korekce presbyopie, výskyt nežádoucích optických fenoménů, cca okolo 7%. Následovně jsme posuzovali v další studii, jaký má vliv složitost designu IOL u dvou MF IOL (AT LISA tri a Liberty B flex) vyrobených ze stejného materiálu (BENZ 25) na výskyt nežádoucích světelných fenoménů jak při denních činnostech, tak v noci. Zjistili jsme, že je korelace mezi složitostí technického řešení přenosu světelné energie u jednotlivých IOL. Závěrem jsme určili kritéria, kdy je riziko operace únosné. U pacientů s kataraktou je operace s MF IOL nebo MF TIOL správná, při jinak zdravých očních tkáních a s vyloučením hraničních refrakčních stavů. Operace čistě z refrakčních pohnutek při jinak dobré korigované ostrosti představuje riziko nad 5% výskytu rušivých optických jevů za nočních světelných podmínek, což je pro nás neakceptovatelné pro možnou ztrátu profesní způsobilosti u leteckého personálu. **Klíčová slova: HD analýza, kvalita optického systému oka, noční vidění, denní vidění, nitrooční čočka, astigmatismus, presbyopie, nežádoucí optické fenomény, letecký personál**

Summary

I present a set of annotated publications based on our studies conducted at the Institute of Aviation Health Prague since 2016. Our primary task is to care for and assess the vision of aviation personnel, issuing licenses in several qualification classes. From hobby flying, to civil commercial aviation, to military supersonic aviation. A good quality of vision is a natural prerequisite and this is required in all circumstances, especially lighting conditions (day, dusk and night). HD analysis provides us with valuable information of the quality of the optical system of the eye (KOSO), where the instrument measures the scattering of the light flux entering the eye and back hitting the detector. By determining the light point scattering index OSI, we derive further functions of point scattering PSF and contrast quality MTF. According to the width of the entrance aperture and pupil under day or night light conditions. We measured KOSO in eyes after cataract surgery with different implanted intraocular lenses (IOLs). Monofocal (IOL), monofocal toric (TIOL) and multifocal and multifocal toric (MF IOL, MF TIOL). We demonstrated that the KOSO of all types of IOLs is at a high level under both day and night light conditions compared to the KOSO of eyes with cataract. Patients appreciated most the correction of astigmatism with toric IOL variants under low light conditions with preoperative status. . However, for MF IOLs, in addition to the significant benefit of presbyopia correction, they reported an incidence of undesirable optical phenomena, about 7%. Subsequently, in another study, we assessed the effect of IOL design complexity in two MF IOLs (AT LISA tri and Liberty B flex) made of the same material (BENZ 25) on the incidence of undesirable light phenomena during both daytime and nighttime activities. We found that there is a correlation between the complexity of the technical design of the light energy transfer in each IOL. Finally, we determined the criteria when the risk of surgery is tolerable. Surgery with MF IOL or MF TIOL is appropriate in patients with cataract, with otherwise healthy ocular tissues and excluding borderline refractive conditions. Surgery purely for refractive reasons with otherwise good corrected acuity poses a risk of over 5% of disturbing optical phenomena in nighttime lighting conditions, which we find unacceptable due to the potential loss of professional competence in airline personnel. **Keywords: HD analysis, quality of the optical system of the eye, night vision, day vision, intraocular lens, astigmatism, presbyopia, undesirable optical phenomena, aerospace personnel.**

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Předmluva

V současné době se při operacích lidské čočky snažíme dosáhnout co nejpřirozenějších zrakových funkcí. Výsledné zrakové funkce by se měly blížit zrakovým funkcím a zrakové ostrosti normální přirozené čočky.

Cílem naší práce bylo zhodnotit kvalitu vidění po operaci šedého zákalu a vhodnost designu implantátu pro náročná povolání, např. letců, řídících letového provozu nebo řidičů, zejména za zhoršených světelných podmínek.

Na očním oddělení Ústavu leteckého zdravotnictví se vyjadřujeme ke kvalitě vidění a schopnosti vykonávat danou profesi. Využili jsme i naší laboratoř pro noční vidění, kde můžeme hodnotit zrakovou výkonnost u vojenského leteckého personálu za specifických podmínek.

1. Úvod

V současné době jsme v rozvinutých zemích pokročili v nitrooční chirurgii při operacích šedého zákalu (nejčastěji prováděná operace na lidském těle) nejen k odstranění zkalené původní čočky, ale také k opravě a vylepšení stávajících refrakčních vad lidského oka. Jsme schopni navrátit některé funkce vidění, kterými disponujeme v mladším věku, nebo kompenzovat stávající vrozenou refrakční vadu. To vše posunulo možnosti očního lékařství daleko dopředu a v současné době můžeme výrazně přispívat ke kvalitě života u starších pacientů. Osobně jako oční lékař kladu důraz při operacích mých pacientů, abychom při těchto operacích přinesli pacientům všechny možné výhody, vyplývající ze současných technických i vědeckých možností. Samozřejmě cílíme na úplnou nezávislost na brýlové korekci tam kde to zdravotní podmínky dovolují. European Society and Refractive Surgery (ESCRS) na základě 4149 lékařů deklaruje, že (63%) chirurgů preferuje trifokální IOL ke korekci presbyopie (1). Podobné procento preferencí očních chirurgů uvádí další publikace (Logothetis et al.) (2). Jako primář očního oddělení na Ústavu leteckého zdravotnictví léčím oči leteckého personálu, který má ty nejvyšší nároky na kvalitu vidění. Dystopické fenomény, kompromisní suboptimální vidění za nočních podmínek je uváděno relativně často, zvláště u difrakční technologie (3,4). Proto jsme se zaměřili na tyto efekty v našich studiích. Výsledky zrakové ostrosti a jejich dlouhodobá stabilita je závislá na mnoha vlastnostech IOL (5-6). Materiál a design optiky IOL má hlavní vliv na výslednou zřetelnost (10-13). Navíc materiál, okraj optické částí IOL, haptická část má vliv na opacifikaci zadního pouzdra (PCO), což v důsledku snižuje zřetelnost (14-16). PCO sice lze řešit jednoduše NdYAG capsulotomií, ale může vést k poškození optiky IOL, elevaci nitroočního tlaku (NOT) nebo cytooidnímu makulárnímu edému (17).

Díky využití dlouholetých zkušeností pana prof. MUDr. Pavla Rozsívala PhD. FEBO jsme pokročili při operacích šedého zákalu na úroveň plně srovnatelnou se světovými pracovišti a dnes naše výsledky srovnáváme na této úrovni. Dále spolupracujeme na vývoji a ověřování nových implantátů největších výrobců.

V této disertační práci předkládáme soubor odborných textů, které se věnují dané tématice z různých úhlu pohledu. V první řadě jaké jsou možnosti korekce astigmatismu během operace katarakty, predikce výsledku a jeho stability. Správně korigovaný astigmatismus je dle mého názoru nejdůležitějším faktorem pro kvalitní noční vidění. Je obecně známý fakt, že astigmatismus při širší zornici více ovlivňuje kvalitu optického systému oka, více zkresluje obraz a podstatně klesá zraková ostrost. Proto je nanejvýš vhodné jej kompenzovat.

Ve druhém tématu hodnotíme z naší klinické praxe korekci presbyopie a zároveň rohovkového astigmatismu v při operaci katarakty a výslednou kvalitu optického systému oka, která je základem pro kvalitu vidění nejenom za denních, ale i za zhoršených světelných podmínek. Lze očekávat, že sférický equivalent (SEQ) je nižší u torické varianty Bi Flef 677TAY než u netorické. (18) Toto je elementárním předpokladem pro náročné povolání a nezávislost na brýlích. Dalším limitem je co nejnižší výskyt vedlejších optických fenoménů, rychlost neuroadaptace a schopnost z dané operace těžit. Samozřejmostí je stabilita pooperačních výsledků s minimem hraničních stavů.

Ve třetím tématu se věnujeme opět našim zkušenostem s rozdíly v jednotlivých implantátech a to konkrétně dvou prémiových multifokálních nitroočních čoček (MF IOL) AT LISA tri a Liberty Bi flex, kvalitě optického systému oka a zejména vedlejšími fenomény, které jsou rozhodující při volbě této korekce presbyopie u již zmíněných náročných povoláních. Všechny před a pooperační data jsou k dispozici v (Mendeley Data depositary database from doi 10.17632/y65k7s6f7.1) (19). Zraková ostrost a refrakční výsledky jsou současně publikovány Reinsteinem et al. (20).

Čtvrté téma je doplňkové téma bilaterální operace katarakty v jedné době a vnímání citlivosti operace jednotlivých očí pacienty. V hodnocení zvažujeme pro a proti oboustranné operaci v jedné době. Z hlediska případných komplikací je dneska tento postup přijatelný, za podmínky velmi zkušeného chirurga a přísného dodržování sterility. Každá operace je provedena odděleně, po celkové přípravě pacienta i sálu. Nespornou výhodou pro pacienta je rychlejší rekonvalescence, menší cestovní zátěž a rychlejší návrat do běžného života. Také neuroadaptace je snadnější. I my volíme tento postup v případech, kde se jedná o běžnou refrakční operaci, bez hraničních nálezů a s jasnou predikcí výsledku.

2. Hlavní cíle práce

1. Srovnat kvalitu optických parametru oka po implantaci různých designů IOL za denních a nočních podmínek (objektivní vyšetření na HD analyzátoru). HD analýza je pokroková metoda, která nám umožňuje hodnotit kvalitu optického systému oka (KOSO) a objektivizovat potenciál vidění po operaci, také nám ukazuje kvalitu chirurgického výkonu (KOSO před a po operaci katarakty). Dále nám umožňuje spolu s komplementárními vyšetřeními (OCT, Pentacam autorefraktometr, ERG, PERG, VEP) odlišit v případě špatného vizu podíl KOSO od funkce zrakové dráhy.

2. Srovnat výskyt vedlejších optických fenoménů u jednotlivých druhů IOL za denních, a nočních podmínek. Složitost konstrukce a design IOL má za úkol věrně napodobit distribuci světelného toku a přenos na sítnici. Samozřejmě s přesností a pokrokem dosahujeme stále leších parametrů. Dynamická distribuce světelného toku při různých velikostech zornice je klíčem k omezení rušivých fenoménů. Materiál, design a výskyt opacifikace zadního pouzdra (PCO) má vliv na výskyt nežádoucích efektů i na stabilitu pooperačních výsledků v čase.

3. Vyhodnotit vhodnost jednotlivých typů IOL pro náročné profese jako jsou piloti, řidiči letového provozu nebo řidiči. Ve zmíněných profesích je nutno odlišit skupinu pacientů s refrakčním zájmem od skupiny s šedým zákalem. Naším úkolem bylo vyhodnotit přiměřené riziko v refrakční skupině versus zisk ve kvalitě vidění. Na druhé straně stojí skupina pacientů s šedým zákalem a sníženou zrakovou ostrostí a tady je na místě poskytnout to nejlepší i za cenu přiměřeného rizika (MAGISTER ORANDI OPTIMUS NECESSITAS, nutnost, ta nejlépe prosbám naučí).

3. Optický systém oka

Oko se skládá z mnoha různých struktur, které v souladu zastávají různé funkce, nezbytné pro vidění. Dále je zajišťován souhyb očí pomocí okohybných svalů, jejichž cílem je fungování obou očí, jako jednoho orgánu. Přídavné orgány (víčka a slzný aparát) poskytují ochranu vnějších částí oka. Když je souhra systému narušena, pocítíme to jako zhoršení kvality nebo výkonnosti vidění.

Oční koule se skládá na povrchu s bělimy (sclera), přecházející vpředu do rohovky (cornea), střední vrstvu tvoří cévnatka (choroidea), řasnaté tělísko (corpus ciliare) a duhovka (iris), na tu naléhá vnitřní vrstva sítnice (retina). Nitro oka vyplněno sklivcem (corpus vitreum) a nitrooční tekutinou, v předním segmentu komorovou vodou (humor aquosus)

Oko můžeme přirovnat k optickému systému sestávajícímu z několika komponent, které společně mají za úkol, aby se světlo správně dopadalo na sítnici a vytvořilo jasný obraz. Základními složkami tohoto systému jsou rohovka, čočka, zornice a sítnice.

3.1 Rohovka

- **Funkce:** Rohovka je průhledná přední část oka, která se chová jako hlavní čočka systému, láme světelné paprsky směrem k sítnici.
- **Kvalita:** Průhlednost rohovky závisí na její kvalitě a správném zakřivení. Jakékoliv nepravidelnosti v zakřivení nebo průhlednosti mohou vést k refrakčním chybám, jako jsou astigmatismus, krátkozrakost a dalekozrakost.

3.2 Čočka

- **Funkce:** Čočka je průhledná bikonvexní struktura, která dále mění svojí lomivost pro světelné paprsky tak, aby přesně dopadaly na sítnici. Čočka je schopna měnit svůj tvar, což umožňuje oku zaostřovat na objekty v různých vzdálenostech, proces známý jako akomodace.
- **Kvalita:** Kvalita čočky může být ovlivněna stárnutím, které vede ke ztrátě pružnosti (presbyopie) a vývoji katarakty, což způsobuje zamlžení čočky.

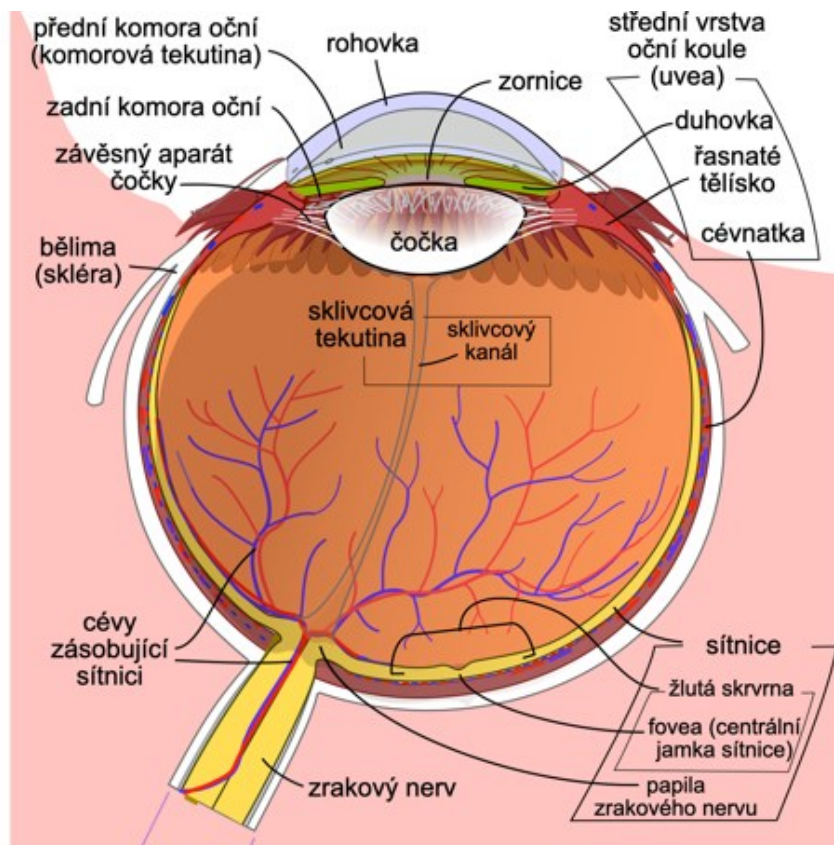
3.3 Zornice

- **Funkce:** Zornice, otvor uprostřed duhovky, reguluje změnou svojí velikosti množství světla vstupujícího do oka.
- **Kvalita:** Zdravá reakce zornice na světlo (rozšiřování a zužování) je klíčová pro optimální vizuální výkon za různých světelných podmínek.

3.4 Sítnice

- **Funkce:** Sítnice je vrstva buněk na zadní straně oka, která obsahuje fotoreceptory (tyčinky a čípky) a transformuje světelné signály na nervové impulsy, které jsou vedeny do mozku.
- **Kvalita:** Zdraví a hustota fotoreceptorů, zejména v oblasti makuly (centrální část sítnice), jsou zásadní pro ostré centrální vidění. Degenerace sítnice, jako je makulární degenerace, může výrazně ovlivnit kvalitu vidění.

Celková kvalita optického systému oka závisí na zdraví a funkčnosti těchto komponent. Jakékoliv poškození nebo degenerace těchto částí může vést k snížení zrakové ostrosti a dalším problémům s viděním. Pravidelné kontroly u očního lékaře pomáhají zajistit, že jakékoliv problémy budou včas identifikovány a léčeny.



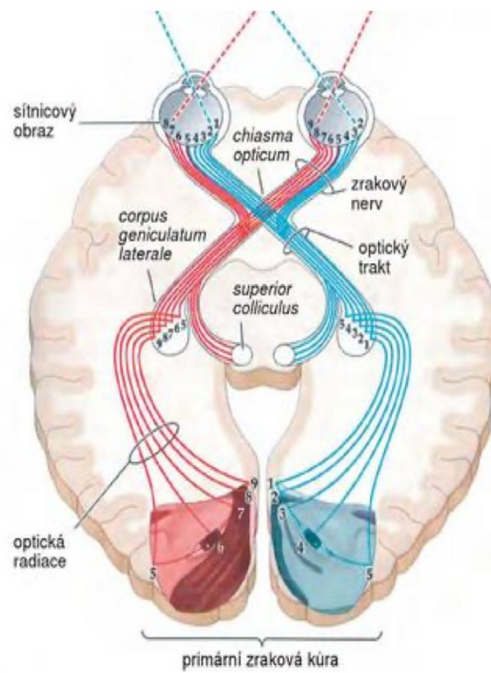
Obrázek 1: Struktura lidského oka. (Zdroj: [Rhcastilhos, And Jmarchn, CC BY-SA 3.0](#), via Wikimedia Commons)

Obrázek 1. Anatomická struktura lidského oka

4. Zraková dráha

Světlo po dopadu na sítnici vytváří akční potenciály, které opouští oko prostřednictvím axonů gangliových buněk. Ty společně tvoří zrakový nerv, který míří do mozku. Předtím než se ale dostane do mozku, je část vláken zrakového nervu křížena. Informace je tak vedena do zrakové kůry mozku (area 40) k dalšímu zpracování. Tím vzniká obraz o té části okolního prostředí, kterou můžeme vidět očima. Název tohoto pozorovatelného prostoru je zorné pole a skládá se ze dvou částí se zorného pole pravého a levého oka. Monokulární část vidění je oblast, kterou můžeme vidět pouze jedním okem. Překrývající se zorné pole obou očí je základem pro vytvoření trojrozměrného obrazu v mozku a to díky rozdílnému úhlu pohledu obou očí, tedy binokulárního vidění. Světelné paprsky dopadající na sítnici jsou převrácené a zmenšené, a co je důležité, levá část zorného pole dopadá do pravé části oční koule, a naopak. Informace dopadající do levých částí bulbů putuje do levé mozkové hemisféry, informace z pravých částí očních bulbů do pravé (Obr.2).

V optickém nervu dochází ke křížení nervových vláken (v chiasma opticum), od kterého dále vedou neurony (tractus opticus) do thalamu (corpus geniculatum). Axony těchto neuronů se pak nazývají radiatio optica a vedou do primární zrakové kůry týlního laloku mozku, známé také jako Brodmannova oblast 17 (Rokyta 2000). Do koncového mozku se dostane jen část vláken zrakového nervu (20 %-30 %), zbytek vláken směřuje do colliculi superioris středního mozku (FOX 2011), kde se podílí na kontrole pohybu očí a koordinaci s pohybovým a sluchovým ústrojím, zajišťující rovnováhu. Všechny informace ze zrakových dráh z obou očí jsou pak sloučeny do jednoho výsledného obrazu okolí.



Obrázek 2. Zrakový systém člověka, včetně projekce vláken zrakového nervu z pravého a levého oka do mozkové kůry - optická dráha (Šikl 2012, s.68)

5. Proces vidění

- **Světelné podněty:** Vše začíná, když světlo dopadá na objekty v zorném poli a odráží se do oka. Intenzita a vlnová délka odraženého světla určují jas a barvu, které vidíme.
- **Vstup do oka:** Světlo prochází rohovkou, zornicí a čočkou, které společně fokusují světelné paprsky na sítnici.
- **Fotorecepce:** Na sítnici světlo dopadá na fotoreceptorové buňky, tyčinky a čípky. Tyčinky jsou citlivější na světlo a jsou více zastoupeny ve větší části sítnice, což je činí efektivními v špatných světelných podmínkách. Čípky, které jsou koncentrovány v centrální části sítnice (makula), jsou zodpovědné za vidění detailů a barev.
- **Zpracování informací:** Fotoreceptory přeměňují světelné podněty na elektrické signály, které jsou posílány do mozku prostřednictvím optického nervu. Mozek pak interpretuje tyto signály jako konkrétní obrazy.

6. Kontrastní citlivost

Aby oko mohlo efektivně zpracovávat kontrasty, musí být schopno detekovat jemné rozdíly v intenzitě světla mezi různými částmi vizuálního pole. Tato schopnost závisí na zdraví a funkci fotoreceptorů a také na kvalitě optického systému oka, který musí být schopen přesně zaostřovat světelné paprsky na sítnici, aby se zabránilo rozmazání obrazu.

Faktory ovlivňující kontrastní citlivost

- **Věk:** S věkem kontrastní citlivost obvykle klesá, což může být důsledkem změn v čočce a sítnici.
- **Zdravotní stav oka:** Stavy jako katarakta, glaukom nebo makulární degenerace výrazně ovlivňují kontrastní citlivost.
- **Světelné podmínky:** Kontrastní citlivost se mění v závislosti na úrovni osvětlení. V **nízkém osvětlení je kontrastní citlivost nižší.**
- **Význam kontrastní citlivosti:** Kontrastní citlivost je klíčová pro mnoho běžných aktivit, jako je řízení, čtení a rozpoznávání tváří. Zlepšení nebo udržení dobré kontrastní citlivosti je důležité pro udržení kvality života, zejména u starších dospělých nebo osob se zrakovými postiženími.

7. Oslnění

Oslnění je vizuální fenomén, který nastává, když je oko vystaveno příliš intenzivnímu světlu, což vede k dočasnému snížení citlivosti. To může být způsobeno přímým zdrojem světla, jako je slunce, nebo odrazem světla od povrchů, jako jsou voda, sníh nebo vozovka. Oslnění může být nepříjemné a v některých případech i nebezpečné, zejména při řízení vozidla nebo provádění jiných činností vyžadujících dobré vizuální vnímání.

7.1. Mechanismus oslnění

Oslnění se děje, když je množství světla, které vstupuje do oka, příliš velké na to, aby si oko mohlo účinně poradit. To vede k několika fyziologickým reakcím:

- **Rozptyl světla:** V oku, zejména v rohovce a čočce, dochází k rozptylu nadměrného světla. Tento rozptyl způsobuje, že světlo zasahuje více oblastí sítnice, což snižuje kontrast a tím ostrost obrazu.
- **Přesycení fotoreceptorů:** Silné světlo může přesytit čípky a tyčinky (fotoreceptory na sítnici), čímž dočasně snižuje jejich schopnost zpracovávat vizuální informace. To vede k zhoršení vnímání detailů a barev.
- **Vyblednutí (Bleaching) pigmentů:** Intenzivní světlo může způsobit chemickou reakci v pigmentech, jako je rodopsin v tyčinkách, což vede k jejich dočasnému vyblednutí a snížení citlivosti na světlo.
- **Zornicový reflex (Pupillary reflex):** V reakci na intenzivní světlo se zornice zúží. Tento reflex, známý jako mióza, pomáhá omezit množství světla vstupujícího do oka, **ale může trvat několik sekund, než se plně projeví.**

7.2. Typy oslnění

- **Oslnění odleskem:** Způsobeno odrazem světla od povrchů, jako jsou vodní hladiny, sníh nebo mokré vozovky.
- **Přímé oslnění:** Nastává, když je zdroj intenzivního světla přímo v zorném poli, jako například při pohledu do slunce.

7.3. Zvládání oslnění

- **Použití slunečních brýlí:** Pomáhá filtrovat nadměrné množství světla a UV záření.
- **Použití clon nebo štítů:** V autě lze použít sluneční clony k blokování přímého světla.
- **Adaptivní zornice:** V některých případech mohou být užitečné fotochromatické čočky, které se automaticky přizpůsobují změnám světelných podmínek.
- **Zlepšení osvětlení a kontrastu:** V interiérech může být užitečné zlepšit osvětlení a kontrast, aby se snížil dopad oslnění od vnějších světelných zdrojů.

Oslnění je významným faktorem ovlivňujícím vizuální pohodlí a bezpečnost, a proto je důležité pochopit jeho účinky a naučit se, jak jeho negativní dopady minimalizovat.

8. Fyziologie vidění

Fyziologie vidění se liší v závislosti na světelných podmínkách, což ovlivňuje, jak dobře vidíme během dne a v noci. Rozdíly ve vidění za denních a nočních podmínek jsou způsobeny především anatomickými a funkčními rozdíly mezi dvěma typy fotoreceptorů v sítnici: tyčinkami a čípkami.

8.1. Vidění za denních podmínek (fotopické vidění)

Za denních podmínek, kdy je dostatek světla, je aktivní především čípkové vidění. Čípky jsou fotoreceptory, které se nacházejí hlavně v centrální části sítnice, známé jako makula. Tyto buňky jsou zodpovědné za vnímání barev a detailního vidění, což je důležité pro činnosti jako čtení nebo rozpoznávání obličejů.

- **Vysoká rozlišovací schopnost:** Čípky umožňují ostře vidět a rozlišovat jemné detaily.
- **Barevné vidění:** Čípky jsou citlivé na různé vlnové délky světla, což umožňuje vnímání barev.
- **Menší citlivost na světlo:** Čípky potřebují více světla pro aktivaci než tyčinky, proto nejsou efektivní v šeru nebo téměř úplné tmě.

8.2. Vidění za nočních podmínek (skotopické vidění)

V noci nebo za špatných světelných podmínek převládá tyčinkové vidění. Tyčinky jsou mnohem citlivější na světlo než čípky a jsou rozmístěny po celé sítnici, ale nejsou přítomny v makule.

- **Vysoká citlivost na světlo:** Tyčinky jsou extrémně citlivé na nízké světelné úrovni, což umožňuje vidění i za velmi slabého osvětlení.
- **Žádné barevné vidění:** Tyčinky nemohou rozlišovat barvy, což znamená, že vidění za noci je téměř výhradně v odstínech šedi.
- **Nižší rozlišovací schopnost:** Tyčinky nerozlišují detaily tak ostře jako čípky, což znamená, že noční vidění není tak detailní.

8.3. Adaptace na světlo a tmu

Oko se musí přizpůsobit přechodům mezi světelnými a tmavými podmínkami, což se nazývá adaptace na světlo a tmu. Tento proces zahrnuje chemické změny v fotoreceptorech a může trvat několik minut až hodin.

- **Adaptace na tmu:** Při přechodu z jasného světla do tmy potřebují fotoreceptory čas na regeneraci pigmentů (např. rodopsinu v tyčinkách), které jsou nezbytné pro citlivost na světlo.
- **Adaptace na světlo:** Naopak, když vstoupíme z tmavého prostředí do jasně osvětleného, dochází k dočasnému oslnění, dokud se čípky nepřizpůsobí vyšší úrovni světla.

Rozumění těmto procesům je klíčové pro pochopení, jak různé podmínky ovlivňují naše vidění a jak mohou být oči náchylné k únavě nebo poškození v extrémních světelných podmínkách.

9. Analýza kvality optického systému oka (KOSO)

Vyšetřovací techniky oka, které se zaměřují na analýzu kvality optického systému oka bez zahrnutí optické dráhy, zahrnují různé metody a přístroje, které umožňují posoudit stav a fungování předních částí oka. Tyto technologie se používají k diagnostice a sledování různých očních onemocnění a stavů. Některé z hlavních technik zahrnují:

- **Refrakční vyšetření** - Toto základní vyšetření určuje dioptrickou chybu oka (krátkozrakost, dalekozrakost, astigmatismus). Používají se různé přístroje jako autorefraktometry.
- **Keratometrie** - Keratometr měří zakřivení rohovky, což je důležité pro diagnózu astigmatismu
- **Topografie rohovky** - Tato technika poskytuje detailní mapu zakřivení rohovky, která je důležitá pro plánování refrakčních operací, diagnózu keratokonu a dalších rohovkových dystrofií.
- **Pachymetrie** - Měření tloušťky rohovky, které je kritické pro pacienty podstupující laserovou operaci oka a pro sledování pacientů s podezřením na glaukom.
- **Biometrie** - Měření délky oka a dalších parametrů, které jsou důležité pro výpočet síly nitrooční čočky při operaci katarakty.
- **Světelná koherentní tomografie (OCT) předního segmentu** - OCT předního segmentu poskytuje vysoké rozlišení obrazů předních struktur oka, včetně rohovky, duhovky a čočky, což je užitečné pro řadu diagnostických a terapeutických aplikací.
- **Scheimpflugova kamera** - Tato technika umožňuje trojrozměrné zobrazení přední části oka a je užitečná pro přesné měření a analýzu rohovky a čočky.
- **Interferometrie** - Používá se k měření kvality a množství slzného filmu, což je klíčové pro diagnostiku suchého oka.

10. HD Analýza

HD analyzátor, známý také jako analýza vysokého rozlišení optického systému oka, je moderní diagnostické zařízení používané k posouzení kvality optického systému oka.

Toto zařízení poskytuje podrobné informace o různých optických vlastnostech oka, včetně aberací vyššího řádu, které mohou významně ovlivnit kvalitu vidění.

Jak HD analyzátor funguje

HD analyzátor používá pokročilé technologie jako je Hartmann-Shack senzor, k měření a analýze světelných vln procházejících okem. Zařízení vyhodnocuje, jak světlo proniká skrze různé části oka a jak se lomí, což umožňuje identifikovat jakékoliv optické zkreslení původního signálu.

10.1. Co HD analyzátor měří ?

- **Celkové aberace:** Měří celkové optické aberace v oku, včetně sférických a cylindrických odchylek.
- **Aberace vyššího řádu:** Speciálně se zaměřuje na složitější optické chyby, které nemusí být korigovány standardními brýlemi nebo kontaktními čočkami.
- **Point Spread Function (PSF):** Analyzuje, jak bodový zdroj světla vytváří obraz na sítnici, což ovlivňuje ostrost vidění.
- **Modulation Transfer Function (MTF):** Hodnotí, jak systém přenáší kontrast v různých frekvencích detailů z objektu do obrazu.

10.2. Klinické využití

- **Před refrakční a kataraktovou chirurgií:** Pomáhá lékařům rozhodnout o nejlepší metodě korekce vidění, včetně výběru intraokulárních čoček.
- **Diagnostika a sledování očních onemocnění:** Pomáhá identifikovat a monitorovat stavy jako je keratokonus nebo jiné abnormality rohovky.
- **Výzkum a vývoj:** Používá se ve výzkumu pro lepší pochopení optických vlastností oka a vývoj nových očních léčebných metod a technologií.

10.3. Výhody HD analýzy

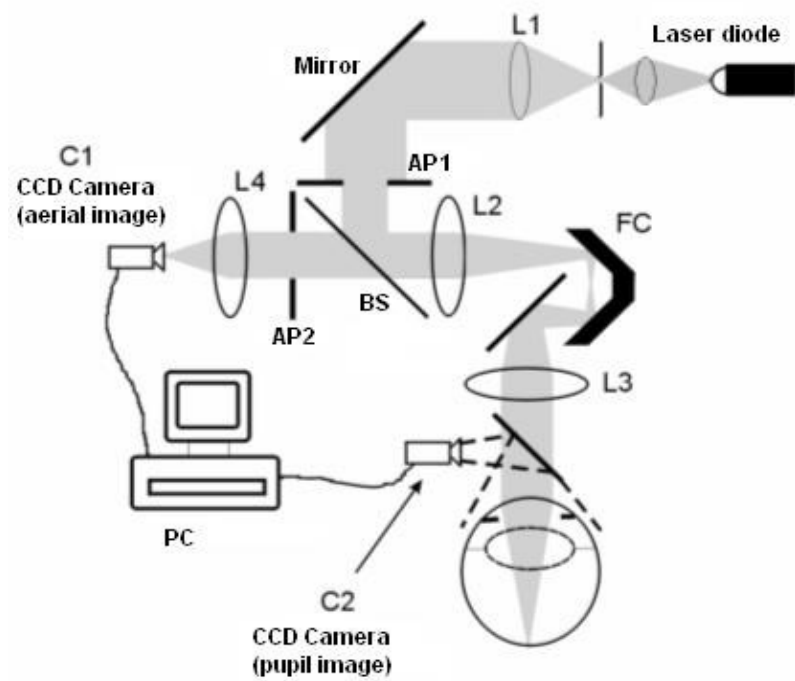
- Poskytuje velmi přesné a detailní informace o optickém systému oka.
- Umožňuje efektivněji predikovat refrakci.
- Zlepšuje výsledky chirurgických zákroků oka tím, že poskytuje přesnější údaje pro plánování operace.
- HD analyzátor je tedy cenným nástrojem v moderní oftalmologii, který umožňuje lékařům poskytnout pacientům lepší diagnostické a léčebné možnosti pro optimalizaci kvality vidění.

10.4. HD Analyzátor - přístroj

Společnost VISIOMETRICS vyvinula HD AnalyzerTM, přístroj založený na technice dvojitého průchodu, který umožňuje objektivní vyhodnocení kvality optického systému oka (KOSO) bez účasti zrakové dráhy. Světlo se projikuje na sítnici (1. průchod) a poté se odražením od sítnice dostává zpět (2. průchod). HD AnalyzerTM analyzuje velikost a tvar odraženého světelného paprsku a poskytuje komplexní informace o KOSO, včetně aberací vyšších řádů.

HD AnalyzerTM se hodí pro měření KOSO za různých světelných podmínek, měření stability slzného filmu a zbytkové refrakční vady, které mohou ovlivnit kvalitu zraku za zhoršených světelných podmínek. Přístroj také umí stanovit míru pseudo-akomodace, která může významně ovlivnit výsledek operace při změnách fokusace.

Technika dvojitého průchodu využívá laserovou diodu s vlnovou délkou 780 nm. Světelný paprsek prochází filtrem, kolimátorem, děličem paprsku a čočkami, než dorazí na sítnici. Poté se odražené světlo vrací zpět a prochází druhou umělou zornicí (AP2), která je konjugována s rovinou zornice oka. Efektivní výstupní zornicí bude buď AP2 nebo přirozená zornice, podle toho, která je menší. Měření je možné provést pro různé průměry AP2.



Obrázek 3. Schéma HD analyzátoru

11. Rozdělení implantátů podle fyzikálních vlastností

Kvalita vidění po implantaci nitroočních čoček (IOL) se může lišit v závislosti na typu implantátu a individuálních faktorech pacienta, jako je stav sítnice, věk a přítomnost jiných očních onemocnění. Různé typy IOL nabízejí různé výhody a mohou být vhodnější pro různé životní styly a požadavky na vidění. Zde je srovnání několika běžných typů nitroočních čoček:

11.1. Monofokální IOL

Monofokální čočky poskytují jasný obraz na jednu vzdálenost (nejčastěji na dálku). Pacienti s monofokálními IOL často potřebují brýle pro čtení nebo práci na blízko.

- **Výhody:** Vysoká kvalita obrazu na určenou vzdálenost, méně problémů s haló efektem nebo světelnými artefakty.
- **Nevýhody:** Omezená flexibilita pro vidění na různé vzdálenosti bez použití brýlí.

11.2. Torické IOL monofokální

Torické IOL jsou určeny pro pacienty s astigmatismem. Tyto čočky mají speciální design, který koriguje astigmatismus vedle korekce základní vady.

- **Výhody:** Poskytuje jasné vidění pro pacienty s astigmatismem, což je něco, co standardní monofokální nebo multifokální čočky nemohou nabídnout.
- **Nevýhody:** Vyžaduje přesné umístění během chirurgie, aby byl zajištěn správný astigmatický korekční efekt.

11.3. Multifokální IOL a jejich torické varianty

Multifokální čočky umožňují vidění na více vzdáleností (dálka, střední vzdálenost a blízko). Toto je dosaženo pomocí různých optických zón na implantátu, které lomí světlo na různé vzdálenosti. Torické varianty korigují preexistující rohovkový astigmatismus a tím lze dosáhnout korekce astigmatické vady a plně využít víceohniskovost implantované čočky.

- **Výhody:** Možnost vidět na různé vzdálenosti bez nutnosti brýlí.
- **Nevýhody:** Může způsobit optické nežádoucí jevy jako jsou haló efekty nebo oslnění, které mohou být rušivé, zejména v noci.

11.4. Akomodativní IOL

Akomodativní čočky jsou navrženy tak, aby napodobovaly přirozený akomodační mechanismus oka tím, že se mírně pohybují nebo mění tvar v oku, čímž se upravuje ohnisková vzdálenost v závislosti na tom, zda se díváme do dálky nebo na blízko.

- **Výhody:** Snaží se poskytnout přirozenější vidění na různé vzdálenosti.
- **Nevýhody:** Efektivita akomodace může být omezená a nemusí být tak účinná jako přirozená akomodace mladých očí. Z našich zkušeností vyplývá omezená akomodace.

11.5 Shrnutí

Výběr správného typu nitrooční čočky závisí na mnoha faktorech, včetně zrakových potřeb a očekávání pacienta, životního stylu, a také zdravotního stavu oka. Je důležité důkladně probrat možnosti a vydefinovat možnosti pro konkrétního pacienta.

To nám může pomoci určit nejlepší typ čočky pro individuální potřeby pacienta, aby bylo dosaženo optimálních výsledků vidění po operaci.

12. Praktické využití HD analýzy a KOSO u jednotlivých typů IOL za různých světelných podmínek, naše zkušenosti

HD analyzátor měří KOSO pomocí obrazu vstupujícího do oka přes všechny struktury optického systému, který se odráží od sítnice a vystupuje zpět až do přístroje, kde se detekuje jeho roptyl a zkreslení. Popisuje se pomocí funkcí PSF, OSI, MTF, ze kterých se dá matematicky vyhodnotit možná dosažitelná zrková ostrost. Je to velmi užitečný předpoklad, který chirurgovi umožňuje hodnotit svojí práci a korigovat případné chyby. Jsme tímto způsobem schopni zobrazit, jaké zlepšení ve fyzikální rovině jsme pacientovi operací přinesli. Další neméně důležitá tematika je přenos a zpracování obrazu od sítnice až do mozku, která odpovídá výsledné zrkové ostrosti na definované vzdálenosti a případný výskyt rušivých jevů. To jsme vyhodnotili v našich studiích a následně publikovali.

Na KOSO dle našich měření na HD analyzátoru měly vliv nekorigované refrakční vady, zejména astigmatismus, který významně snižoval KOSO za soumravných a nočních světelných podmínek.

Při záměru refrakční operace na přirozené čočce musíme korigovat zejména – základní refrakční vadu, dále astigmatismus a zohlednit kvalitu slzného filmu.

Astigmatismus se vždy zvýrazní u širší zornice, zejména za špatných světelných podmínek, proto je důležité jej korigovat, pokud chceme dosáhnout dobré KOSO a nezávislosti na brýlích při náročnějších světelných podmínkách.

V první naší studii jsme hodnotili 35 očí u 22 pacientů před a po operaci katarakty se záměrem korigovat preformovaný rohovkový astigmatismus, stabilitu jeho korekce, tzn. rotační stabilitu implantátu a zrkovou stabilitu včetně výskytu následné katarakty.

Mimo publikaci jsme hodnotili mimo jiné rozptylovou funkcí PSF na HD analyzátoru při široké a úzké zornici (tedy za denních a nočních podmínek). Potvrdilo se nám, že korekce astigmatismu je jedním z nejdůležitějších parametrů dobrého vidění za zhoršených světelných podmínek.

Kvalita otického systému se odvíjí od kvality jednotlivých tkání (rohovka, čočka nebo IOL, transparence sklivce a případné retinální patologie).

V našem zájmu pozorování bylo sledovat, jak jednotlivé implantáty ovlivňují KOSO při vstupní dobré kvalitě očních tkání. Měřili jsme při úzké vstupní aperuře (pod 3 mm),

odpovídající denním světelným podmínkám a při široké apertuře (nad 4 mm) a zároveň široké zornici (v místnosti byla tma). Šíře zornice je do značné míry individuální záležitostí, nicméně jsme nastavenou šíři apertury orámovali maximální vstup za denních a nočních podmínek a tím jsme docílili standartizace vyšetření.

Nejprve jsme měřili KOSO u pacientů s monofokální IOL 677 (Y) se žlutým filtrem mimo mezopickou oblast. KOSO u těchto očí dosahovalo excelentních výsledků jak za denních, tak za nočních světelných podmínek ve všech parametrech (OSI, MTF, PSF) Obr.5, ve srovnání s předoperační KOSO u očí s kataraktou. Obr. 4.

Dále jsme stejným způsobem měřili KOSO u očí s TIOL Bi-Flex 677(Y), kde jsme dosahovali při dobré korekci astigmatismu srovnatelných hodnot, což opodstatňuje korekci astigmatismu jako hlavní vady pro dobré noční vidění.

V dalších měřeních se nám potvrdilo, že při použití MF IOL, nebo MF TIOL s dobrou korekcí preformovaného korneálního astigmatismu je přenos optickou soustavou na vysoké úrovni jak za denních, tak nočních světelných podmínek. Případným hendikepem je výskyt vedlejších nežádoucích fenoménů a rychlost neuroadaptace i při dobrém přenosu obrazu na sítnici. Z fyzikálního principu naše zvolené implantáty vykazovaly vysokou kvalitu přenosu obrazu a minimální rozptyl světelného toku v obou směrech (do oka a zpět). Proto je zásadní pro potenciální uživatele přenos a zpracování světelného signálu od sítnice až po vizuální kortex. Po ověření dobré KOSO při implantaci prémiových implantátů jsme se soustředili na praktické vizuální schopnosti a ev. vedlejší fenomény pomocí dotazníku Obr. , kde byly zařazeny otázky jak na denní, tak na noční aktivity.

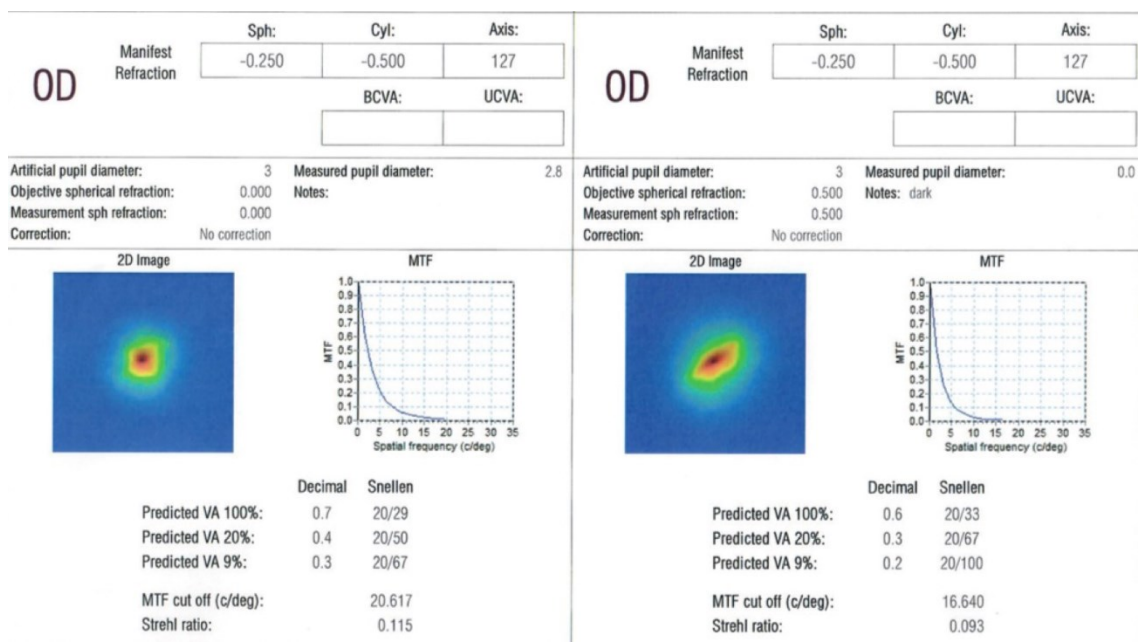
Ze třetího sledování a srovnáním dvou MF IOL AT LISA tri a LIBERTY B Flex nám vyplynulo, že oba implantáty vykazují vysoký stupeň KOSO, nicméně výskyt limitujících vedlejších fenoménů je vyšší u IOL se složitější konstrukcí (AT LISA tri) a tudíž je na zvážení, jaké povolání anebo jaké zájmy pacient preferuje. Naše zkušenosti potvrzují, že technicky jsme schopni při operaci katarakty dosáhnout vysoké úrovně přenosu obrazu na sítnici (HD analýza), nicméně plastické funkce mozku budou hrát významnou roli v pochopení a interpretaci zrakového vjemu.

Implantologie urazila obrovský kus cesty k návratu přirozených vlastností čočky a pokrok ve fyziologii vidění se stále zdokonaluje a vyvíjí. Zlešuje se predikce výsledků a s nadsázkou se dá říci, že dnes již dokážeme ušít implantát na míru klientovi. Trend

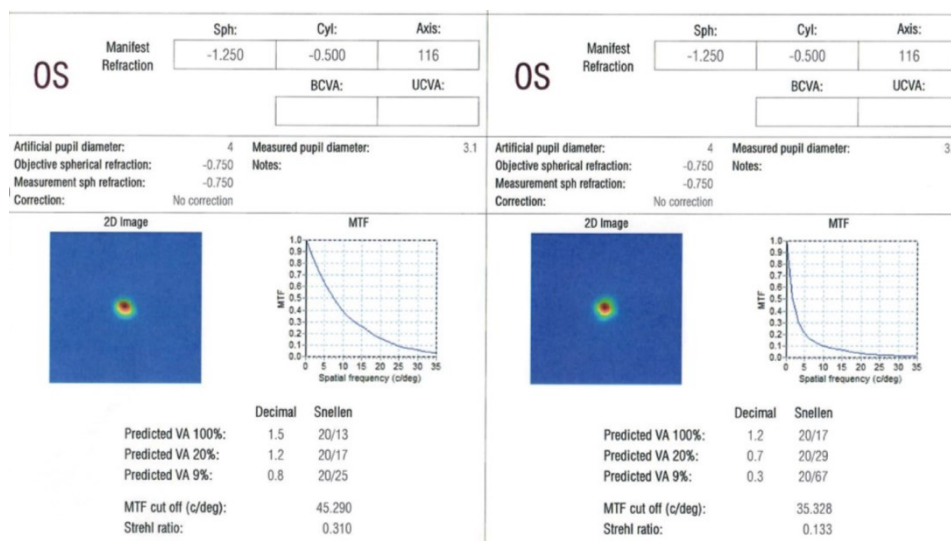
individualizace optických parametrů oka včetně simulace pooperačních schopností je již dnes dostupný např. systém RALV s praktickým testem konkrétních dostupných implantátů předřazených před okem klienta. Tím si vyšetřovaný dokáže zhruba představit, jaké kvality vidění po operaci dosáhne a lékař dostane dobrou zpětnou vazbu. S těmito znalostmi a znalostí vlastních chirurgických výsledků dokážeme lépe nakonfigurovat pacientovi řešení.

Refrakční chirurgie, zvláště CLE, náleží do skupiny výběrové operativy, je nutné si uvědomit, že klient velmi špatně nese jakékoliv rušivé fenomény. Měla by být prováděna maximálně zodpovědně a obezřetně, s primárním cílem zlepšit zrakové schopnosti pacienta, až po té z ekonomického pohledu. Zkušenosti při této disciplíně chirurg získává nejen při rutinních operacích katarakty, ale také zpětnou vazbou a zkoumáním pooperačních výsledků a sebereflexí a to po celou dobu praxe.

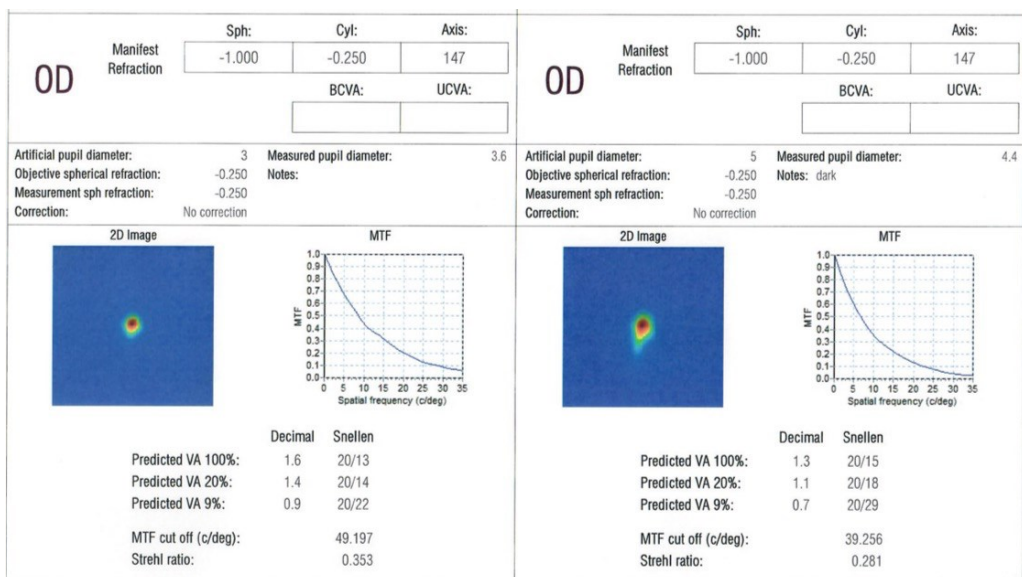
V současné době z posudkového hlediska u náročných povolání nelze univerzálně doporučit implantaci složitých druhů IOL, zvláště refrakčních operací. Riziko vedlejších fenoménů je stále nad 5% u odoperovaných pacientů. U řešení senilní katarakty, kdy posuzovaný již nesplňuje kritéria pro výkon profese, tam lze s jistým rizikem pro další výkon profese zvolit tyto implantáty. Je samozřejmostí provádět tyto výkony s vyšetřením všech částí oka a zohlednit případnou patologii jiných očních tkání, vyjma čočky, která je nahrazována. Po zhojení a zrakové rehabilitaci musí posuzovaný splnit veškeré potřebné testy. Také musíme v čase prokázat stabilitu zrakových funkcí, tudíž je potřeba v prvním roce častějších kontrol včetně profesního posouzení.



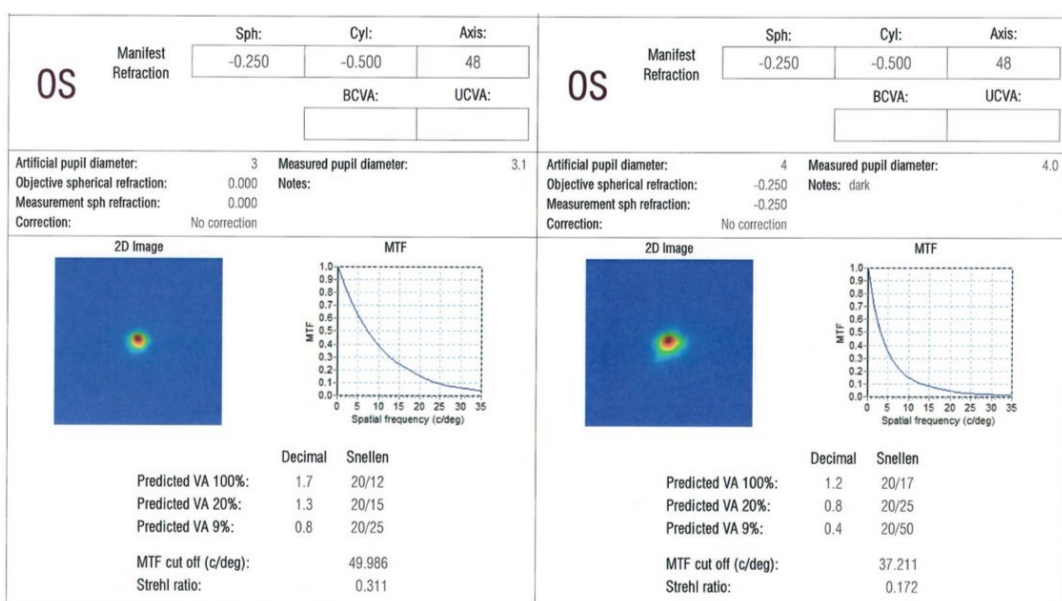
Obrázek 4. HD analýza zobrazuje sníženou KOSO u oka s kataraktou



Obrázek 5. HD analýza o implantované monofokální IOL se žlutým filtrem mimo mesopickou oblast za denních a nočních podmínek



Obrázek 6. HD analýza TIOL za denních a nočních podmínek



Obrázek 7. HD analýza u MF IOL za denních a nočních podmínek

Komentář publikovaných prací

ID: 513894

Nováček L V, Němcová M, Tyx K, Lahodová K, Rejmont L, Rozsival P, Studený P. Evaluation of Astigmatismus-Correcting Efficiency and Rotational Stability after Cataract Surgery with a Double-Loop Haptic Toric Intraocular Lens:A 1-Year Follow-Up. *Biomedicine Hub*. 2021-02-17(1):30-41. ISSN 2296-6870. DOI: 10.1159/000513894, původní recenzovaný článek v časopisu

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Nováček L V, Němcová M, Sičová K, Tyx K, Rozsival P, Němčanský J, Studený P. Simultaneous Presbyopia- and Astigmatism-correction with a Novel Trifocal Toric Intraocular Lens a One-year Follow-up. *Biomedicine Hub*. 2021-6(1):30-41DOI: 10.3390/jcm11144194 ISSN: 2077-0383 původní recenzovaný článek v časopisu

ID: 10153268

Nováček L V, Němcová M, Tyx K, Lahodová K, Rejmont L, Rozsival P, Studený P. Comparison of Clinical Outcomes, Visual Quality and Visual Function of Two Presbyopia-Correcting Intraocular Lenses Made from the Same Material, but with Different Design and Optics *Journal of Clinical Medicine*. 2021-07-24 10(15) 3268. ISSN 2077-0383. DOI: 10.3390/JCM10153268, původní článek v časopisu IF = 4,242 ID:5584906 Studený P, Vránová J,

Nováček L. Use of Simultaneous Bilateral Cataract Surgery (SBCS) to Optimize Parameters Affecting the Subjective Perception of the Procedure. *Journal of Ophthalmology*.2021, 8 pages, ISSN 2019-0058 DOI:10.1155/2021/5584906, původní článek v časopisu: IF = 1,909

Studie 1 Publikace – Hodnocení efektivity korekce astigmatismu, rotační stability po operaci katarakty a implantaci torické nitrooční čočky s haptiky typu Double-Loop

(Evaluation of Astigmatism-Correcting Efficiency and Rotational Stability after Cataract Surgery with a Double-Loop Haptic Toric Intraocular Lens)

V posledních letech operace katarakty není soustředěna jenom na náhradu zkalené čočky, ale zahrnuje také případy pouze lehce opákných čoček se zaměřením na vysokou přesnost korekce refrakčních vad, který přináší trvalý výsledek do budoucna (1) Ferre-Blasco et.al. (2). v jejich studii bylo zahrnuto 4540 očí, uváděli pozoruhodný výskyt 87% očí s preformovaným astigmatismem. V současné studii 13012 očí (6506 pacientů) bylo uvedeno, že 43,5% očí vykazovalo korneální astigmatismus větší, než 1,0 D cyl, který byl příčinou nežádoucích efektů po operaci katarakty, a významně ovlivňoval zrakovou ostrost a kvalitu vidění, pokud nebyl korigován. (3)

Navzdory tomu, že současné modely torických IOL jsou designovány s vysokou přesností, stále je otázkou individuálního umění biometrie. Bereme-li v potaz při kalkulaci řadu sofistikovaných parametrů (včetně zadního povrchu rohovky), stále jsou některé proměnné ovlivňující výsledek. Precizní srovnání všech dostupných komponent zvyšuje úspěch korekce astigmatismu při kataraktové chirurgii. (6)

Na základě literatury, která hodnotí výsledky po implantaci TIOL, jsme zjistili, že udávají výsledky do ½ roku po implantaci. (7-13) Dlouhodobá rotační stabilita je samozřejmě velmi důležitá. Pouze málo publikovaných studií uvádí dlouhodobé výsledky Bi-Flex 677(Y) monofokální, intrakapsulárně implantované TIOL (14,15)

Naše retrospektivní studie hodnotila 35 očí u 22 pacientů, kteří podstoupili operaci katarakty s preformovaným rohovkovým astigmatismem. Byla u nich implantována torická monofokální IOL Bi.Flex 677TA(Y). Mimo hodnocení zlepšení zrakové ostrosti a korekce refrakčních chyb jsme provedli hodnocení pomocí vektorové analýzy. Tabulka 1 popisuje charakteristiku studijní skupiny. Do analýzy jsme zahrnuli pouze subjekty s normálním nálezem, mimo zkalenou čočku.

Výsledky zrakové ostrosti byly velmi dobré a stabilní, pacienti udávali vysokou spokojenost zejména při řízení v noci. Doslova se jim prodloužil aktivní čas až do noci.

Signifikantní zlepšení bylo dosaženo jak v nekorigované, tak v korigované zrakové ostrosti. (UDVA a CDVA) ve srovnání s předoperačními hodnotami. Tab. 1.

Tabulka 1. ukazuje refrakční výsledky ve 3 a 12 měsíci poperačně, kterých bylo mimojiné dosaženo záhy po implantaci TIOL. Porovnáním hodnot residuální refrakce (SEQ a CYL) při pooperačních kontrolách prokazujeme stabilitu v čase

Correction	Preoperative	Postoperative (at 3 months)	Postoperative (at 12 months)	<i>p</i> value preop vs. M3*	<i>p</i> value M3 vs. M12*
<i>Distance</i>					
UDVA, D					
Mean ± SD	0.32±0.18	0.92±0.08	0.93±0.13	<0.0001	0.0339
Range	0.01–0.60	0.80–1.00	0.50–1.00		
CDVA, D					
Mean ± SD	0.65±0.19	0.97±0.06	0.96±0.08	<0.0001	0.9146
Range	0.15–1.00	0.80–1.00	0.70–1.00		
SPH, D					
Mean ± SD	0.61±2.23	–0.10±0.19	0.01±0.29	0.0396	0.0337
Range	–4.0 to +5.00	–0.50 to +0.25	–0.75 to +0.75		
CYL, D					
Mean ± SD	–1.02±1.10	–0.19±0.29	–0.17±0.31	<0.0001	0.6563
Range	–3.75 to +1.00	–1.00 to 0.00	–1.00 to 0.00		
SEQ, D					
Mean ± SD	0.10±2.25	–0.19±0.30	–0.08±0.41	0.1739	0.0557
Range	–4.50 to +4.88	–0.75 to 0.25	–1.25 to 0.75		
<i>Near</i>					
UNVA (Jaeger)				n.a.	n.a.
Mean ± SD	8.46±4.38	n.a.	n.a.		
Range	0–13				
CNVA (Jaeger)					
Mean ± SD	2.33±1.76	1.09±0.38	1.27±0.72	<0.0001	0.5000
Range	0–10	1–3	1–4		
Bold type denotes significance. * <i>p</i> values of no more than 0.05 were considered statistically significant.					

Studie 2. Publikace – Simultánní korekce presbyopie a astigmatismu s novou multifokální torickou nitrooční čočkou, roční zkušenosti (*Simultaneous Presbyopia- and Astigmatism-correction with a Novel Trifocal Toric Intraocular Lens a One-year Follow-up*)

Simultánní korekce presbyopie a astigmatismu pomocí MF TIOL Liberty toric 677

Ve druhé studii jsme se zabývali současnou korekcí presbyopie a preformovaného rohovkového astigmatismu pomocí MF TIOL, jejíž hlavní konstrukce a opěrná plocha haptiků se shoduje s TIOL z předchozí studie, pouze na optické část je designován vzorec refrakčně-difrakční pro korekci presbyopie. Výhodou bylo, že jsme u dané konstrukce IOL měli ověřenou rotační stabilitu a výbornou predikci refrakčního výsledku, což nám skýtalo výhodu při volbě daného implantátu a následné biometrii. Z pooperačních výsledků jsme mohli konstatovat, že naše očekávání byla dosažena, IOL se jevila velmi stabilní, bez pooperačního rotování a taktéž predikce refrakce se neodchylovala od zavedeného standardu. Dohromady se jeví námi zvolené řešení, jako velmi efektivní a spolehlivé.

Při vyplnění dotazníku na běžné aktivity bylo 100% z respondentů bez obtíží vykonávat běžné venkovní aktivity. Pouze 7% uvádělo větší potíže z práce na počítači na standardní vzdálenost, při přiblížení na čtecí vzdálenost byli schopni pracovat bez větších potíží. Další naší zájmovou oblastí byly noční aktivity a zejména řízení v noci. 64,3% osob uvádělo, že čtení a práce na blízko za nízkých světelných podmínek je bez potíží, pouze 35,7% uvádělo mírné obtíže. Řízení byli schopni všichni, 42,9% bez obtíží, 28,6% pouze s mírnými potížemi a zbylých 28,6% se středními problémy. V souhrnu viz tab. se celková spokojenost projevila u převážné většiny pacientů, přes 80%. U zbytku vyšetřovaných byly celkové potíže do středního stupně, takže přínos operace hodnotili také velmi pozitivně.

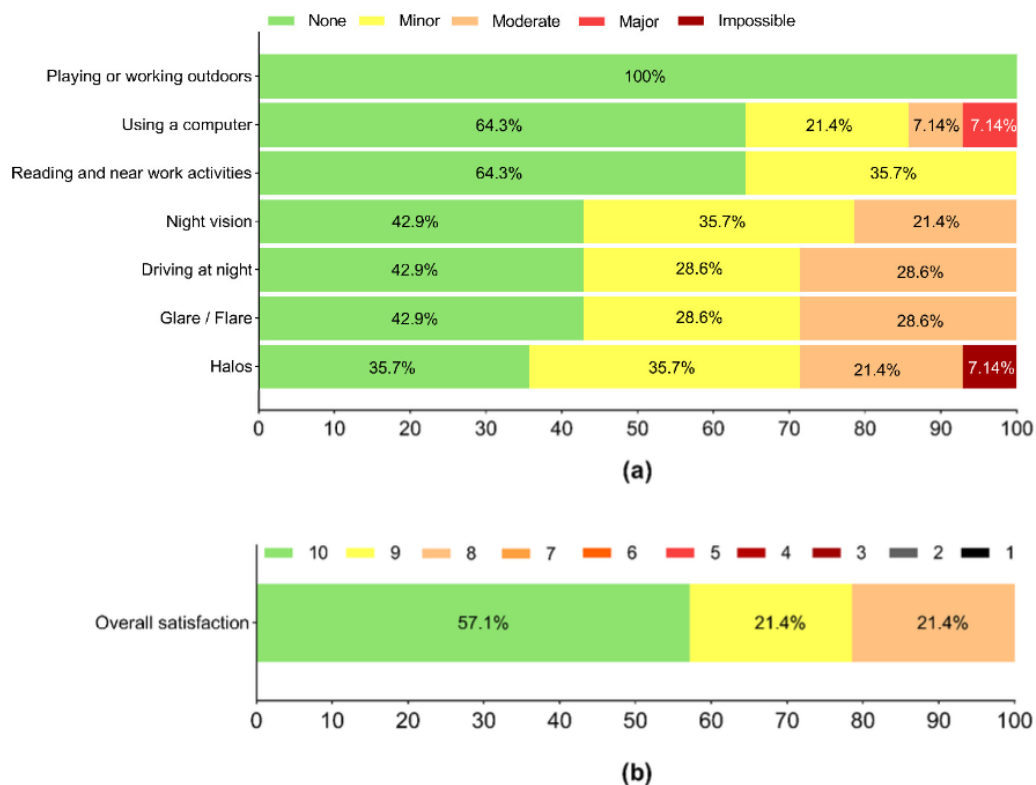


Figure 7. Visual function questionnaires reflected no or minor difficulties while performing general daily activities (a,b), and high patient satisfaction on a scale of 1 to 10 (1 = lowest satisfaction, 10 = highest satisfaction). Horizontal axes represent the percent (%) of patient responses, while colours represent the possible responses.

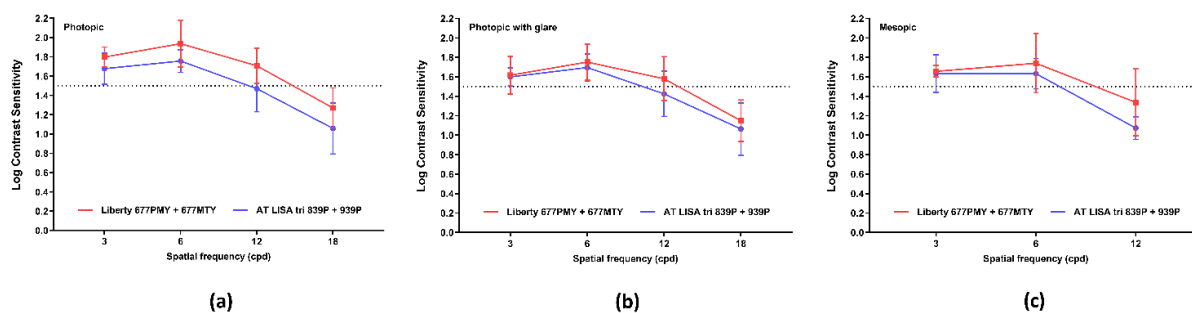
Obrázek 8. Dotazník zachycuje žádné mírné potíže v denním životě (a,b) a vysokou spokojenost pacientů ve škále 1 až 10 (1 = nejnižší spokojenost, 10 = nejvyšší spokojenost), horizontální osa reprezentuje (%) odpovědí pacientů, zatím co barevná škála označuje spokojenost

Studie 3 Publikace -Srovnání klinických výsledků zrakové kvality dvou presbyopii korigujících nitroočních čoček vyrobených ze stejného materiálu, ale s jiným designem optiky (*Comparison of Clinical Outcomes, Visual Quality and Visual Function of Two Presbyopia-Correcting Intraocular Lenses Made from the Same Material, but with Different Design and Optics*)

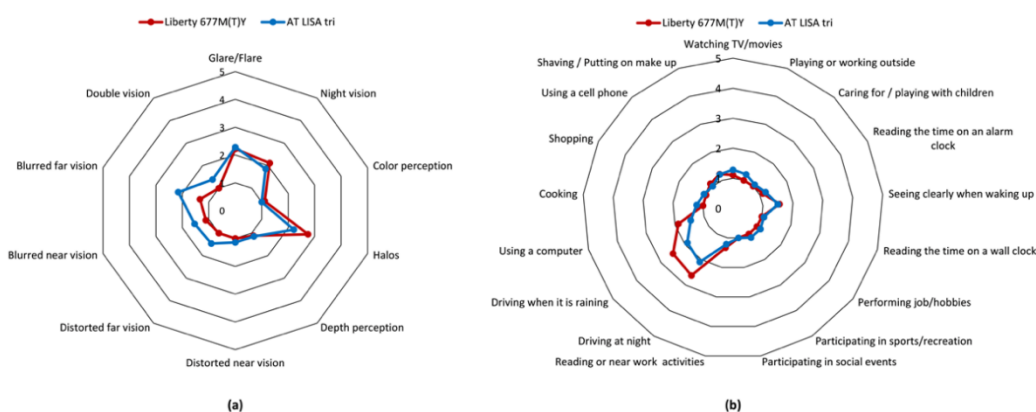
Z další naší studie týkající se srovnáním dvou designu MF IOL

Tato semiprospektivní paralelní, srovnávací studie testovala klinické výsledky kvality vidění, kontrastní citlivost, zrakové funkce, dysfotopsie, závislost na brýlích, celkovou spokojenost po unilaterální nebo bilaterální implantaci jedné, ze dvou presbyopii korigujících nitroočních čoček (Liberty® 677MY or AT LISA® tri 839M) u 28 pacientů (50 očí). Klinické výsledky byly posouzeny 3 a 12 měsíců pooperačně. Výsledky zrakové ostrosti odrážely refrakční výsledky. Obě IOL prokazovaly ostré vidění do dálky, na střední vzdálenost i na čtení, což korespondovalo s publikovanými daty (21-28). Tyto výsledky jsou nižší, než uváděl Serdiuk et al a Piovela et al. (21,22), ačkoli pozdější publikace uváděly lepší výsledky, týkající se binokulárního vizu (22). U 89% u Liberty očí vs 59% AT LISA očí dosahovalo refrakčně do plus/mínus 0,5D cílové emetropie. Refrakční stabilita byla prokázána u obou IOL. Vyšší proporce pacientů s Liberty bylo schopno dosáhnout nekorigované zrakové ostrosti 20/20 (UDVA: 56% vs 41%, UNVA 83% vs 66%). Zajímavostí je, že intermediální zraková ostrost byla měřena v naší studii na 66cm, zatímco v ostatních studiích byla měřena na 80 cm (21, 22, 28-30). KOSO byl komparativní u obou použitých IOL. Vyšší kontrastní citlivost byla dosažena u Liberty IOL 16,7% u Liberty, zatímco 40,6% u AT LISA tri očí vyžadovalo NdYAG capsulotomii během prvního roku po implantaci pro signifikantní zhoršení vizu. Zatímco obě čočky jsou vyrobeny ze stejného materiálu, rozdíl v klinických výsledcích PCO vyplývá z jiného designu a povrchu optické části u zkoumaných čoček.

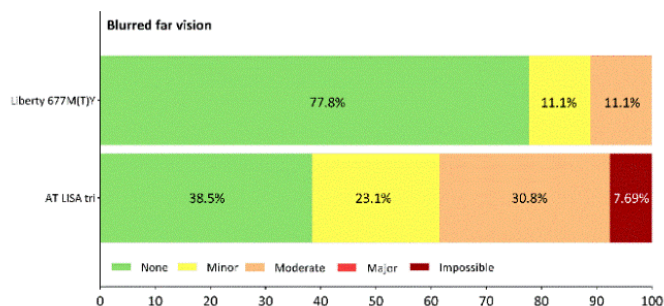
Z Praktického hlediska je důležitá kontrastní citlivost nejen za fotopických podmínek, ale rozhodující pro náročná povolání je kontrastní citlivost za mesopických podmínek. Z našich výsledků vyplývá lehký rozdíl mezi zkoumanými čočkami ve prospěch IOL s méně přechodovými zónami, nicméně u obou IOL je velmi stále na dobré úrovni viz Obr.9.



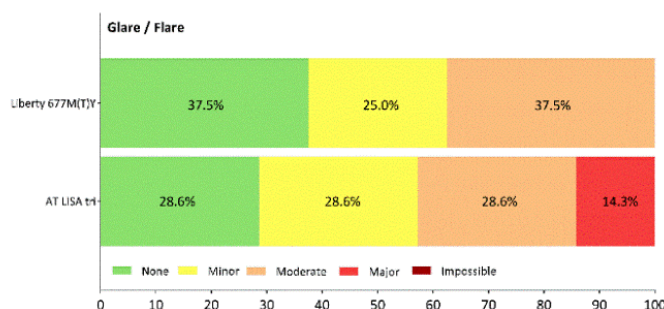
Obrázek 9. Graf Kontrastní citlivosti, měřena za různých světelných podmínek, 12 měsíců po operaci. (a) za fotopických podmínek. (b) za fotopických podmínek s glare (c) za mesopických podmínek



Obrázek 10. Graf odpovědí - Hlavní na (a) dysfotopisie a (b) posouzení zrakových funkcí použitím modifikovaného dotazníku 12 měsíců po operaci. 1= žádné potíže, 2 = minimální potíže, 3 = střední potíže, 4 = znatelné potíže, 5=nedokážu rozeznat- nedoprovází, žádné signifikantní rozdíly mezi oběma IOL nebyly zaznamenány

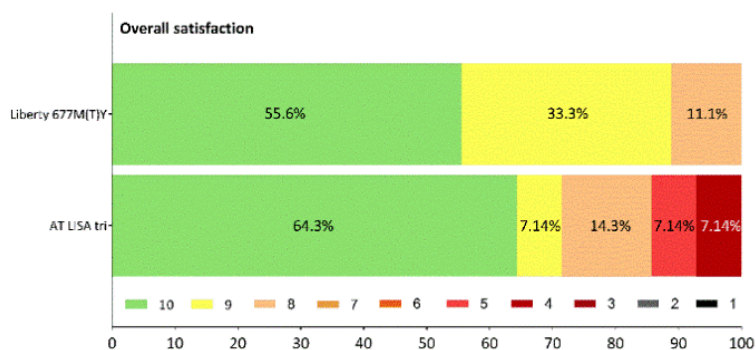


(a)



(b)

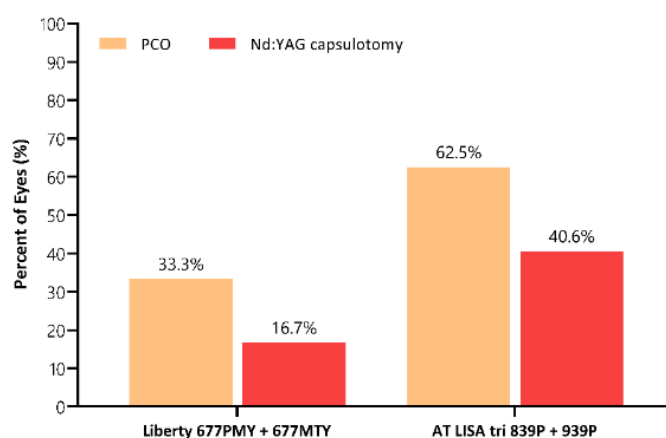
Obrázek 11. Distribuce odpovědí na dotazy položené pacientům na obtíže způsobující (a) zamlžené vidění, (b) glare/flare. Subjektivní hodnocení byl učiněn pomocí modifikovaného dotazníku (Visual Function Questionnaire form) 12 měsíců pooperačně



Obrázek 12. Celková spokojenost uváděná pacienty po implantaci IOL. Obě skupiny uváděly vysokou míru spokojenosti, přesto, že ve skupině AT LISA tri byly uváděny obtíže s větší variabilitou. 10 = nejvyšší stupeň v žebříčku, 1 = nejnižší stupeň v žebříčku

Z dotazníku, ve kterém jsme zohlednili nežádoucí zrakové obtíže vylývá, že obě zkoumané čočky měly i po 12 měsících sledovací doby minimální výskyt závažnějších rušivých fenoménů. Na druhou stranu drtivá většina pacientů byla schopna vykonávat většinu činností bez potíží jak denních Obr.12.

Výskyt PCO ovlivňující KOSO s následnou NdYAG capsulotomií je shrnut v grafu.



Obrázek 13. Graf procentuálního zastoupení očí, u kterých se musela provést NdYAG capsulotomie pro významnou opacifikaci zadního pouzdra, zhoršující zrakovou ostrost, Zastoupení NdYAG laserové capsulotomie v prvním pooperačním roce.

Studie 4. Publikace Simultánní bilaterální operace šedého zákalu v jedné době optimalizace parametrů ovlivňující subjektivní vnímání procedury (*Use of Simultaneous Bilateral Cataract Surgery (SBCS) to Optimize Parameters Affecting the Subjective Perception of the Procedure*)

Komentář:

Simultánní bilaterální operace katarakty (SBCS) je stále ještě relativně kontroverzní procedura. Hlavními riziky jsou oboustranná endoftalmitida nebo refrakční chyba. Na druhé straně SBCS má také nesporné výhody, jako je rychlejší zraková rehabilitace, nižší riziko nosokomiálních infekcí a nižší cena pro obě strany. Další výhodou, která nebyla zatím popsána v literatuře, je minimální rozdíl ve vnímání bolesti pacientem. V tomto ohledu hraje mnoho okolností, např. momentální rozpoložení pacienta, komunikace s pacientem a personálem, snížená anxiosita mezi procedurami. Z celkového nadhledu jak uvádějí pacienti, když už jsem tady, tak radost z první operace kompenzuje strach z druhé.

Ve studii bylo operováno 50 (100 očí) pacientů oboustranně, kteří byli operováni identicky na obou očích. Potom jsme vytvořili další skupinu 50 pacientů (100 očí) a postupně lehce měnili podmínky mezi první a druhou operací.

V první podskupině jsme měnili anestezii mezi operacemi. Na jenom oku byla jenom topická a na druhém oku jsme přidali k topické i Mydraine (Phenylephrine hydrchloridum, Tropicamidum, Lidocaicaini hydrochloridum).

V další podskupině (č.2) jsme měnili lehce iluminaci mezi operacemi, na jenom oku 40% a na druhém 80% intenzity na mikroskopu OPMI Lumera 700 (Carl Zeiss Medidac AG, Jena, Germany).

V následující skupině (č.3) jsme menili rozvěrač (oba typy Lieberman), jeden s uzavřevřenými staranicemi, druhý s otevřeními.

Ve 4. podskupině chirurg prováděl zadní kapsulorhexi na jednom oku, druhé ponechal bez.

V poslední 5. skupině chirurg komunikovat s pacientem během první operace celou dobu v maximální míře a během druhé minimálně.

Výsledky: V první skupině 50 pacientů (100 očí), kde byly operace provedeny za identických podmínek nebyly rozdíly statisticky významné. Z toho vyplývá, že dodržení stejných podmínek pacient nevnímá rozdíl mezi operacemi.

Tabulka. 2. Vnímání bolesti, tlaku, a glare v kontrolní podskupině (beze změn parametrů mezi operací pravého a levé oka).

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TABLE 2: Perception of pain, pressure, and glare in the control subgroup (without change of any parameter between the right and left eye): mean $\pm$ SD, median (min-max); p values of Wilcoxon signed-rank test between right and left eye.

Eye	Pain		Pressure		Glare	
	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)
Both eyes	0.72 $\pm$ 1.11	0 (0-5)	1.02 $\pm$ 0.85	1 (0-4)	1.12 $\pm$ 1.20	0 (0-4)
Right eye	0.70 $\pm$ 1.14	0 (0-5)	1.04 $\pm$ 0.92	1 (0-4)	1.10 $\pm$ 0.85	0 (0-4)
Left eye	0.74 $\pm$ 1.07	0 (0-5)	1.00 $\pm$ 0.77	1 (0-3)	1.14 $\pm$ 0.92	1 (0-4)
p value right vs. left		0.299		0.344		0.161

Tabulka 3. Porovnání vnímání doby zákroku oproti kontrolní skupině (beze změn parametrů mezi operací pravého a levého oka)

TABLE 3: Comparison of perception of time of surgery in the control subgroup (without change of any parameter between right and left eye): mean $\pm$ SD; p values of paired t -test between right and left eye and between real and subjectively perceived time.

Eye	Real time (sec)	Subjectively perceived time (sec)	p value real vs. perceived
	Mean $\pm$ SD	Mean $\pm$ SD	
Both eyes	261.62 $\pm$ 74.79	255.90 $\pm$ 131.20	0.686
Right eye	260.76 $\pm$ 65.48	258.26 $\pm$ 124.98	0.903
Left eye	262.48 $\pm$ 83.81	253.54 $\pm$ 138.49	0.484
p value right vs. left	0.913	0.864	

V dalších podskupinách, kde jsme měnili parametry mezi očima jsme také nezaznamenali statisticky významné rozdíly, kromě jednoho parametru a tím byla skupina s topickou anestezii v.s. topickou a intrakamerální, kde nižší obtíže vykazovala skupina s kombinovanou anestezii.

První zmínka v literatuře o SBCS byla v roce 1952 (14), kde tento postup použit u ICCE procedury. Od té doby jsme se přesunuli k mikroincisní chirurgii s fakoemulzifikací (10), která je mnohem bezpečnější a předvídatelnější. Riziko náhlého úmrtí během druhé celkové anestezie výrazně převyšuje případnou oboustrannou slepotu díky významným komplikacím (6), navíc dnes operace provádíme v lokální anestezii. Předchozí studie uvádějí, že bolestivost druhé operace vztažené k první je vyšší (15_16). Yu et al. Publikoval výsledky u 127 pacientů, kde byl interval mezi operacemi cca 1. měsíc.

Tabulka 4. porovnání vnímání bolesti, tlaku a glare s jednotlivých podskupinách

TABLE 4: Comparison of perception of pain, pressure, and glare between eyes with and without changing parameters of surgery in 5 subgroups: mean $\pm$ SD, median (min-max); *p* values of Wilcoxon signed-rank test.

Subgroup	Pain		Pressure		Glare	
	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)
<i>(1) Anesthesia</i>						
Only topic	0.44 $\pm$ 0.81	0 (0-3)	0.60 $\pm$ 0.70	0 (0-3)	0.62 $\pm$ 1.01	0 (0-3)
Intracameral	0.32 $\pm$ 0.71	0 (0-3)	0.52 $\pm$ 0.58	0 (0-2)	0.62 $\pm$ 1.05	0 (0-4)
<i>p</i> value topic vs. intr.		0.032*		0.351		1.000
<i>(2) Light intensity</i>						
40%	0.80 $\pm$ 1.50	0 (0-7)	0.88 $\pm$ 0.96	0 (0-3)	0.82 $\pm$ 1.10	0 (0-4)
80%	0.92 $\pm$ 1.83	0 (0-10)	0.82 $\pm$ 1.02	0.5 (0-4)	0.86 $\pm$ 1.11	0.5 (0-4)
<i>p</i> value 40% vs. 80%		0.444		0.537		0.598
<i>(3) Speculums</i>						
Solid	0.49 $\pm$ 0.83	0 (0-3)	0.57 $\pm$ 0.67	0 (0-2)	0.67 $\pm$ 1.09	0 (0-4)
Wire	0.50 $\pm$ 0.73	0 (0-2)	0.47 $\pm$ 0.58	0 (0-2)	0.61 $\pm$ 1.06	0 (0-4)
<i>p</i> value solid vs. wire		0.837		0.301		0.083
<i>(4) PPCCC</i>						
Intact	0.50 $\pm$ 1.28	0 (0-6)	0.90 $\pm$ 0.93	1 (0-3)	0.78 $\pm$ 1.13	0 (0-3)
PPCCC	0.46 $\pm$ 1.05	0 (0-8)	0.94 $\pm$ 0.91	1 (0-3)	0.72 $\pm$ 0.99	0 (0-4)
<i>p</i> value intact vs. PPCCC		0.659		0.699		0.444
<i>(5) Communication</i>						
No	1.18 $\pm$ 1.85	0 (0-7)	1.00 $\pm$ 1.18	1 (0-4)	1.30 $\pm$ 1.25	1 (0-4)
Speaking	1.16 $\pm$ 1.844	0 (0-10)	1.00 $\pm$ 1.16	1 (0-4)	1.30 $\pm$ 1.27	1 (0-4)
<i>p</i> value no vs. speaking		0.932		1.000		1.000

*Statistically significant results are marked in bold.

Evaluation of Astigmatism-Correcting Efficiency and Rotational Stability after Cataract Surgery with a Double-Loop Haptic Toric Intraocular Lens: A 1-Year Follow-Up

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Keywords

Intraocular lens · Astigmatism correction · Toric lens · Cataract · Rotational stability

Abstract

Objectives: The aim of this study was to assess the clinical outcomes, predictability of results, efficiency of astigmatism correction, and rotational stability of the Bi-Flex 677TAY (Medicontur Medical Engineering Ltd., Zsámbék, Hungary) monofocal toric intraocular lens (IOL) designed for cataract patients with astigmatism. **Methods:** The IOLs were implanted either mono- or binocularly, following routine cataract surgery. Visual and refractive outcomes, as well as off-axis rotation were assessed throughout a 1-year follow-up period. All clinical data for this work were collected retrospectively. Vector analysis based on the Alpins method was performed to assess the efficiency of astigmatism correction. **Results:** No complications or adverse events occurred during surgery or the follow-up period. IOL implantation brought 88% of eyes into the ± 0.50 D, and 100% into the ± 1.00 D range compared to the target spherical equivalent refraction, emmetropia. Astigmatism correction brought

similar results: 94% of eyes had a residual cylindrical error of not higher than ± 0.50 D, and 97% were within ± 1.00 D. Vector analysis resulted in a correction index of 0.96 and a difference vector of 0.17. Both refractive and visual outcomes showed long-term stability. During the 12-month follow-up period, no eyes had a rotation of $>5^\circ$. Absolute rotation after 1 year was $1.42 \pm 1.89^\circ$ (median = 0°), while signed rotation was $1.06 \pm 2.12^\circ$ (median = 0°). **Conclusion:** The Bi-Flex 677TAY monofocal toric IOL, designed by Medicontur Medical Engineering Ltd., represents an efficient and safe solution for cataract patients with astigmatism. Clinical and refractive outcomes are predictable, and rotational stability ensures long-term visual comfort.

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Introduction

In recent years, cataract surgery has evolved from the simple removal and replacement of the opaque crystalline lens to high-precision refractive surgery to avoid further vision correction [1]. Ferrer-Blasco et al. [2], in their

study that included 4,540 eyes, reported that a remarkable 87% of cataract patients had preoperative astigmatism. In a recent study of 13,012 eyes (i.e., of 6,506 cataract patients), it was reported that 43.5% of the eyes had a corneal astigmatism of at least 1.00 diopters (D), which has been shown to have an adverse effect on the best achievable surgical outcome, and is enough to significantly reduce both visual acuity and the quality of postoperative vision when left untreated [3].

In recent years, several toric intraocular lenses (IOLs) have been introduced onto the market that are all designed to efficiently correct preoperative astigmatism. An effective toric IOL is characterized by a high level of astigmatism-correcting ability (meaning that the refractive outcomes are as close as possible to the intended postoperative spherical and cylindrical refraction), high predictability of the refractive and visual outcomes, and excellent rotational stability which prevents the loss of astigmatism correction as a result of off-axis rotation of the lens.

Apart from the latest IOL models designed with high precision, numerous state-of-the-art measurement devices, and the latest advanced calculation formulas that take the results of several biometrical parameters into consideration, sometimes even integrating (or modeling) the astigmatism of the posterior corneal surface, are available [4, 5]. Precise IOL alignment is a further component contributing to the eventual success rate of surgical astigmatism correction [6].

Based on a literature search for the clinical outcomes following the implantation of the toric IOLs, we realized that the majority of papers published results after a follow-up period of ≤ 6 months [7–13]. The stability of the refractive and visual results over longer periods of time and of the IOL position are also very important, however. Only a small number of studies have been published on the Bi-Flex 677TA(Y) monofocal, toric, capsular-bag IOL [14, 15]. The purpose of this investigation was to assess the long-term efficacy and stability of the abovementioned toric lens. Our retrospective evaluation was complemented with a vector analysis based on the Alpíns method; it is expected that this will provide a more accurate assessment of the astigmatism-correcting ability of the IOL in question.

Materials and Methods

Patient Population

This retrospective, noncomparative, one-site, one-surgeon, one-lens, clinical investigation involved 35 eyes (of 22 cataract patients), all of which had preoperative corneal astigmatism repre-

senting an indication for the implantation of an astigmatism-correcting IOL following removal of the cataractous crystalline lens. The pre- and postoperative records of patients receiving mono- or binocular surgery performed by the same experienced surgeon (L.V.N.) between April 2017 and February 2019 were collected and evaluated. The data management and the clinical study adhered to the principles of the Declaration of Helsinki [16].

The subset of patients included in the assessments was selected carefully. Subjects with congenital eye disease, previous corneal laser refractive surgery, amblyopia, uveitis, eye trauma, and/or other corneal or intraocular pathologies were not included in the further assessment.

Pre- and Postoperative Assessment

Prior to surgery, a detailed ocular examination was performed including corneal topography, aberrometry (TRK-2P, Topcon Europe Medical B.V., Capelle aan den IJssel, The Netherlands), anterior-segment examination (Oculus Pentacam 70700, OCULUS Optikgeräte GmbH, Wetzlar, Germany), posterior-segment examination with a slit lamp (SL-D4, Topcon Europe Medical B.V.), and optical biometrics including axial length (AXL), anterior-chamber depth (ACD), keratometry (K1, K2), and white-to-white measurements (IOL Master 700, Carl Zeiss Meditec AG, Jena, Germany). Intraocular pressure was also measured in all cases. Monocular distance visual acuity (both uncorrected [UDVA] and corrected [CDVA]) was assessed by using the SC-1600 Snellen Chart optotypes (Nidek Co., Ltd., Tokyo, Japan), while corrected near vision (CNVA) was measured with the Jaeger reading card.

The same measurements were repeated with the same protocols at 1 day, 1 week, 1, 2, and 3 months, and then 1 year postoperatively. The surgical position of the implanted toric IOL was determined and documented by slit-lamp examination during surgery and at each postoperative visit, with measurement performed in artificial mydriasis (slit lamp SL 120 with SL imaging module, Carl Zeiss Meditec AG).

All pre- and postoperative measurements were performed by the same person (M.N.).

Rotational stability was evaluated by comparing the position of the IOL at each postoperative visit to the intended torus position (surgical position). The mean absolute rotation (focusing only on the degree of rotation) and signed rotation (rotation clockwise was counted as a negative and counter-clockwise as a positive rotation) were also determined. Rotation between the intended torus position and the first postoperative visit on day 1 was regarded as misalignment, and between day 1 and the following visits as toric IOL rotation.

The efficiency of astigmatism correction was evaluated with the VectrAK vector analysis software (ASSORT Pty. Ltd., Cheltenham, VIC, Australia) based on the Alpíns method [17, 18]. The analysis is described in detail in the “Vector Analysis” section.

Bi-Flex 677TA(Y)

The Bi-Flex 677TA(Y) monofocal, toric IOL (Medicontur Medical Engineering Ltd., Zsámbék, Hungary) has an overall diameter of 13.0 mm and an optic diameter of 6.0 mm. The optic is connected to the haptics without haptic angulation (Fig. 1). The double-loop haptic design ensures a large contact angle ($2 \times 88.8^\circ$) with the wall of the capsular bag [19]. The single-piece IOL is manufactured from a hydrophilic acrylic copolymer with a final water content of 25% and a refractive index of 1.46 measured at 23 °C

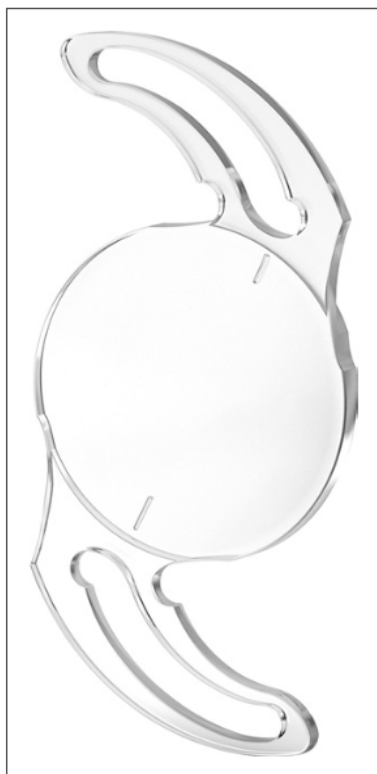


Fig. 1. The Bi-Flex 677 monofocal toric IOL is available as transparent (677TA) and with a blue-light filter (677TAY).

(Abbe No. 58). All lenses include a UV-absorber, while a blue-light filter is optional and depends on the model chosen (677TA represents the transparent model and 677TAY represents the yellow model). The IOL is aspheric with neutral asphericity and has a patented special 360° square edge to inhibit the migration of lens epithelial cells and consequently prevent the development of posterior-capsule opacification (PCO). The torus is marked with 2 marks indicating the flat axis on the edge of the optic. The lens is available in cylindrical powers of +1.0 to +10.0 D (IOLs outside of this range are produced on request).

In each case, spherical equivalent (SEQ), cylindrical power (CYL), and the correct position of the optimal IOL chosen for implantation were determined using the online IOL calculator of the manufacturer [20]. All eyes were targeted to emmetropia, and the surgically induced astigmatism (SIA) of the surgeon was also taken into consideration. Calculations were performed using the Haigis formula [21], while the Abulafia-Koch correction recommended by the manufacturer was not applied [5], as posterior corneal astigmatism had already been taken into account by the IOL Master 700 optical biometer.

Surgical Technique

Under local anesthesia and following pupil dilation, a 2.2-mm, clear corneal incision was made in each case at the position recommended by the IOL calculator, and the anterior chamber was filled with viscoelastic material (Visco-MC 2%, Medicontur Ltd.; Eye Gel Plus 2.4%, Kosmetik Konzept KOKO GmbH, Leichlingen, Germany; or Hydromel 2.5%, Unimed Pharma spol. sro., Bratislava, Slovakia). Circular curvilinear capsulorhexis was performed, and the opaque crystalline lens was removed by phacoemulsification in all cases. The tested IOLs were folded and implanted with the MedJet B1B or MA 2.2 injector (Medicontur Ltd.). In-the-bag implantation with sutureless wound closure was performed in all cases. After the implantation and the removal of the ophthalmic viscosurgical device, the IOL was rotated to its final position by accurately aligning the toric reference marking of the IOL, according to the markerless toric IOL alignment tool of the Callisto eye system (Carl Zeiss Meditec AG).

Antibiotic and antimicrobial eye drops were administered intraoperatively in each case to reduce the risk of surgical infection, while antibiotic and anti-inflammatory eye drops were administered postoperatively.

In the case of binocular implantation, a 1-week interval was maintained between the 2 surgeries.

Vector Analysis

Vector analysis and graphical displays were performed using the Alpins method [17, 18], facilitated by the VECTrAK astigmatism analysis program v2.4.6 (ASSORT Pty., Ltd.). Analysis was performed according to the protocol previously described by Bacherneegg et al. [15]; briefly, based on manifest refraction and topographic astigmatism, astigmatism to the corneal plane was calculated in each case, and preoperative values were compared to the results measured 12 months postoperatively.

Three fundamental vectors and the relationship among them were examined. These are the target-induced astigmatism vector (TIA), the surgically induced astigmatism vector (SIA), and the difference vector (DV) [17, 18].

TIA represents the astigmatic change (by magnitude and axis) the surgery was intended to induce, so the actual measured preoperative corneal topographic astigmatism was used. SIA refers to the astigmatic change (by magnitude and axis) that the surgery actually induced. The SIA is a quantity calculated by subtracting the phacoemulsification-adjusted preoperative corneal astigmatism from the postoperative refractive cylinder calculated to the corneal plane. Based on these 2 vectors, the correction index (CI) can be determined. The CI is calculated by dividing SIA by TIA. The CI value is preferably 1.0. It is >1.0 if overcorrection occurs and <1.0 if there is undercorrection.

The induced astigmatic change (by magnitude and axis) that enables the initial surgery to achieve its intended target is described by the third fundamental vector, the DV. The DV is the actual measured postoperative refraction remaining after treatment. It is an absolute measure of success and is preferably zero.

The cumulative histogram of the magnitudes of the preoperative corneal astigmatism and postoperative refractive astigmatism at the corneal plane, and the double-angle plots of preoperative and postoperative refractive astigmatism (including centroid values with SDs and 95% confidence ellipses of the dataset and of the centroid values) were plotted according to the method presented by Abulafia et al. [22].

Statistical Analysis

All data were collected in Microsoft Excel (Microsoft Inc., Redmond, WA, USA), and later evaluated using GraphPad Prism v8.3.0 software (GraphPad Software Inc., San Diego, CA, USA). All pre- and postoperative data collected during the study are available after deidentification from the Mendeley Data depository database (DOI: 10.17632/r2v99nw7vg.2) [23].

Pre- and post-operative data on 22 patients (35 eyes) were included in the analyses. Descriptive statistics (mean, SD, median, minimum, maximum, and 95% confidence ellipse) were calculated in all cases. All variables were tested for normal distribution using the D'Agostino and Pearson test. Depending on the results, comparisons between matching pre- and postoperative variables were performed using either the paired two-tailed *t* test (in the case of normal distribution) or the Mann-Whitney U test (when a non-parametric test was required). Visual and refractive outcomes are presented according to the standards for reporting refractive outcomes of IOL-based refractive surgery published recently by Reinsteins et al. [24]. The stability of refractive outcomes was also assessed during the follow-up period.

Results are presented as mean $\pm$ SD along with the range defined by the minimum and maximum values in brackets in the case of each analysis. $p \leq 0.05$ were considered to be statistically significant in all cases.

Results

This retrospective study evaluates the visual and refractive characteristics of 35 eyes of 22 astigmatic cataract patients preoperatively, and then after cataract surgery that included the implantation of the toric Bi-Flex 677TA(Y) IOL. Apart from the assessment of visual improvement and the correction of refractive errors, the rotational stability of the lens and the efficacy of astigmatism correction using vector analysis were also determined.

Table 1 presents the characteristics of the study population. Only subjects diagnosed with normal ocular conditions during biomicroscopy or funduscopy examinations were included in the analyses.

The mean spherical equivalent of the implanted IOLs was 22.2 ± 2.52 D (16.0 D; 27.5 D), while the mean cylindrical power of the lenses was 1.70 ± 0.86 D (1.0 D; 3.75 D).

No IOL-related complications could be detected during surgery in any of the cases. Intraocular pressure (IOP) remained in the normal range (<20 mm Hg) during and following the operation (15.6 ± 3.05 mm Hg preoperatively; 15.7 ± 2.66 mm Hg at day 1, and 14.6 ± 2.72 mm Hg 12 months after surgery). On the first postoperative day, 1 eye showed symptoms of inflammation characterized by anterior-chamber cells (grade 3+) and flare, and 9 eyes had developed slight corneal edema, but these con-

Table 1. Demographic and preoperative characteristics of the study population

Gender	
Female	14 (63.6)
Male	8 (36.4)
Age, years	66.7 ± 5.4 (50–74)
AXL, mm	23.22 ± 1.20 (21.22–25.92)
ACD, mm	2.94 ± 0.49 (1.85–4.03)
K1, D	42.74 ± 1.93 (40.14–47.14)
K2, D	44.53 ± 1.91 (41.13–48.73)
CYL, D	-1.54 ± 1.23 (–4.50 to –1.50)
SEQ, D	0.46 ± 2.61 (–6.75 to +5.13)
UDVA (decimal)	0.32 ± 0.18 (0.01–0.60)
BDVA (decimal)	0.65 ± 0.19 (0.15–1.00)
UNVA (Jaeger lines)	8.46 ± 4.38 (0.00–13.0)
BNVA (Jaeger lines)	2.33 ± 1.76 (0.00–10.00)
IOP, mm Hg	15.7 ± 3.07 (10.0–25.0)

Values are expressed as mean $\pm$ SD (range) or *n* (%).

ditions had cleared up by the second postoperative week in all the affected cases. No further abnormalities that could have correlated directly with the surgery or the IOL itself could be revealed during the 12-month follow-up period. During the 3-month postoperative visit, 1 patient was diagnosed with binocular dry-type age-related macular degeneration (AMD), but her visual acuity and refractive values did not reflect her retinal condition. By the end of the first postoperative year, 1 patient implanted monocularly with the toric IOL developed an epiretinal membrane, which resulted in a significant deterioration of her vision; she was thus excluded from the evaluation of the 12-month results. One other patient moved abroad during the follow-up period and was lost to follow-up. PCO was detected in 9 eyes in the course of the 12-month follow-up.

Visual Outcomes

A significant improvement was achieved in both monocular UDVA and CDVA compared to the preoperative values (Table 2). Figure 2 demonstrates that all eyes had a Snellen visual acuity of at least 20/25 (Fig. 2a), and that most of the eyes achieved the best possible visual acuity (UDVA was the same or better than CDVA in 90.9% of the cases; Fig. 2b). The results were shown to be stable over time, with no remarkable differences found between those obtained 3 months and 1 year after surgery (Table 2; Fig. 2c, d).

As a consequence of cylindrical correction, a significant increase in corrected near visual acuity could be also

Table 2. Visual acuity, required spherical and cylindrical correction, and differences between the pre- and postoperative measurements after the implantation of the Bi-Flex 677TA(Y) astigmatism-correcting IOL

Correction	Preoperative	Postoperative (at 3 months)	Postoperative (at 12 months)	<i>p</i> value preop vs. M3*	<i>p</i> value M3 vs. M12*
<i>Distance</i>					
UDVA, D					
Mean ± SD	0.32±0.18	0.92±0.08	0.93±0.13	<0.0001	0.0339
Range	0.01–0.60	0.80–1.00	0.50–1.00		
CDVA, D					
Mean ± SD	0.65±0.19	0.97±0.06	0.96±0.08	<0.0001	0.9146
Range	0.15–1.00	0.80–1.00	0.70–1.00		
SPH, D					
Mean ± SD	0.61±2.23	−0.10±0.19	0.01±0.29	0.0396	0.0337
Range	−4.0 to +5.00	−0.50 to +0.25	−0.75 to +0.75		
CYL, D					
Mean ± SD	−1.02±1.10	−0.19±0.29	−0.17±0.31	<0.0001	0.6563
Range	−3.75 to +1.00	−1.00 to 0.00	−1.00 to 0.00		
SEQ, D					
Mean ± SD	0.10±2.25	−0.19±0.30	−0.08±0.41	0.1739	0.0557
Range	−4.50 to +4.88	−0.75 to 0.25	−1.25 to 0.75		
<i>Near</i>					
UNVA (Jaeger)				n.a.	n.a.
Mean ± SD	8.46±4.38	n.a.	n.a.		
Range	0–13				
CNVA (Jaeger)					
Mean ± SD	2.33±1.76	1.09±0.38	1.27±0.72	<0.0001	0.5000
Range	0–10	1–3	1–4		

Bold type denotes significance. * *p* values of no more than 0.05 were considered statistically significant.

observed ($p < 0.0001$; Table 2). Three months postoperatively, all patients were able to read at least line 2 on the Jaeger reading chart, and the results did not change significantly up to the end of the first postoperative year ($p = 0.5000$; Fig. 3a, b).

Refractive Outcome Predictability

Before the cataract surgery and implantation of the toric IOL, only 31.4% of eyes had a spherical equivalent refraction of no more than 0.5 D, and 42.9% of eyes were within 1.0 D from emmetropia. Three months postoperatively, 87.9% of eyes were detected to be within 0.5 D, and all (100%) were within 1.0 D (Fig. 4a). Cylindrical correction was found to be similarly effective. While only 40% of eyes had a refractive cylinder of no more than 0.5 D, and 62.9% of eyes were within 1.0 D according to the preoperative measurements, surgery brought about a significant increase in their cylindrical correction; 94% were found to be within 0.5 D, and 100% of the eyes were within the 1.0 D range (Fig. 4b). In the majority of the cases, these refractive outcomes remained stable during the first

postoperative year (Fig. 4c, d). The preoperative estimation of refractive outcomes was shown to be highly predictable; the mean error in residual refraction (achieved values vs. preoperative estimations) was -0.12 ± 0.33 (-0.66 to 0.72) diopters in the case of SEQ, and 0.18 ± 0.31 (-0.55 to 0.77) diopters in the case of CYL.

Surgery and the implantation of a toric IOL brought a significant improvement in the manifest spherical and cylindrical refraction of the eyes. Table 2 presents the refractive results measured 3 and 12 months postoperatively; these refractive outcomes had already actually been achieved immediately after implantation of the toric lens. Comparing the residual refraction values (SEQ and CYL) at each postoperative visit, the results proved to be stable over time, with no significant changes observed (Table 2).

Vector Analysis

The efficiency of the Bi-Flex 677TA(Y) toric lens in correcting corneal astigmatism was examined in detail using vector analysis based on the Alpins method [17, 18]. Figure 5 shows the cumulative histogram of the magni-

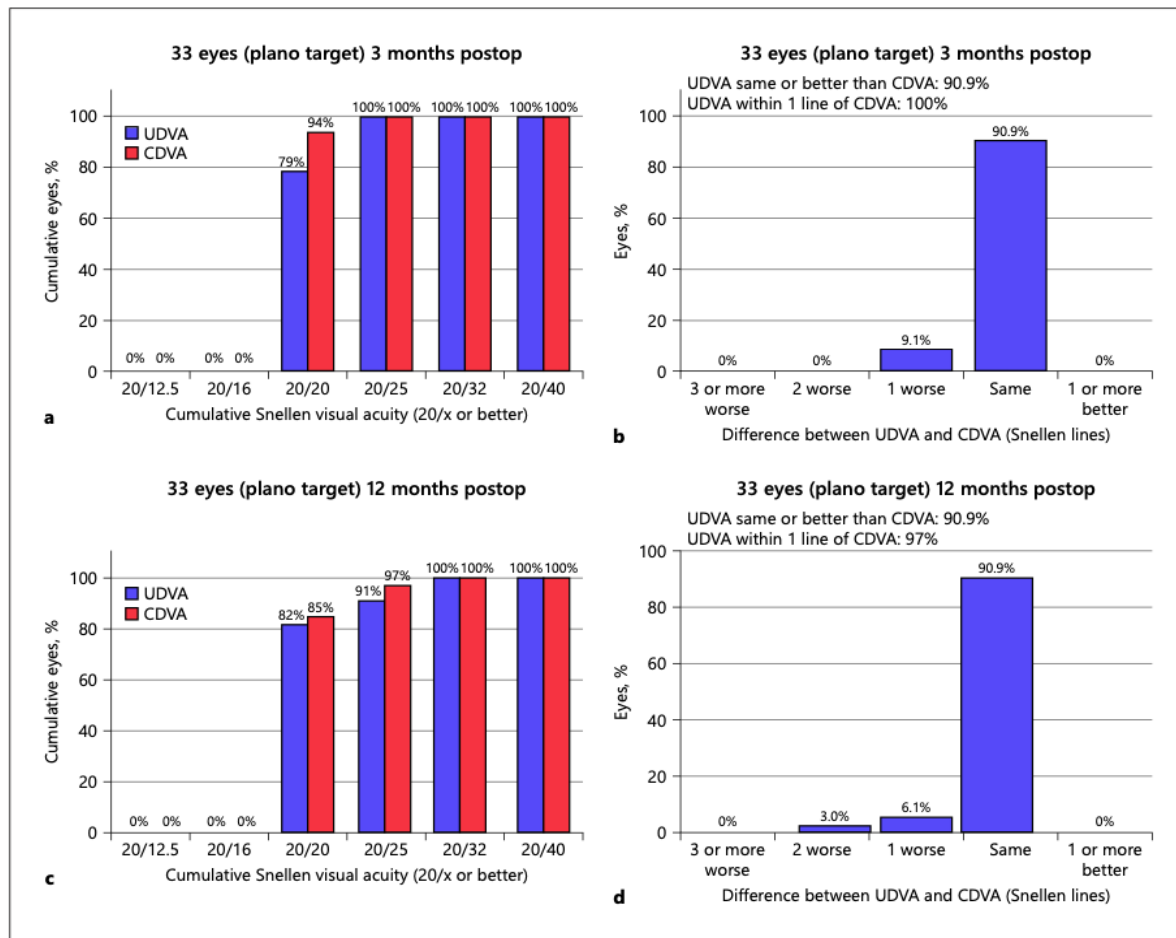


Fig. 2. a, c Cumulative histograms of uncorrected and corrected distance visual acuity measured 3 and 12 months postoperatively. **b, d** Results are similar at both postoperative visits. Uncorrected visual acuity is close to the best possible values.

tudes of preoperative corneal astigmatism and postoperative refractive astigmatism at the corneal plane. The double-angle plots of pre- and postoperative refractive astigmatism (including centroid values with SDs and 95% confidence ellipses of the dataset and of the centroid values) are plotted in Figure 6. From the preoperative mean absolute corneal astigmatism of 2.04 ± 1.02 D, refractive astigmatism decreased to a mean of 0.17 ± 0.31 D 12 months postoperatively.

Vector analysis could be performed with the pre- and postoperative data of 24 eyes. Postoperative measure-

ments were performed 1 year postoperatively. The fundamental vectors of astigmatism (TIA and SIA), and their relationships (DV and CI) are presented in Figure 7a–d, respectively. TIA had an arithmetic mean of 1.5 D, and the vector mean was 1.01 D Ax 2° (Fig. 7a). SIA was similar, having an arithmetic mean of 1.45 D and a vector mean of 0.95 D Ax 5° (Fig. 7b). These similar values resulted in a low DV of 0.17 D (vector mean: 0.09 D Ax 158° ; Fig. 7c), which is close to the optimal DV value of zero. Reflecting the DV, the CI was shown to be high; the arithmetic mean was 0.96 (Fig. 7d). This is close to the optimal

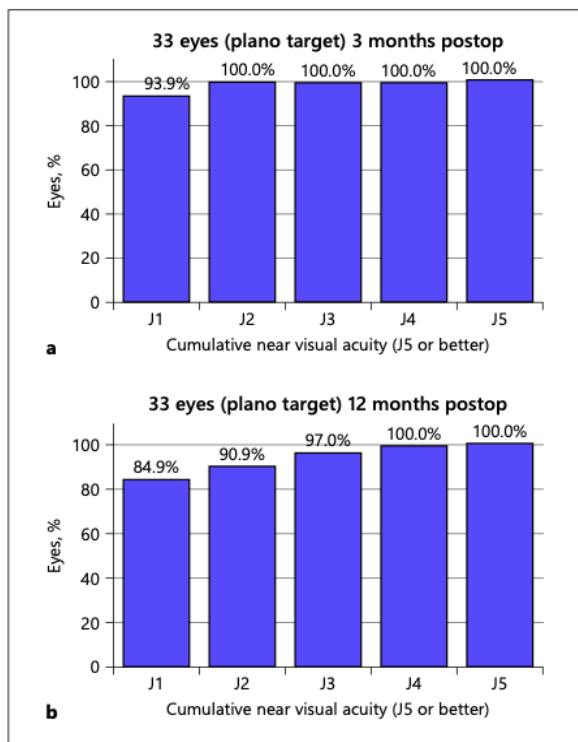


Fig. 3. a, b Cumulative histograms of corrected near visual acuity measured 3 and 12 months postoperatively with the Jaeger reading card are similar ($p = 0.500$).

1.00 value but shows a slight undercorrection of astigmatism.

Rotational Stability of the IOL

Rotational stability of the lens was examined according to the conventional method, i.e., comparing the position of the IOL at each postoperative visit to the intended (surgical) position of the lens. In the first 24 h after surgery, only an average rotation of $0.57^\circ \pm 2.19^\circ$ could be observed, and there was no need for repositioning in any of the cases. Based on this, it can be stated that there was no misalignment in any cases. Further rotations are presented in Table 3. In the case of signed rotation, clockwise rotation was counted as a negative rotation and counter-clockwise rotation as a positive rotation. Absolute rotation disregards the direction of rotation, taking only the magnitude of the rotation into consideration. A rotation of $>5^\circ$ in any direction could not be observed in any of the

Table 3. Rotational stability compared to the surgical position of the implanted IOL throughout the 12-month follow-up period

Follow-up visit	Signed	Absolute
Day 1	0.63 ± 2.18	1.37 ± 1.80
Day 7	0.74 ± 2.63	1.84 ± 2.00
Month 1	0.54 ± 2.54	1.63 ± 1.90
Month 3	0.91 ± 2.67	1.88 ± 2.09
Month 12	1.06 ± 2.12	1.42 ± 1.89

Results are presented as mean $\pm$ SD, and expressed in degrees ($^\circ$).

cases, with all IOLs (100%) remaining within 5° relative to the intended IOL position during the entire follow-up period.

Discussion

The aim of our retrospective data collection was to assess the visual and refractive outcomes, and efficacy of the astigmatism correction as well as evaluate the refraction and rotational stability of the clinical results after the implantation of the Bi-Flex 677TA(Y) monofocal, toric, capsular-bag IOL. Only a limited number of publications are available on this particular lens [14, 15], and only 1 presents results obtained during a longer follow-up period (12 months) [15]. Hardly any studies are available that include postoperative monitoring for longer than 3 months, with most publications on astigmatism-correcting IOLs presenting their results after ≤ 3 months of follow-up. Nevertheless, it is of major importance to increase knowledge on the long-term stability of all (toric) lenses, as rotation is known to reduce the astigmatism-correcting potential of the IOL [25], and uncorrected or inappropriate correction of astigmatism results in decreased vision [26].

Our evaluation of pre- and postoperative data collected during the first postoperative year after the implantation in 35 eyes (of 22 astigmatic cataract patients) of the Bi-Flex 677TA(Y) monofocal, toric IOL revealed that this lens is safe and highly efficient in correcting both spherical and cylindrical errors. Excellent UDVA was measured at each follow-up visit (this study shows data from the 3-month and 12-month follow-up visits only). Mean UDVA at 12 months was 0.93 ± 0.13 (decimal). This is comparable to the results published by Bachernegg et al. [15] for the same lens (UDVA = 0.06 ± 0.16 ; logMAR), and is even superior to the results published about other

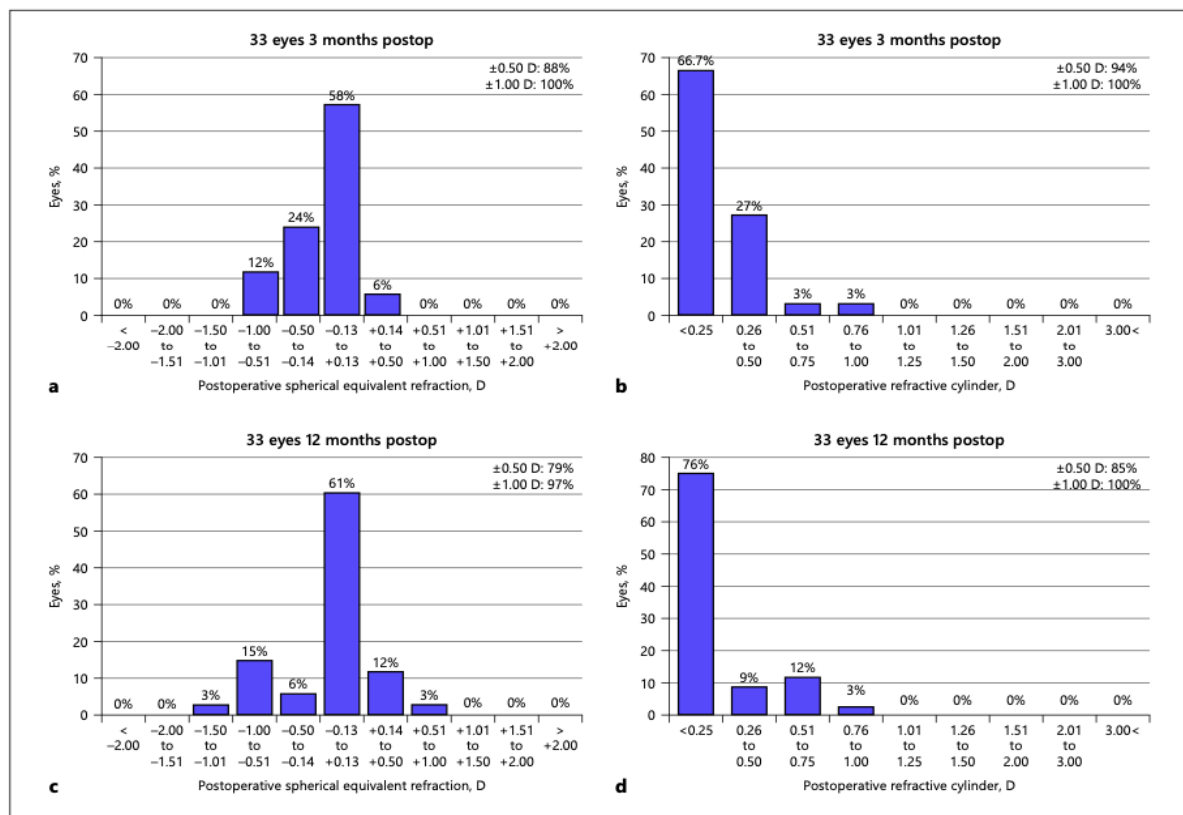
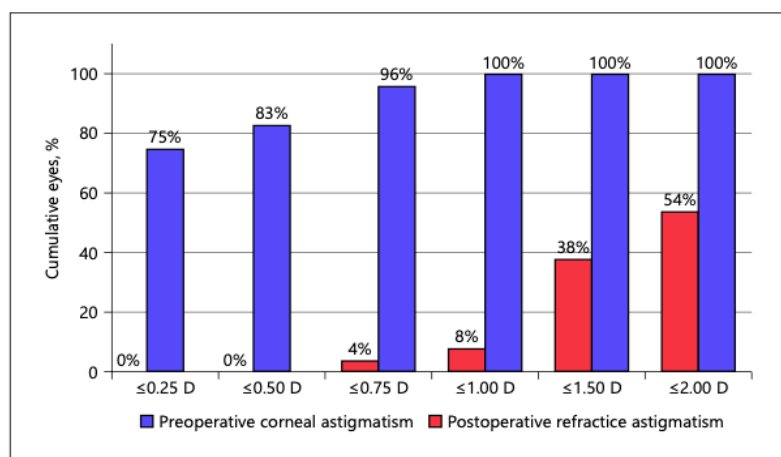


Fig. 4. Postoperative spherical equivalent refractions (SEQ) and residual cylindrical refractions (CYL) show stability over time. Results are close to the target refraction, emmetropia. **a** SEQ 3 months postop. **b** CYL 3 months postop. **c** SEQ 12 months postop. **d** CYL 12 months postop.

Fig. 5. Cumulative histogram of the magnitudes of preoperative corneal astigmatism and refractive astigmatism measured 12 months postoperatively at the corneal plane shows efficient astigmatism correction achieved by the Bi-Flex 677TA(Y) IOL after cataract surgery.



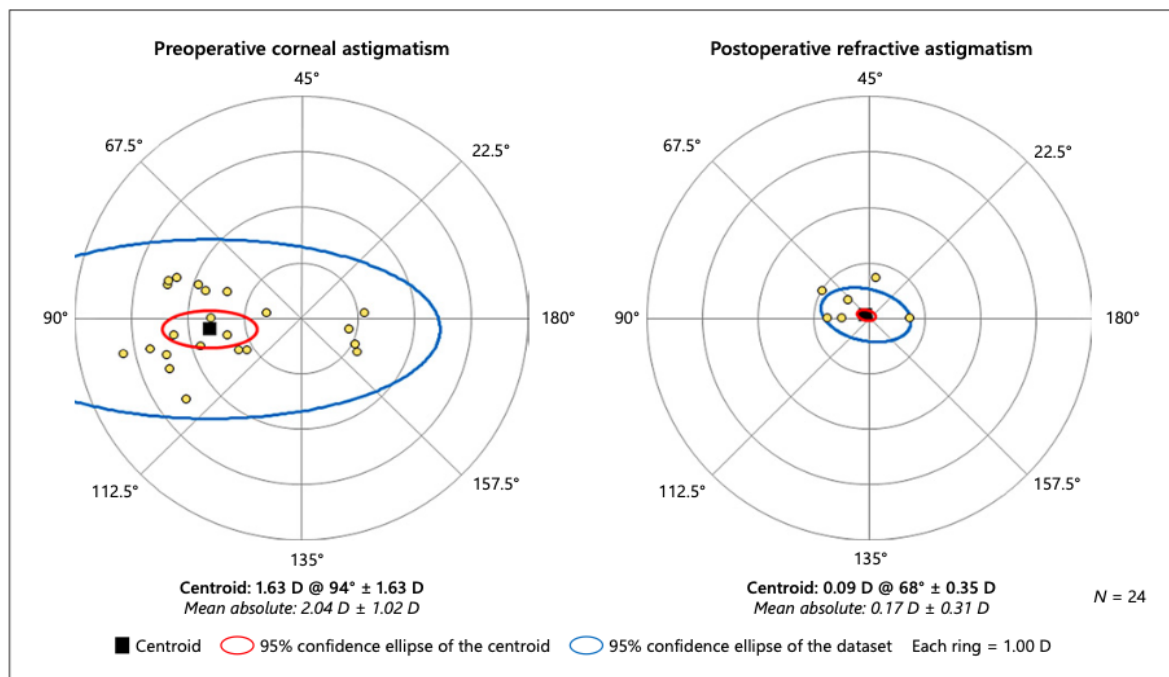


Fig. 6. Double-angle plots of preoperative and refractive astigmatism measured 12 months postoperatively. Centroid values with SDs and 95% confidence ellipses of the dataset and of the centroid values reflect efficient astigmatism correction achieved by the Bi-Flex 677TA(Y) IOL.

toric IOLs on the market. Alió et al. [13] reported a mean UDVA of 0.65 ± 0.22 (decimal) achieved by the Zeiss Acri. Comfort 646TLC lens 3 months postoperatively, which is inferior to the results in our cohort. Similarly, Kawahara and Takayanagi [12] reported 0.17 ± 0.13 (logMAR) for the Alcon AcrySof IQ toric lens, and Jung et al. [11] found 0.09 ± 0.09 (logMAR) for the Precizon toric IOL and 0.08 ± 0.12 (logMAR) for the Tecnis Toric lens. The visual acuity achieved with multifocal toric lenses is similar, or even somewhat lower than the results mentioned above [27, 28].

The Bi-Flex 677TA(Y) lens was proved to efficiently correct both spherical and cylindrical refractive errors, also in the long term. Our analysis of 33 eyes resulted in a -0.17 ± 0.13 D of residual cylindrical refraction. This is much closer to the target refraction, emmetropia, than the 0.73 ± 0.55 D residual cylinder reported for the AcrySof IQ toric IOL [12] and the -0.31 ± 0.29 D and -0.41 ± 0.33 D postoperative cylinders for the Precizon and Tecnis toric IOLs, respectively [11]. Our audit shows even

lower residual astigmatism than the study by Bachernegg et al. [15] did for the same IOL (postoperative CYL = 0.28 ± 0.61 D). We are aware that it is not only the IOL itself, but also the patient population, the measurement techniques, the precision of the IOL calculation formulae, and the accuracy of the IOL alignment during surgery all contribute to the final refractive and visual outcomes [4–6]. However, the vector analysis we performed also confirmed that the Bi-Flex 677TA(Y) toric lens has high potential for efficiently correcting preoperative astigmatism. The 2 basic vectors, TIA and SIA, were similar to each other, which means that the cylindrical refractions that were actually achieved were close to the intended target. These 2 vectors determined the DV, which was consequently low ($DV = 0.17$; 0.09 Ax 158°), pointing to efficient astigmatism correction. This result is in agreement with the high CI of 0.96, which is close to the optimal value of 1.00; however, it also reflects a slight undercorrection of astigmatism. If we compare these results to the corresponding values published for other toric IOLs, we

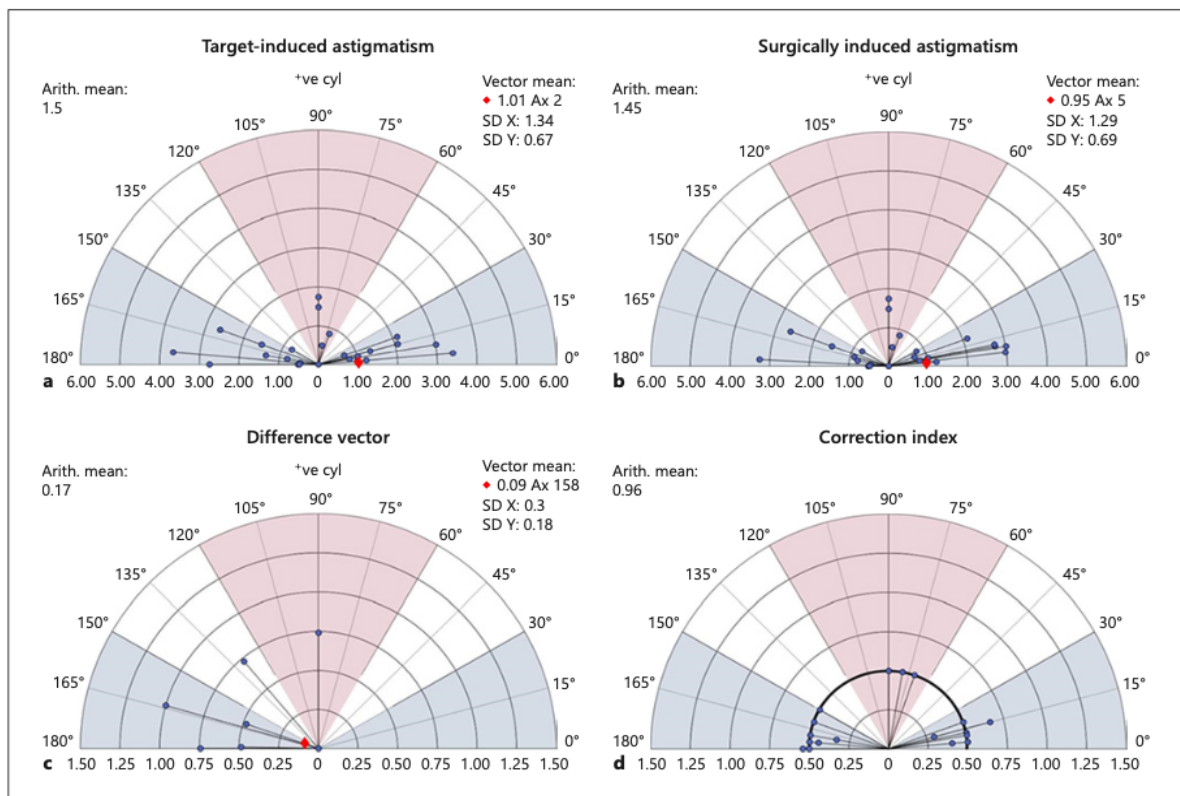


Fig. 7. **a** Target-induced astigmatism. **b** Surgically induced astigmatism. **c** The difference vector. **d** The correction index based on preoperative corneal and postoperative manifest refractions measured 12 months after toric IOL implantation. Calculations were performed by the Alpins vector analysis method.

can conclude that the monofocal, toric Bi-Flex 677TA(Y) lens is a good option for cataract patients with preoperative corneal astigmatism (Table 4).

During the first postoperative year following implantation of the Bi-Flex 677TA(Y) lenses, no off-axis rotation of $>5^\circ$ could be observed (Table 4). In contrast, in a recent study, Piovella et al. [28] reported that only 93.8% of the eyes implanted with the AT LISA tri 939MP toric lens had a rotation of $\leq 5^\circ$ 1 year after surgery. The superior rotational stability of the Bi-Flex lens is ensured by its special double-loop haptics, which have a large contact angle ($2 \times 88.8^\circ$) with the wall of the capsular bag [19]. This comparison with the AT LISA tri 939MP toric lens also confirms the hypothesis that plate haptic IOLs may be less stable in the long term, especially in large eyes [9].

Taking into consideration that no severe adverse events or complications were observed during the first postoperative year after the IOL implantation, and based on a detailed analysis of the study population, we conclude that the Bi-Flex 677TA(Y) toric IOL is a reliable and efficient solution for cataract patients who also wish to receive treatment for their preoperative corneal astigmatism.

Our intention is to perform a prospective study on the Liberty 677MTY trifocal toric IOL by the same manufacturer, as the Liberty IOL has the same stable Bi-flex design, and astigmatism correction is widely known to be a key factor in achieving the most favorable visual outcome with multifocal lenses, and consequently providing patients independence from wearing spectacles and an uncompromised quality of vision.

Table 4. Visual and refractive outcomes, IOL rotation, and vector analysis results after the implantation of toric IOLs

First author [ref.], year	IOL model (manufacturer)	Follow-up, months	Eyes/ patients, n	Calculation formula	UDVA (logMAR)	Vector analysis		DV	CI	Residual refractive cylinder (D)	IOL rotation (°)
						TIA	SIA				
Our study	Bi-Flex 677T (Medicontur)	12	35/22	Haigis	0.99±0.13 (decimal)	1.50 (1.01 Ax 2°)	1.45 (1.01 Ax 2°)	0.17 (0.09 Ax 158°)	0.96	-0.17±0.31	1.06±2.12 (-2; +5)
Bachner-egg [15], 2015	Bi-Flex 677T (Medicontur)	12	30/20	Haigis	0.06±0.16	2.35±0.66 (0.6 Ax 180°)	2.39±0.73 (0.8 Ax 177°)	0.41±0.45 (0.3 Ax 82°)	1.02±0.25	0.28±0.61	0.2±2.41 (-4; +3)
Krall [27], 2015	AT Torbi 709M (Zeiss)	3	88/71	n.r.	0.15±0.18	2.37±1.15 (n.r.)	2.54±1.21 (n.r.)	0.46±0.46 (n.r.)	1.09±0.21	n.r.	-0.6±1.4 (-3; +2)
Kawahara [12], 2016	AcrySof IQ toric (Alcon)	1.5	18/16	SRK/T	0.17±0.13	2.00±0.85 (n.r.)	1.90±0.99 (n.r.)	0.87±0.56 (n.r.)	0.95	0.73±0.55	n.r.
Jung [11], 2018	Precision toric (Ophtec) Tectis Toric (I&I)	3	40/40	SRK/T	0.09±0.09 (P) 0.08±0.12 (T)	1.41±0.49 (P) 1.41±0.43 (T)	1.35±0.52 (P) 1.57±0.79 (T)	0.31±0.23 (P) 0.42±0.26 (T)	0.97±0.25 (P) 1.08±0.27 (T)	-0.31±0.29 (P) -0.41±0.33 (T)	1.50±0.84 (P) 2.56±0.68 (T)
Piovella [28], 2019	AT LISA tri 939MP (Zeiss)	12	227/114	n.r.	0.10±0.14	1.55±0.91 (n.r.)	1.57±0.93 (n.r.)	0.59±0.30 (n.r.)	0.94±0.34	n.r.	93.8% within 5°
Alió [13], 2010	AcriComfort 646 TLC (Zeiss)	3	21/12	n.r.	0.65±0.22 (decimal)	4.54±2.72 (1.20 Ax 2°)	4.18±2.66 (0.99 Ax 1°)	0.47±0.61 (0.23 Ax 8°)	0.91±1.23	-0.45±0.63	1.75±2.93 (0; 10)

Results are presented as mean ± SD. TIA, SIA, and DV are shown in arithmetic values and mean vector values (in parentheses). IOL, intraocular lens; UDVA, uncorrected distance visual acuity; D, diopter; TIA, target-induced astigmatism; SIA, surgically induced astigmatism; DV, difference vector; CI, correction index; n.r., not reported.

Statement of Ethics

As the data were obtained retrospectively, according to Institutional Review Board and national regulations, no ethics approval was required for the current clinical evaluation. The data management and the entire clinical study adhered to the principles of the Declaration of Helsinki. Each patient gave their informed consent to participate.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

L.V.N. was the general designer, main coordinator, and surgeon of this study. He took part in drafting the manuscript. M.N. was responsible for calculation of the power of the implanted IOLs, examination of patients before surgery, follow-up, registration of IOL-axis, acquisition of data from all examination work, and assessment of postoperative results. K.T. performed the Pentacam, endothelial microscopy, OCT, and HD analyzer examinations, collected data and completed the protocols. K.L. was responsible for preparing patients in the operating room, assistance during surgery, control of perioperative procedures (administration of medication, etc.), completing perioperative forms, and recording undesirable events. L.R. was responsible for examining all retinal findings, solving any vitreoretinal complications in cases needing vitreoretinal surgery, and critical assessment of retinal findings. P.R. was the general advisor of the project. He assessed the material of the IOL and the surgical protocol and helped in data interpretation. He also performed critical revision of the work. P.S. advised us on the choice of a suitable operative technique, helped with the interpretation of corneal findings pre- and postoperatively, and supervised the entire project.

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Article

Comparison of Clinical Outcomes, Visual Quality and Visual Function of Two Presbyopia-Correcting Intraocular Lenses Made from the Same Material, but with Different Design and Optics

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Abstract: This semi-prospective, parallel, comparative investigation evaluated the clinical outcomes and quality of vision (contrast sensitivity, visual function, dysphotopsia, spectacle use, overall satisfaction) after mono- or bilateral implantation of two presbyopia-correcting intraocular lenses (IOL)—the Liberty® 677MY or the AT LISA® tri 839M—in 50 eyes of 25 cataract patients. Clinical outcomes were assessed 3 and 12 months postoperatively. Eighty-nine percent of eyes implanted with the Liberty IOL and 59% of eyes implanted with the AT LISA IOL achieved a refractive outcome ± 0.5 diopters of the target (emmetropia). Refractive outcomes were stable with both lenses. The proportions of eyes with 20/20 uncorrected distance visual acuity (UDVA) and 20/20 uncorrected near visual acuity (UNVA) were higher in the Liberty group than in the AT LISA group (UDVA: 56% vs. 41%; UNVA: 83% vs. 66%). Optical quality assessment results were comparable for the two IOLs. Superior photopic contrast sensitivity was found with the Liberty lens. The rate of Nd:YAG capsulotomy at the 12-month follow-up was 16.7% in the Liberty group and 40.6% for the AT LISA IOL. Considering that both lenses are made from the same material, we propose that the noted differences in clinical outcomes may derive from differences in design and optical surface between the two IOLs.

Keywords: presbyopia; multifocal intraocular lenses (MIOL); cataract; visual outcomes; visual function; contrast sensitivity; dysphotopsia; posterior capsule opacification; 677MY; 839M

1. Introduction

A growing reliance on intermediate vision in the modern world has contributed to an evolution in presbyopia-correcting intraocular lenses and the introduction of new trifocal intraocular lens (IOL) technologies that can provide functional vision without correction across a full range of distances. Although the latest technologies have brought an extended depth of focus and light-adjustable intraocular lenses, a recent survey performed by the European Society of Cataract and Refractive Surgery (ESCRS), based on the responses of 2149 doctors, has shown that the largest percentage (63%) of surgeons still prefer trifocal intraocular lenses when choosing an IOL for presbyopia correction [1]. Similar surgeons' preferences were reported by Logothetis et al. in a recent paper [2].

These IOLs have become the focus of recent clinical research aiming to reveal possible differences between trifocal IOL models, highlighting the advantages and possible target group of each type. In addition to the refractive outcome and visual acuity at multiple

distances, measures of visual quality are of particular interest. Dysphotopic events and compromised vision in sub-optimal light conditions are reported relatively frequently with multifocal IOLs, especially those with diffractive optical surface technologies [3,4]. Cataract surgeons cite problems with the nighttime quality of vision and loss of contrast visual acuity as their most common concerns relating to presbyopia-correcting IOLs [1].

Visual outcomes after cataract surgery and the long-term stability of the results are influenced by multiple features of an IOL [5–9]. Both IOL material and optical design play major roles in the final visual outcome [10–13]. In addition, IOL material, optic edge profile, and haptic design influence the development of posterior capsule opacification (PCO), which usually results in decreased vision [14–16]. PCO is easy to treat by performing Nd:YAG laser capsulotomy, but the procedure can lead to IOL damage, intraocular pressure (IOP) elevation, cystoid macular edema and retinal detachment [17].

Our study aimed to compare the refractive outcomes, visual performance, and quality of vision (contrast sensitivity, optical quality, visual function, dysphotopsia, spectacle use and overall satisfaction) after cataract surgery with bilateral implantation of two different trifocal IOLs that are made from the same material, but differ in their optical surface characteristics and other design features.

2. Materials and Methods

The current investigation was carried out at a single center, the Department of Ophthalmology, Institute of Aviation Medicine, Prague, Czech Republic. The study was conducted according to the guidelines of the Declaration of Helsinki [18] and approved by the Ethics Committee of the University Hospital Hradec Králové (Approval number: 20210 J01; date of approval: 25 May 2021). Prior to any intervention, each patient was given detailed information about the surgery and the objectives of our study. Each subject gave his or her written consent about contributing to and participating in this research.

All patients had bilateral age-related cataracts amenable to surgery using the phacoemulsification method, with implantation of a capsular bag IOL. All patients had normal ocular conditions, including normal anterior segment, healthy retinal status, and clear intraocular media apart from the cataract.

Special attention was paid to not including any patients with a history of intraocular or corneal surgery, congenital eye abnormality, or eye trauma. Patients with non-age-related cataracts, irregular astigmatism, diabetic retinopathy, age-related macular degeneration or any other retinal diseases, glaucoma, amblyopia, uveitis, pseudoexfoliation syndrome, iris neovascularization, severe myopia, or abnormal pupillary function were excluded.

All surgeries were performed by the same surgeon (L.N.) between April 2017 and September 2019 using the phacoemulsification technique. After local anesthesia, a clear corneal incision was made at 135° with a length of 1.7 mm that was later extended to 2.2 mm for IOL implantation. A paracentesis was made at 45°. After filling up the anterior chamber with the viscoelastic material, and removing the cataractous lens, the AT LISA tri 839MP IOL (Carl Zeiss Meditec AG, Jena, Germany) or Liberty 677PMY IOL (Medicontur Medical Engineering Ltd., Zsámbék, Hungary) was implanted. IOL selection for each patient was affected by financial issues. The same IOL was implanted bilaterally.

The AT LISA tri 839MP and Liberty 677PMY IOLs are made of the same hydrophilic–hydrophobic acrylic copolymer material (Benz-25 (Benz Research & Development, Sarasota, FL, USA)), but they have different designs. The AT LISA tri 839MP has an overall diameter of 11 mm, an optic diameter of 6.00 mm, and plate haptics. The Liberty 677PMY is larger in terms of overall diameter and has a double-loop haptic design. The optic of both IOLs is based on diffractive optical principles, but they use different approaches to achieve trifocality. Further technical features of the two study devices are summarized in Supplementary Table S1. The Liberty IOL was implanted using either the Medjet B1B or the Medjet MA 2.2 injector by Medicontur. The AT LISA IOLs come preloaded in the 2BLUEMIXS® 180 injector-cartridge set. After complete removal of viscoelastic material, the incisions were left sutureless in all cases. Antibiotic and antimicrobial eye drops were

administered intraoperatively in each case to reduce the risk of surgical infections, and antibiotic and anti-inflammatory eye drops were administered postoperatively. Fellow eyes were operated on during the first postoperative week using the same protocol.

Optimal IOL refractive power was determined based on thorough preoperative measurements. Data were collected from autorefractometry, pachymetry (Topcon TRK-1P, Topcon Europe Medical BV, Capelle aan den IJssel, the Netherlands), and biometry (IOL-Master 700, Carl Zeiss Meditec AG, Jena, Germany), including axial length (AL), anterior chamber depth (ACD) keratometry values and axes (K1, K2), and white-to white distance (WTW). Anterior segment biomicroscopy and funduscopy were performed using an Oculus Pentacam 70700 (OCULUS Optikgeräte GmbH, Wetzlar, Germany). The online Medicondur IOL Optimizer was used for Liberty IOL power calculations. We applied the Haigis formula, taking the true net power (keratometry from IOLMaster, compared with keratometers from Pentacam) into account, i.e., considering the posterior surface of the cornea. Each eye had a refractive target of emmetropia, and a surgically induced astigmatism (SIA) of +0.25 diopters (D) was included in the calculations. In cases where the calculator recommended a toric model, the Liberty 677MTY toric presbyopia-correcting IOL was chosen for implantation. Power calculations for the AT LISA tri were performed with similar parameters and using the recommendations of the IOLMaster. The toric version of the AT LISA tri (939MP) was implanted when an astigmatism-correcting IOL was recommended.

Follow-up visits were scheduled for 1 day, 1 week, and 1, 3, 6 and 12 months after surgery. The examined parameters, which were identical to those performed preoperatively, included visual acuity (uncorrected and corrected distance, intermediate, near) at 4 meters, 60 cm and 35 cm, respectively, and subjective and refractive errors (sphere, cylindrical error, spherical equivalent), also measured with an autorefractometer (Topcon TRK-1P, Topcon Europe Medical BV, Capelle aan den IJssel, the Netherlands). Defocus curves were plotted binocularly in photopic conditions at the 12-month visit. Contrast sensitivity measurements were performed in photopic, mesopic, and photopic conditions with glare (CSV-1000, Vector Vision Inc, Greenville, OH, USA) at 12 months following surgery. Measurements were taken at spatial frequencies of 3, 6, 12, and 18 cycles per degree (cpd) in each case (only 3, 6 and 12 cpd were measured in mesopic conditions). Optical quality, including the objective scatter index (OSI), modulation transfer function (MTF) cut-off values, and tear film analysis with tear-film OSI, were also assessed using the HD Analyzer (Visiometrics SL; Barcelona, Spain).

Detailed slit-lamp, biomicroscopy, and funduscopy examinations of the anterior and posterior segments were carried out to identify any complications or unexpected ocular conditions. The presence of PCO was documented at each visit.

All data were collected in a Microsoft Excel file (Microsoft Inc, Redmond, WA, USA), and further statistical analysis was performed using the GraphPad Prism 9.0.1 statistical software (GraphPad Software Inc., San Diego, CA, USA). All pre- and postoperative data collected during the current study are available after de-identification in the Mendeley Data depository database from doi:10.17632/y6n5k7s6f7.1 [19].

Descriptive statistics (mean, standard deviation, median, minimum, maximum, and 95% confidence intervals) were calculated in all cases. All variables were tested for normal distribution using the D'Agostino and Pearson tests. Depending on the results, comparisons between matching pre- and postoperative variables were performed using either the paired two-tailed *t*-test (in the case of normal distribution) or the Mann–Whitney test (when a non-parametric test was required). Comparison of the two cohorts represented by the implanted IOL model was carried out using the unpaired *t*-test, the Mann–Whitney test, the Kolmogorov–Smirnov test, or the multiple unpaired *t*-test (Holm–Sidak method), based upon specific request. The visual and refractive outcomes are presented according to the standards for reporting refractive outcomes of IOL-based refractive surgery, as recently published by Reinstein et al. [20].

The results are presented as mean $\pm$ standard deviation (SD) in the case of each analysis; p -values of 0.05 or less were considered to be statistically significant in all cases.

3. Results

The Liberty IOL was implanted in 24 eyes of 12 patients, and the AT LISA tri IOL was implanted in 32 eyes (16 patients). Data were analyzed for all eyes in the AT LISA tri group and from 18 eyes of 9 patients in the Liberty group, after excluding 3 patients who were lost to follow-up after the 6-month visit. Eleven eyes of seven patients in the Liberty group, and four eyes of two patients in the AT LISA tri group required a toric IOL. As all preoperative characteristics (apart from corneal astigmatism) and postoperative results were comparable in the non-toric and toric cohorts within each IOL group, data were pooled for the analyses in each group.

Supplementary Table S2 presents the demographic data and preoperative characteristics of the two IOL groups. Average age (Liberty 56.0 ± 6.81 years; AT LISA tri 51.0 ± 7.28 years), female/male ratio (3:1), and all biometric parameters were comparable between the two groups. Preoperative uncorrected distance, uncorrected near and corrected near visual acuity (UDVA, UNVA, and CNVA) were also similar in the two groups. There was a small, but statistically significant difference in corrected distance VA (CDVA) between the Liberty and AT LISA tri groups (0.02 ± 0.05 logMAR vs. 0.11 ± 0.22 ; $p = 0.0226$).

3.1. Refractive Correction

Spherical and cylindrical errors were effectively corrected in both IOL groups. The refractive outcomes achieved at postoperative month 3 were stable through month 12 in both cohorts (Table 1). The mean spherical equivalent refraction (SEQ) was significantly closer to the target (emmetropia) in the Liberty group at both 3 and 12 months.

Table 1. Postoperative residual spherical (SPH), cylindrical (Cyl) and spherical equivalent (SEQ) refractions measured 3 and 12 months postoperatively. Data are presented as mean $\pm$ SD.

Residual Refraction	IOL	Month 3	Month 12	Month 3 vs. Month 12 $p = 1$
SPH	Liberty	0.05 ± 0.21	-0.47 ± 0.47	0.6193
	AT LISA tri	-0.06 ± 0.36	-0.27 ± 0.43	0.3189
	$p = 2$	0.0004 *	0.0739	
Cyl	Liberty	-0.39 ± 0.63	-0.44 ± 0.27	0.3276
	AT LISA tri	-0.35 ± 0.37	-0.54 ± 0.30	0.0879
	$p =$	0.7865	0.0499 *	
SEQ	Liberty	-0.20 ± 0.32	-0.23 ± 0.39	>0.9999
	AT LISA tri	-0.24 ± 0.39	-0.60 ± 0.44	0.6062
	$p =$	0.0021 *	0.0054 *	

¹ Comparison of the residual refractions measured during the two visits was performed using the paired two-tailed Wilcoxon or Mann–Whitney test. p -values of ≤ 0.05 were considered as statistically significant (*). ² Comparison of the residual refractions measured in the two IOL-groups was performed using the Kolmogorov–Smirnov test. p -values of ≤ 0.05 were considered as statistically significant (*).

At postoperative month 12 in the Liberty group, the residual SEQ was ± 0.5 D of emmetropia in 89% of eyes and ± 1.0 D in 100% of eyes (Figure 1a). In the AT LISA tri group, residual SEQ was ± 0.5 D of emmetropia in 59% of eyes and ± 1.0 D in 88% (Figure 1b). The analysis of residual astigmatism similarly showed better outcomes in the Liberty IOL group (Figure 1c,d).

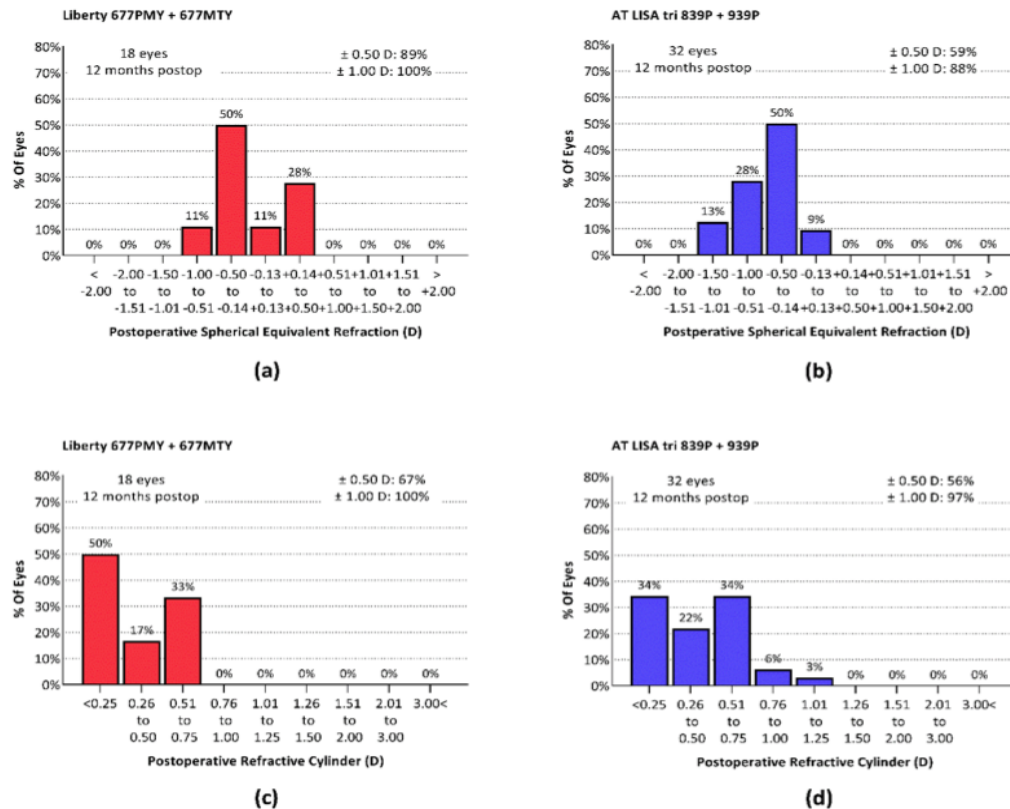


Figure 1. Postoperative spherical equivalent refractions and residual cylindrical refractions measured 12 months postoperatively. (a) Postoperative SEQ Liberty group; (b) postoperative SEQ AT LISA tri group; (c) residual astigmatism Liberty group; (d) residual astigmatism AT LISA tri group.

3.2. Visual Outcomes

Visual acuity outcomes are summarized in Table 2. UDVA and CDVA were significantly better in the Liberty group at postoperative month 3, but they did not differ between groups at month 12. Intermediate and near visual acuities were comparable in the two cohorts at both 3 and 12 months. The visual acuities at all three examined distances were stable during the follow-up period in both IOL groups.

Snellen UDVA 20/25 or better (logMAR 0.1) was achieved by 89% of Liberty eyes and 75% of AT LISA tri eyes (Figure 2a,b). Snellen UNVA of 20/25 or better was achieved by 94% of Liberty eyes and 88% of AT LISA tri eyes (Figure 2c,d). The UDVA was within one line of the CDVA in 100% of Liberty eyes and 80% of AT LISA tri eyes (Figure 2e). In both groups, the CDVA was within one line of CDVA in all eyes (Figure 2f). None of the above differences between groups achieved statistical significance.

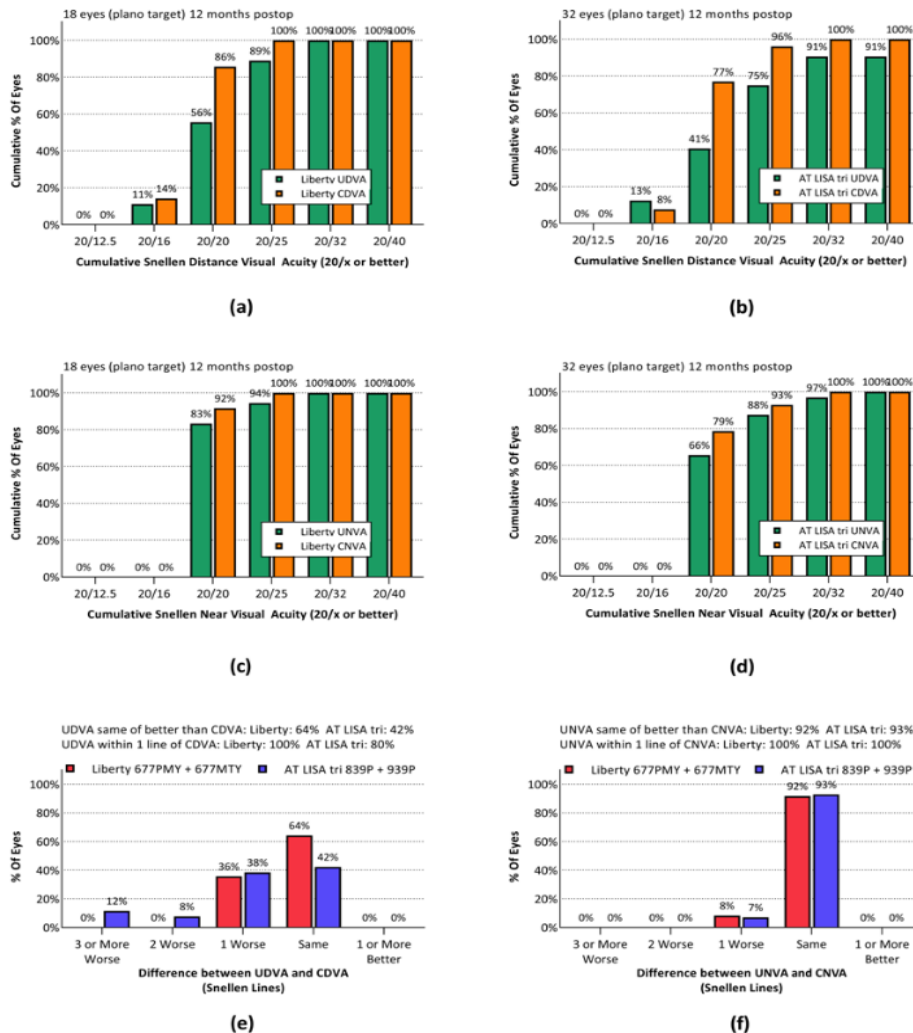


Figure 2. Cumulative Snellen uncorrected and corrected visual acuities for distance and near vision, measured 12 months after surgery. (a) Cumulative distance visual acuities for the Liberty group. (b) Cumulative distance visual acuities for the AT LISA tri group. (c) Cumulative near visual acuities for the Liberty group. (d) Cumulative near visual acuities for the AT LISA tri group. (e) Difference between UDVA and CDVA in Snellen lines for the Liberty group. (f) Difference between UDVA and CDVA in Snellen lines for the AT LISA tri group. UDVA: uncorrected distance visual acuity. CDVA: corrected distance visual acuity. UNVA: uncorrected near visual acuity. CNVA: corrected near visual acuity.

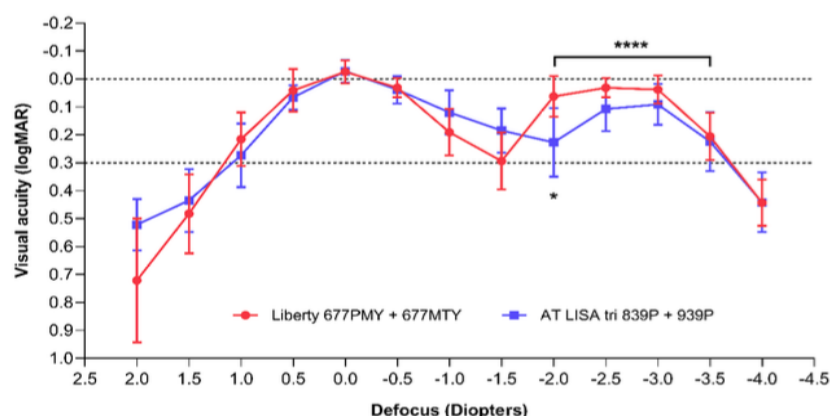
Table 2. Monocular distance (logMAR) and near (Jaeger) visual acuities, measured 3 and 12 months postoperatively. Data are presented as mean $\pm$ SD.

Visual Acuity	IOL	Month 3	Month 12	Month 3 vs. Month 12 $p = ^1$
UDVA	Liberty	0.02 $\pm$ 0.04	0.03 $\pm$ 0.07	0.0469 *
	AT LISA tri	0.13 $\pm$ 0.06	0.10 $\pm$ 0.19	0.3125
	$p = ^2$	0.0033 *	0.2206	
CDVA	Liberty	0.00 $\pm$ 0.03	0.00 $\pm$ 0.04	>0.9999
	AT LISA tri	0.04 $\pm$ 0.06	0.01 $\pm$ 0.05	0.2500
	$p = ^2$	0.0394 *	0.4720	
DCIVA	Liberty	N/A	0.30 $\pm$ 0.10	N/A
	AT LISA tri	N/A	0.18 $\pm$ 0.08	N/A
	$p = ^2$	N/A	0.0001 *	
UNVA	Liberty	0.02 $\pm$ 0.05	0.02 $\pm$ 0.05	>0.9999
	AT LISA tri	0.00 $\pm$ 0.00	0.05 $\pm$ 0.08	0.2500
	$p = ^2$	0.2258	0.2092	
CNVA	Liberty	0.03 $\pm$ 0.06	0.01 $\pm$ 0.03	0.3714
	AT LISA tri	0.00 $\pm$ 0.00	0.03 $\pm$ 0.06	0.5539
	$p = ^2$	0.4286	0.5252	

¹ Comparison of the visual acuities measured during the two visits was performed using the paired two-tailed Wilcoxon or Mann–Whitney test. p -values of ≤ 0.05 were considered statistically significant (*). ² Comparison of the visual acuities measured in the two IOL-groups was performed using the Kolmogorov–Smirnov test. p -values of ≤ 0.05 were considered statistically significant (*). UDVA: uncorrected distance visual acuity. CDVA: corrected distance visual acuity. DCIVA: distance-corrected intermediate visual acuity. UNVA: uncorrected near visual acuity. CNVA: corrected near visual acuity. N/A: not applied.

3.3. Defocus Curves and Area under Curve

Monocular defocus curves were plotted at 12 months postoperatively in photopic conditions (Figure 3). Multiple t -tests performed between the two study groups revealed a significant difference only at the -2.0 D defocus value ($p = 0.0193$). The area under the curve comparisons with a baseline of 0.3 logMAR visual acuity showed similar results in the two groups for the total (TAUC; Liberty = 1.90 ± 0.08 ; AT LISA tri = 1.81 ± 0.09 ; $p = 0.0692$), far (FAUC; Liberty = 0.68 ± 0.04 ; AT LISA tri = 0.65 ± 0.04 ; $p = 0.1446$) and intermediate range (IAUC; Liberty = 0.49 ± 0.05 ; AT LISA tri = 0.53 ± 0.05 ; $p = 0.1446$). In the near vision range (from -2.0 D to -3.5 D defocus), the Liberty IOL was associated with better results than the AT LISA tri IOL (NAUC = 0.65 ± 0.04 vs. 0.54 ± 0.06 ; $p = 0.0004$).

**Figure 3.** Monocular defocus curves of the two IOL models, plotted 12 months after surgery. Pairwise comparisons showed a significant difference only at the -2.0 D defocus value (*), while the area under curve analysis confirmed superior near vision performance for the Liberty IOL ($p = 0.0004$; ****).

3.4. Visual Quality

A detailed visual quality assessment was performed at 12 months postoperatively. Contrast sensitivity was measured, and an optical quality assessment was performed. Visual functions and dysphotopsia could be evaluated based on the responses provided by 9 patients implanted with the Liberty IOLs, and 14 patients implanted with the AT LISA tri IOLs.

3.4.1. Optical Quality

Detailed numerical results of the OQAS analysis are shown in Supplementary Table S3. All examined parameters (MTF cut-off, Strehl ratio, OSI, tear-film OSI, tear-film standard deviation, and tear-film difference) were comparable between the two IOL groups ($p > 0.05$).

3.4.2. Contrast Sensitivity

Photopic, photopic with glare, and mesopic contrast sensitivities are shown in Figure 4. Contrast sensitivity was within the normal range at all measured spatial frequencies with both IOLs. Contrast sensitivity was significantly better with the Liberty than with the AT LISA tri in photopic light conditions at four out of five spatial frequencies (3 cpd: $p = 0.0022$; 6 cpd: $p < 0.0001$; 12 cpd: $p = 0.0019$; 18 cpd: $p = 0.0060$).

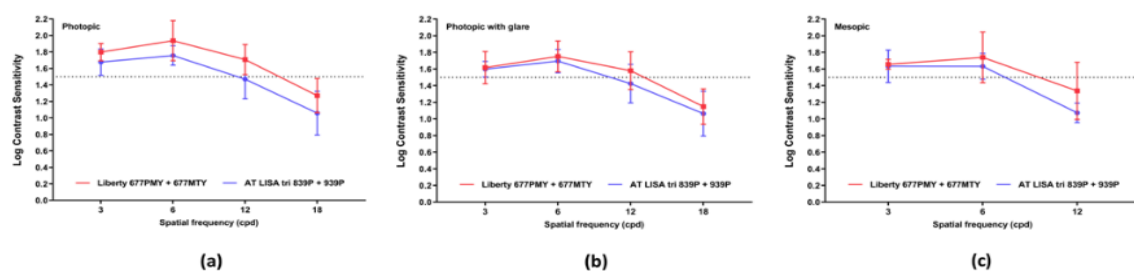


Figure 4. Contrast sensitivity, measured in different light conditions at 12 months postoperatively. (a) In photopic conditions. (b) In photopic conditions with glare. (c) In mesopic conditions (measurements not obtained at 18 cpd). cpd = cycles per degree.

3.4.3. Visual Function, Dysphotopsia, Patient Satisfaction

Patient self-assessments of postoperative visual function and dysphotopic events were collected using a modified visual function questionnaire completed at postoperative month 12. Each item and the possible responses are listed in Supplementary Table S4. Responses were evaluable for 9 patients in the Liberty group and 14 patients in the AT LISA tri group.

Dysphotopic events and other visual disturbances, such as blurred or distorted vision, were rarely reported with either IOL (Figure 5a), and there were no significant differences between the responses given by the patients in the two study groups (Supplementary Table S5). The majority of daily tasks could be performed with no difficulty to only minor difficulties by the vast majority of patients in both IOL groups (Figure 5b).

Blurred far vision was reported by a minority of the Liberty patients, and more often by patients in the AT LISA tri group (Figure 6a; Supplementary Table S5). Glare and flare were the most common dysphotopic phenomena, although most patients rated them as representing no, minor, or moderate difficulties. Major concerns were only reported by AT LISA tri patients (Figure 6b).

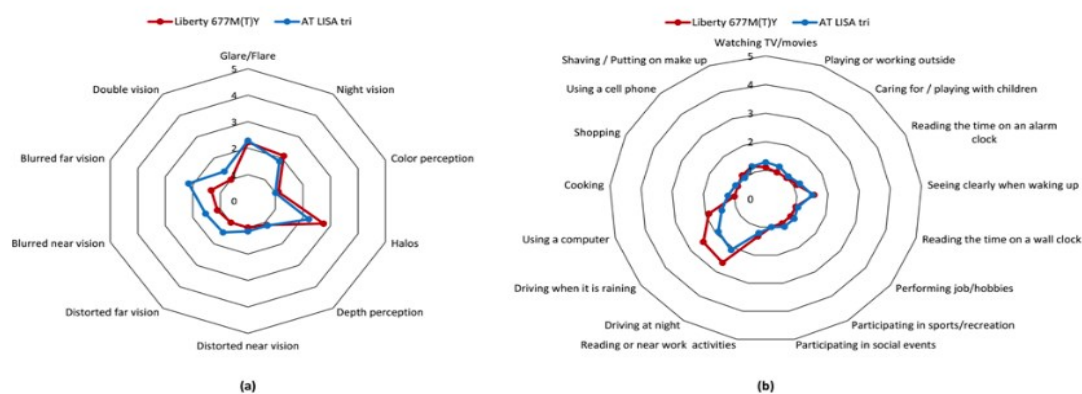


Figure 5. Mean responses for (a) dysphotopsia and (b) visual function assessment using a modified visual function questionnaire completed at 12 months postoperatively. 1 = No difficulties; 2 = minor difficulties; 3 = moderate difficulties; 4 = major difficulties; 5 = cannot accomplish task. No significant differences between the two lenses could be revealed.

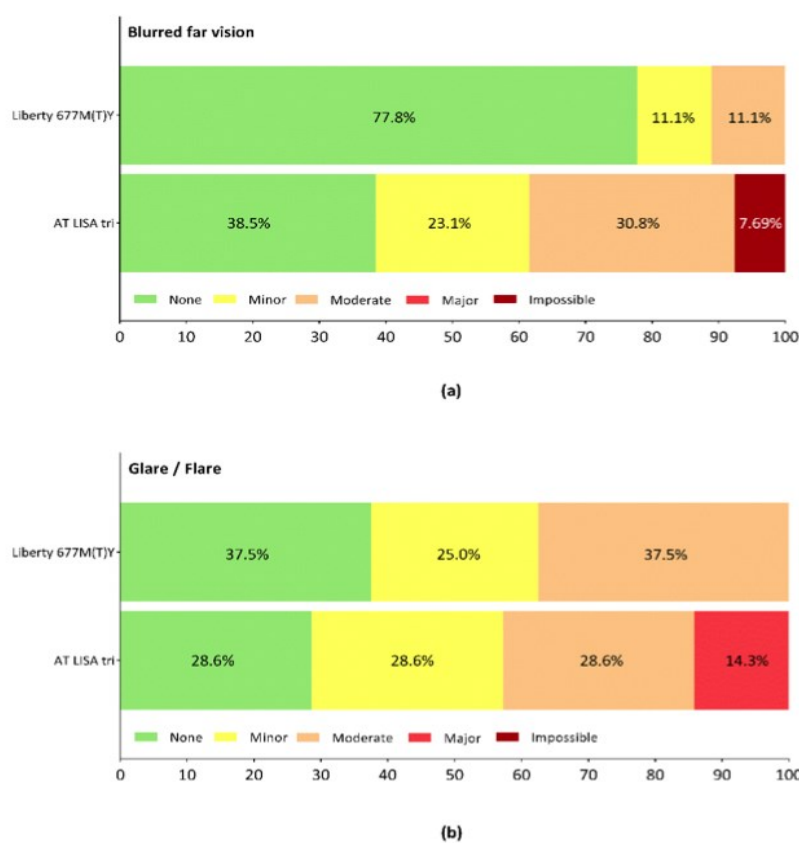


Figure 6. Distribution of responses given by the patients regarding difficulties caused by (a) blurred far vision, and (b) glare/flare. Subjective assessment was performed using a modified visual function questionnaire completed at 12 months postoperatively.

The majority of patients were highly satisfied with the surgical outcomes and their postoperative quality of vision (Figure 7). Only a few complaints came from the AT LISA tri cohort: although all patients (100%) from the Liberty group achieved spectacle independence for far and near vision, and only one patient of the nine (11.1%) required spectacles for intermediate vision from time to time, 14.3% of the AT LISA tri subjects often needed their glasses for far vision and 7.1–7.1% often needed to wear spectacles for intermediate and near vision.

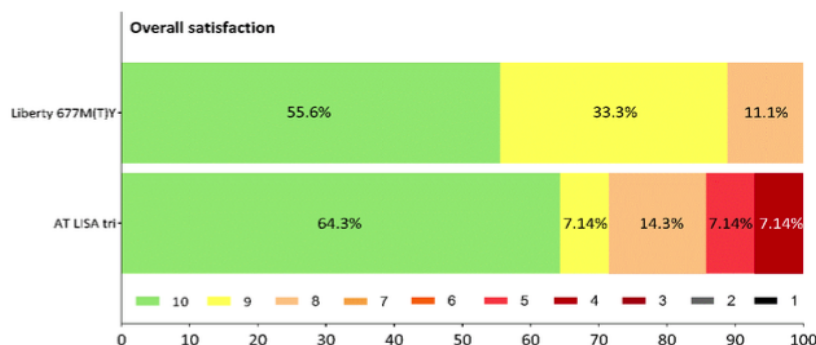


Figure 7. Overall satisfaction reported by patients at 12 months after surgery. 10 = highest ranking; 1 = lowest ranking.

3.5. Posterior Capsule Opacification

During the first 12 months after surgery, PCO developed in 6 (33.3%) of 18 eyes implanted with the Liberty IOL and 20 (62.5%) of 32 eyes in the AT LISA tri group. The percentage of eyes that had Nd:YAG capsulotomy for visually significant PCO was significantly lower in the Liberty group than in the AT LISA tri group (16.7% vs. 40.7%; $p = 0.1171$). The mean time to development of PCO elapsing between the cataract surgery and PCO development was 10.1 ± 1.41 months in the Liberty group and 8.61 ± 4.02 months in the AT LISA tri group cohort; however, this difference was not significant ($p = 0.8000$).

No serious complications related to either the surgery or the IOLs occurred. Across both IOL groups, corneal edema and increased IOP were seen in early follow-up in five and four eyes, respectively, with resolution by the 1-month postoperative visit. Dry eye syndrome was diagnosed at the 12-month visit in four eyes of three patients in the Liberty group and in six eyes of three patients in the AT LISA tri group.

4. Discussion

Our study aimed to characterize and compare the clinical outcomes and quality of vision after the implantation of one of two trifocal IOLs. It includes data from 50 eyes of 25 patients followed up to 12 months after surgery.

Both investigated IOLs effectively corrected refractive and cylindrical errors. However, the Liberty IOL was associated with better refractive predictability. Our results show that the residual SEQ refraction was within 0.5 D of the target in 89% of Liberty eyes and 59% of AT LISA tri eyes. These results are not as good as those reported in a study by Serdiuk et al., where 97% of Liberty eyes and 71% of AT LISA tri eyes achieved a residual $SEQ \leq 0.5$ D [21]. Nevertheless, a difference favoring the Liberty IOL is apparent in both studies [21]. Astigmatism outcomes in our study also showed differences between the two IOL models, with better results achieved with the Liberty IOL. These results suggest that the Liberty lens is associated with more predictable refractive outcomes and a lower risk of postoperative refractive surprises. However, further studies are needed to confirm these findings. Refractive outcomes achieved by the end of the third postoperative month were shown to be maintained with both examined lenses during the entire follow-up period.

Visual outcomes reflect the refractive results. Both IOLs provided sharp vision at multiple distances (far, intermediate, near), and the uncorrected distance, intermediate and near visual acuities are in good agreement with previously published data for these lenses [21–28]. Nevertheless, a remarkably higher proportion of eyes achieved good functional monocular vision at multiple distances with the Liberty lens compared to the plate-haptic AT LISA tri. At 12 months following implantation, 56% of Liberty eyes and 41% of AT LISA tri eyes had a monocular distance vision of at least 20/20 (Snellen), and 89% of Liberty eyes vs. 75% of AT LISA tri eyes achieved at least 20/25. These results are inferior to those reported by both Serdiuk et al. and Piovella et al. [21,22]. However, the latter paper reported binocular results, which are usually more favorable than monocular visual acuities [22].

The intermediate vision results have to be interpreted with consideration of the testing distance. Some studies report data with intermediate vision measured at 80 cm, while others publish data measured at 66 cm from the eye [21,22,28–30]. As the AT LISA tri lens has a +1.66 D addition and the Liberty IOL has a +1.75 D addition calculated at the IOL plane, we find it more expedient to focus on the intermediate vision data measured at 66 cm, which is roughly equivalent to a +1.50 D addition on the defocus curve. Liberty eyes have given somewhat lower results with the +1.50 D addition compared to the AT LISA tri IOL; however, we could not find a significant difference. We did find that patients implanted with the Liberty IOL had significantly better visual performance in the near vision range compared to the AT LISA tri group in 83% of Liberty eyes, but only 66% of AT LISA tri eyes achieved monocular UDVA of 20/20 or better, while 94% of Liberty eyes and 88% of AT LISA tri eyes achieved UNVA of 20/25 or better. Our results are superior to those reported by other authors, although any attempt to make comparisons is limited by a lack of detail regarding their exact measurement conditions and patient population characteristics [21,22].

The results of defocus curve testing are consistent with the VA measurements; the results for VA show that both IOLs provide excellent distance vision. Performance in the intermediate range seems somewhat inferior for the Liberty IOL compared to the AT LISA tri, but the difference is not statistically significant. Furthermore, the visual function assessment results of the two examined lenses are also comparable—not only in the intermediate range but also for near and far distances. The near vision range provided by the Liberty IOL in our study (from about −1.75 D to −3.5 D defocus) was wider than that of the AT LISA tri and similar to that previously reported by Fernández et al. [24]. This difference may explain the higher percentage of Liberty patients achieving spectacle independence for near vision compared to the AT LISA tri group (100% vs. 92.9%). In addition, freedom from glasses for far vision was reported by all patients in the Liberty group, whereas 14.3% of the AT LISA tri patients often required additional correction for far vision.

An optical quality assessment performed using an OQAS system gave identical results for the two lenses, which are made from the same material. Nevertheless, differences between the two IOL groups in visual quality characterized by subjective parameters, such as contrast sensitivity and visual disturbances were recorded. We postulate the differences may be explained by the potential for IOL design and optical surface features to impact visual performance. Mesopic and photopic glare contrast sensitivities were in the physiological range and were similar for both lenses. The photopic contrast sensitivity values, however, were better with the Liberty lens. The latter result is in agreement with the findings of other investigations, including studies reporting lower contrast sensitivity values for the AT LISA tri than we found and a reduction at high spatial frequencies (12 and 18 cpd) [22,26,28]. The contrast sensitivity curves for the Liberty IOL in our patients match those presented in other studies of this lens [23,25].

It is well known that multifocal IOLs are frequently associated with photic disturbances, and that the frequency and intensity of these visual symptoms have a high impact on overall visual quality and hence on patient satisfaction [31–38]. Although the results for

dysphotopsia and visual functions were similar for the Liberty and AT LISA tri IOLs, we recognized that patient responses usually lack extreme ratings in the case of the Liberty IOL. We speculate that better refractive predictability with the Liberty IOL might account for this difference. Although further investigation is required to gather evidence that would support this explanation, patients with higher residual refractive error are more prone to report dysphotopsia and be less satisfied with their overall visual quality [37,38].

The explanation for the better refractive predictability of the Liberty IOL is also unclear. Comparing two MFIOLs, Meng et al. reported that a plate haptic lens had better positional stability in the capsular bag than a lens with a C-loop haptic in myopic eyes ($AXL > 24.5$ mm) and noted no differences in non-myopic eyes (21.0 mm $< AXL \leq 24.5$ mm) [39]. Because AXL was similar in the two IOL groups in our study ($p = 0.6400$), we believe that the differences between groups in the refractive and visual outcomes are not attributable to this anatomical parameter. IOL decentration and tilt were not measured in our study, although both the Liberty and AT LISA tri IOLs have been reported to undergo some decentration following implantation [24,39]. IOL decentration can affect refractive and visual outcomes [38,40]. Kim et al. reported a tendency towards myopia among patients implanted with the AT LISA tri 839MP compared to a group implanted with a C-loop haptic IOL [26].

IOL design is also known to affect PCO development [41–45]. In our cohort, one-third of the Liberty eyes developed PCO during the first postoperative year, and half of these eyes required surgical treatment, namely, Nd:YAG laser capsulotomy. In contrast, almost two-thirds of the AT LISA tri eyes developed PCO, and two-thirds of these eyes had a perceptible decrease in vision that required surgical management. Because all surgeries were performed by the same experienced surgeon using the same surgical protocol with the utmost caution, we believe that the differences in frequency and severity of PCO are likely explained by differences in IOL design [16,46]. We acknowledge that our reported 1-year rates for PCO and Nd:YAG capsulotomy are higher than those reported in other studies [29,47–49]. The definition of PCO and the criteria for performing Nd:YAG capsulotomy, however, may differ between centers.

Our study has its limitations. Patients could not be randomized to an IOL group. However, all surgeries and examinations were performed by the same personnel using the same protocol, equipment, and tools, in order to minimize variations that might affect outcomes. Moreover, our study includes a relatively small number of patients, and therefore our findings should be interpreted carefully. Further investigations including more patients should be performed to confirm the current results. Nevertheless, our clinical investigation provides a detailed and comprehensive comparison of outcomes achieved with the two examined trifocal IOLs.

Our results indicate that both investigated IOLs offer safe and effective presbyopia correction after cataract surgery. Because the IOLs are made of the same material, they seem to provide comparable optical quality, and the majority of patients are highly satisfied with their visual function. Differences in visual acuities at different ranges and contrast sensitivities favoring the Liberty group were observed and may be explained by the different optical surfaces of the two presbyopia-correcting IOL models. Differences in haptic design may explain the remarkable differences between groups in PCO development and severity: the double-loop haptic IOL seems to provide more efficient PCO prevention than the IOL with plate haptics.

5. Conclusions

Although several presbyopia-correcting IOLs are available on the market, and most of them are able to provide good functional vision at multiple distances, there may be differences in the quality of vision they produce. The visual outcomes seem to reflect differences in the optical technology and other design elements implemented by the manufacturer. Surgeons should be aware of possible differences between trifocal IOLs with respect to clinical outcomes, including the possible side effects of dysphotopsia and

reduced contrast sensitivity, and choose the optimal model based on the unique ocular characteristics and visual preferences of each patient.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/jcm10153268/s1>, Table S1: Technical data of the two investigational devices, Table S2: Demographic and preoperative characteristics of the study population, Table S3: Optical quality assessment 12 months following IOL-implantation has shown that all examined parameters are comparable between the two IOL-subsets of patients, Table S4: Visual function self-assessment questionnaire completed by the patients 12 months following IOL implantation, Table S5: Visual function self-assessment of the patients 12 months following IOL implantation.

Author Contributions: Conceptualization, L.V.N. and P.R.; methodology, L.V.N., M.N. and P.R.; software, L.V.N.; validation, M.N., K.T., K.L. and L.R.; formal analysis, L.V.N.; investigation, L.V.N., M.N., L.R.; resources, L.V.N.; data curation, K.T. and M.N.; writing—original draft preparation, L.V.N.; writing—review and editing, L.V.N. and P.S.; visualization, M.N.; supervision, L.V.N., P.R. and P.S.; project administration, L.V.N. and P.R. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available in a publicly accessible repository. The data presented in this study are openly available on Mendeley Data at doi:10.17632/y6n5k7s6f7.1.

Conflicts of Interest: The authors declare no conflict of interest.

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Article

Simultaneous Presbyopia and Astigmatism Correction with a Novel Trifocal Toric Intraocular Lens—A One-Year Follow-Up

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Abstract: The current investigation evaluates the efficiency of the trifocal toric Liberty 677MTY intraocular lens (IOL) in correcting preoperative corneal astigmatism in cataract patients demanding spectacle independence. The retrospective evaluation included 28 eyes of 15 patients with preoperative corneal astigmatism of at least 1.0 Dioptre (D). All patients were followed up for one year postoperatively. Residual refractive errors and visual acuities at multiple distances were measured. Binocular visual acuity and contrast sensitivity defocus curves were plotted. Visual functions and patient satisfaction were assessed. The efficiency of astigmatism correction was determined using the vector analysis method. The mean spherical equivalent refraction (SEQ) improved from 2.72 ± 1.62 D to 0.10 ± 0.48 D. The cylindrical refraction decreased from 1.18 ± 0.45 D to 0.16 ± 0.31 D. Vector analysis proved efficient astigmatism correction with a centroid of 0.10 ± 0.34 D at 161° . Ninety-two percent of eyes resulted within 0.5 D from the target refraction. Visual acuities were 0.1 logMAR or better from +1.0 to -3.5 D defocus values. Visual tasks could be performed without major difficulties. Our patients were highly satisfied. Refractive and visual outcomes with the investigated presbyopia-correcting toric IOL are predictable and the lens provides excellent trifocal vision.

Keywords: intraocular lens; astigmatism correction; presbyopia; toric; trifocal; cataract; rotational stability

1. Introduction

Presbyopia is an age-related impairment reducing the accommodation ability of the crystalline lens, resulting in difficulties while performing near-vision related tasks such as reading, writing, or viewing digital devices [1]. The visual limitations caused by presbyopia reportedly induce distress and low self-esteem in the affected patients [1]. More than half of the middle-aged to the elderly population is affected by presbyopia, with an estimated 1.09 billion cases globally [1].

The surgical correction of presbyopia during cataract surgery or refractive lens exchange offers an efficient restoration of visual comfort at multiple distances. Several multifocal intraocular lenses (IOLs) have been introduced to the market during the last decade. However, the best possible visual outcome can only be accomplished if all refractive errors, including astigmatism, are properly corrected [2–4]. Ferrer-Blasco et al. reported that the majority (87%) of cataract patients had preoperative astigmatism [5],

and another recent study reported that 42% of eyes had corneal astigmatism of at least 1.00 dioptres (D) [3]. This amount of astigmatism is already large enough to compromise both postoperative visual acuity and visual quality if it is left uncorrected [2–5].

Recently, trifocal toric IOLs (TTIOLs) have been developed to provide high-level visual comfort for numerous patients affected by both presbyopia and astigmatism. However, only a limited number of scientific publications are currently available on the clinical outcomes and long-term stability following the implantation of trifocal toric lenses. According to our knowledge, to date, no paper has been published on the clinical performance of the Liberty 677MTY trifocal toric lens.

Our current investigation aimed to assess the refractive and visual outcomes, including the assessment of visual quality and visual functions, and the astigmatism-correcting efficiency of the IOL named above.

2. Materials and Methods

2.1. Subjects

The current retrospective clinical investigation evaluated the pre- and postoperative records of presbyopic cataract patients, who all had preoperative corneal astigmatism. All patients expressed their demand for spectacle independence. The subjects underwent mono- or binocular cataract surgery (2 and 13 patients, respectively) performed by the same experienced surgeon (LVN) between September 2019 and December 2020. The patients included in the assessments were selected carefully. Subjects with congenital eye diseases, uveitis, amblyopia, eye trauma, previous corneal laser refractive surgery, and/or other corneal or intraocular pathologies were not included in the analyses. Only adult patients with normal anterior segment conditions (apart from cataracts), clear intraocular media and healthy retinal status were selected for evaluation.

The current clinical investigation was approved by the Ethics Committee of the University Hospital Hradec Králové (Reference number: 202204 P01; 8 March 2022). The principles of the Declaration of Helsinki were followed during the data management and the entire clinical evaluation [6].

2.2. Pre- and Postoperative Examinations

Before surgery, each patient underwent detailed ocular examination including corneal topography, aberrometry (TRK-2P, Topcon Corporation, Tokyo, Japan), anterior segment examination (Oculus Pentacam 70700, OCULUS Optikgeräte GmbH, Wetzlar, Germany), posterior segment examination with a slit lamp (SL-D4, Topcon, Topcon Corporation, Tokyo, Japan), and optical biometry measuring axial length (AXL), anterior chamber depth (ACD), and keratometry values (K1, K2; IOL Master 700, Carl Zeiss Meditec AG, Jena, Germany). Intraocular pressure was recorded in all cases.

Cataracts were diagnosed based on slit-lamp evaluation and the subjective loss of vision in the case of each subject.

Monocular uncorrected and corrected visual acuities (distance UDVA, CDVA at 4 m; intermediate UIVA, CIVA at 67 cm; near UNVA, CNVA at 35 cm) were assessed using the Vision C iPad application (Clínicas Qvision, Almería, Spain) [7].

The same measurements were performed one day, one week, one, three, and six months, and then one year postoperatively.

Additionally, binocular visual acuity and contrast sensitivity defocus curves were plotted in photopic conditions using the Multifocal Lens Analyzer 3.0 (MLA) iPad application by Clínicas Qvision, Almería, Spain [8]. The recommended protocol of the developers was applied in all cases.

Contrast sensitivity measurements were performed using the CSV-1000 device (VectorVision, Houston, TX, USA) under photopic, photopic with glare and mesopic light conditions.

Our retrospective evaluation included a vector analysis with the Alpíns method, which provides additional information on the astigmatism-correcting ability of the IOL in question.

Rotational stability was evaluated by comparing the position of the IOL during each postoperative visit to the surgical position. Rotation was expressed as the mean absolute rotation (focusing on the degree of rotation), as well as the signed rotation, which also takes the direction of the rotation into account. Clockwise rotation was counted as negative and counterclockwise as positive rotation. Rotation between the intended torus position and that measured on the first postoperative day was regarded as misalignment, while later on as toric IOL rotation.

Visual functions, quality of vision, and patient satisfaction were evaluated with a standard questionnaire one, three, and six months and then one year following surgery.

2.3. The Bi-Flex Liberty 677MTY Intraocular Lens

The Liberty 677MTY trifocal toric IOL (Medicontur Medical Engineering Ltd., Zsám-bék, Hungary) is a hydrophilic, acrylic, single-piece capsular bag lens designed for presbyopia correction. The optic uses the diffractive principles with seven diffractive rings in the centre of the optics while leaving the outer 75% of the lens surface purely refractive. The two toric marks indicate the flat axis on the edge of the optic. The optic is connected to two double-loop haptics without haptic angulation. The IOL has a 360° square edge (also in the optic-haptic junction) to prevent the development of posterior capsule opacification (PCO). The IOL material has 25% water content and includes a UV-absorber and a blue-light filter.

The online calculator of the manufacturer [9] was used for IOL calculation in each case. The target refraction was Plano (emmetropia) in each case, and the personal surgically-induced astigmatism (0.25 D) of the surgeon was always taken into account. The optimal spherical equivalent (SEQ) and cylindrical power (CYL) of the IOL were determined by the Haigis formula [10] for each eye. Posterior corneal astigmatism was considered during the optical biometry measurements performed by the IOL Master 700.

2.4. Surgical Technique

All surgeries were performed under local anaesthesia and following pupil dilation according to the standard cataract surgery protocol using the phacoemulsification method described previously [11]. Clear corneal incisions of 1.7 mm with an extension to 2.2 mm were made at 135°. The toric IOL was positioned by accurately aligning the toric reference marking of the IOL using the toric IOL alignment tool of the Callisto eye system (Carl Zeiss Meditec AG, Jena, Germany).

2.5. Vector Analysis

The cumulative histogram of the magnitudes of the preoperative corneal astigmatism and postoperative refractive astigmatism at the corneal plane (measured 12 months postoperatively) and the double-angle plots of preoperative and postoperative refractive astigmatism (including centroid values with standard deviations and 95% confidence ellipses of the dataset and the centroid values) were plotted according to the method presented by Abulafia et al. [12].

2.6. Statistical Analysis

All data were recorded in Microsoft Excel. Evaluations were performed using the GraphPad Prism 8.3.0 software (GraphPad Software, San Diego, CA, USA). After de-identification, the complete dataset evaluated in the current work were made available in the Mendeley Data depository database (<https://doi.org/10.17632/58xgbgsx8b.1>, accessed on 14 April 2022) [13].

Mean; standard deviation, SD; median; minimum; maximum; and 95% confidence intervals were calculated for all variables. Each parameter was tested for normal distribution using the D'Agostino and Pearson test. Comparisons between matching pre- and postoperative variables were performed using either the paired two-tailed *t*-test or the

Mann–Whitney test, as required. A statistical significance level of $p \leq 0.05$ was applied in each case.

Clinical outcomes are presented according to the standards for reporting refractive outcomes of intraocular lens-based refractive surgery [14].

3. Results

The pre- and postoperative records of 28 eyes of 15 patients (9 females and 6 males) were collected. Table 1 introduces the demographics and baseline optical values of the study population. The average age of the cohort was 52.4 ± 5.26 years. One patient was not eligible for the six-month visit, while another one could not attend the one-year check-up.

Table 1. Demographic and baseline characteristics of the subjects.

Demographic	Mean $\pm$ SD	Range
Age (y)	52.4 ± 5.26	45–64
Sex (n)		
Female	9 (60.0%)	
Male	6 (40.0%)	
AXL (mm)	22.66 ± 1.00	20.80–24.72
ACD (mm)	3.04 ± 0.29	2.54–3.02
K1 (mm)	7.91 ± 0.27	6.98–8.27
K2 (mm)	7.69 ± 0.23	6.89–8.05
CYL (D)	-0.45 ± 0.69	−2.75–0.50
SEQ (D)	2.78 ± 1.67	0.00–6.75
UDVA (logMAR)	0.54 ± 0.30	1.10–0.30
CDVA (logMAR)	0.01 ± 0.07	0.20–−0.10
UNVA (logMAR)	0.31 ± 0.42	0.90–0.20
CNVA (logMAR)	0.17 ± 0.11	0.20–0.00
IOP (mmHg)	15.1 ± 2.86	11.0–20.0
IOL power (D)	24.6 ± 3.69	17.5–33.0
IOL Cylinder (D)	1.23 ± 0.40	1.00–2.50

AXL: Axial length; ACD: Anterior chamber depth; K1 and K2: Keratometry values; CYL: Cylindric refraction; SEQ: Spherical equivalent refraction; D: Dioptre(s); UDVA: Uncorrected Distance Visual Acuity; CDVA: Corrected Distance Visual Acuity; UNVA: Uncorrected Near Visual Acuity; CNVA: Corrected Near Visual Acuity; IOP: Intraocular Pressure; IOL: Intraocular lens.

IOL-related complications could not be observed during surgery. Intraocular pressure was maintained in each case (<20 mmHg) during and after the operation (data not shown). One eye showed symptoms of anterior uveitis one month postoperatively, while two eyes developed endotheopathy three and six months following surgery. These conditions had cleared up within one month in all affected cases. No further adverse events that may be correlated with either the surgery or the IOL implantation occurred during the first postoperative year; however, one patient was diagnosed with dry-eye syndrome one year after surgery.

3.1. Refractive Outcomes—Astigmatism—Correction

The average preoperative spherical equivalent refraction of the patient group was 2.72 ± 1.62 D. Three months postoperatively, 96% of eyes were within 0.5 D, and 96% were within 1.0 D (Figure 1a) from the target refraction, emmetropia. The average subjective refractive astigmatism was -0.41 ± 0.46 D before surgery. The cylindrical correction was found to be effective: 89% of eyes had a residual astigmatism of not more than 0.5 D, and 96% of the eyes were within 1.0 from Plano (Figure 1b). The refractive outcomes remained stable during the first postoperative year in the majority of the cases (Figure 1c,d).

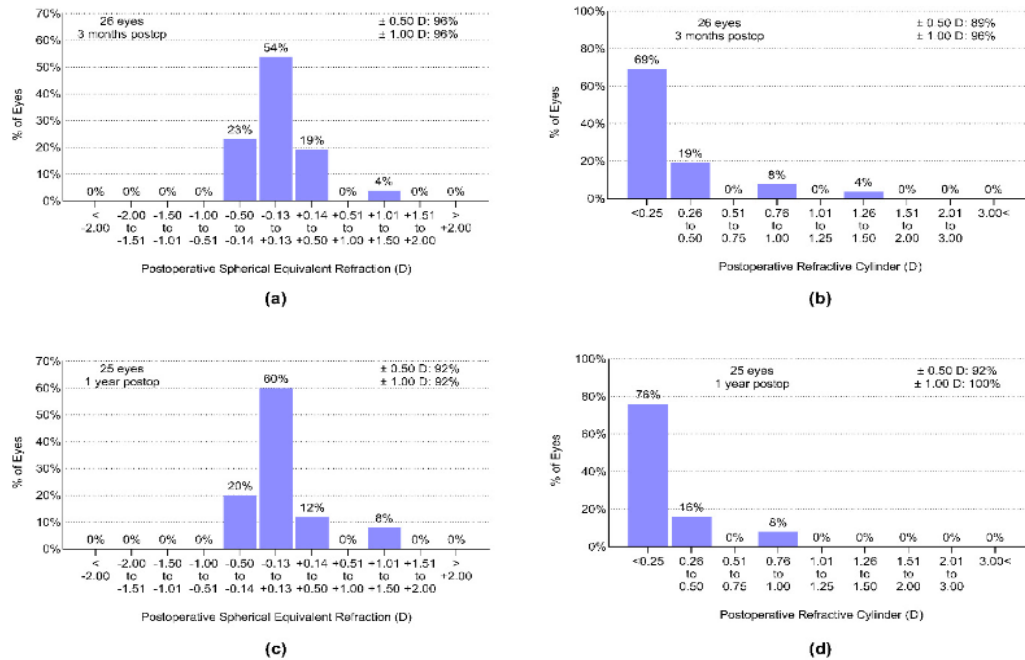


Figure 1. Spherical equivalent refraction and residual refractive cylindric refraction measured three months (a,b) and one year (c,d) postoperatively.

3.2. Vector Analysis

The astigmatism-correcting capacity of the study lens was examined with vector analysis. The magnitudes of the preoperative corneal and postoperative refractive astigmatism (measured 12 months after surgery at the corneal plane) are shown in the cumulative histogram, Figure 2. Figure 3 shows the double-angle plots of preoperative and postoperative refractive astigmatism. Centroid values and the 95% confidence ellipses are indicated in each graph. While the preoperative mean absolute corneal astigmatism was 1.18 ± 0.45 D, a mean residual refractive astigmatism of 0.16 ± 0.31 D could be measured twelve months postoperatively.

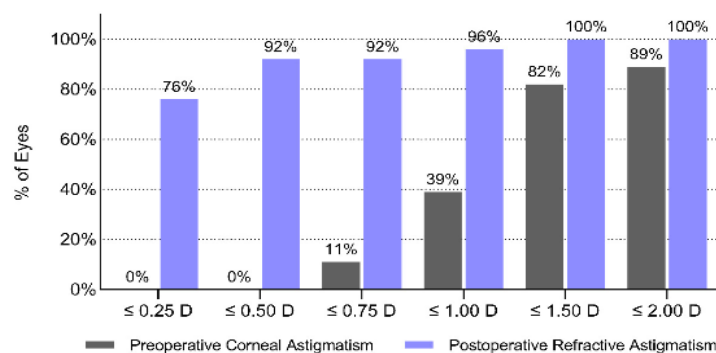


Figure 2. Cumulative histogram of preoperative corneal and postoperative refractive astigmatism measured one year postoperatively at the corneal plane.

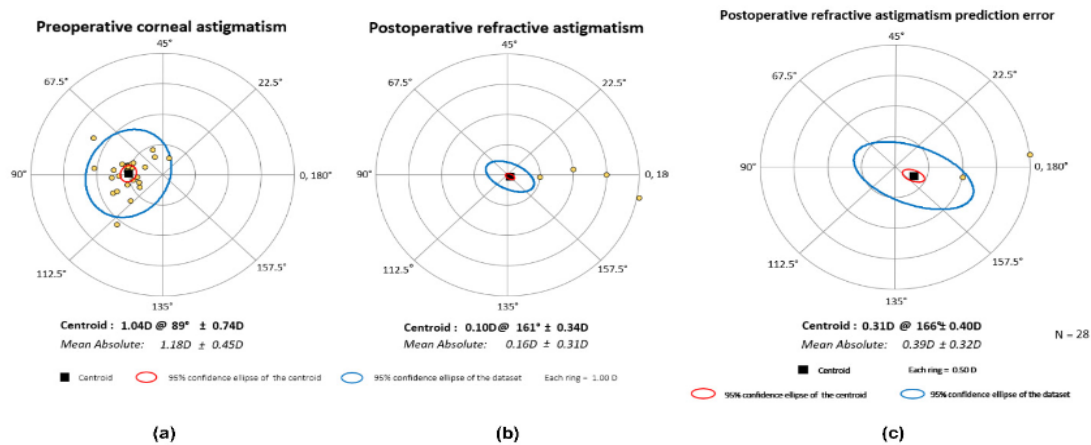


Figure 3. Double-angle plots of preoperative (a) and refractive astigmatism (b) and of the prediction error (c) measured and calculated one year after surgery.

3.3. Rotational Stability of the IOL

The rotational stability was determined by comparing the position of the toric marks of the IOL at each postoperative visit to the surgical position of the lens. There was no need for repositioning in any of the cases. Table 2 presents the average signed and absolute rotations during each postoperative visit. While the signed rotation takes the direction of the rotation into account, the absolute rotation disregards the direction and only considers the magnitude of rotation.

Table 2. Average absolute and signed off-axis rotation 3 months and 1 year following IOL implantation ¹.

Follow-Up Visit	Signed	Absolute
Month 3	−0.68 ± 2.58	2.04 ± 1.67
Month 6	0.04 ± 3.03	2.27 ± 1.95
Year 1	−0.35 ± 3.86	2.96 ± 2.42

¹ Results are presented as mean ± SD and expressed in degrees (°).

3.4. Visual Outcomes

A remarkable gain could be achieved in monocular uncorrected and corrected visual acuities at multiple distances, compared to the preoperative values (Table 3). UDVA increased from 0.54 ± 0.30 logMAR to 0.02 ± 0.08, and UNVA improved from 0.31 ± 0.42 to 0.19 ± 0.12 three months postoperatively, and to 0.21 ± 0.13 one year postoperatively. All measured values remained practically unchanged thereafter; however, a significant improvement in binocular distance-corrected near vision (DCNVA) could be observed between the third and twelfth postoperative months ($p = 0.0176$).

Figure 4a demonstrates the cumulative percentage of eyes in each category of monocular distance visual acuity. The monocular UDVA of 80.8% of the eyes was the same or better than the CDVA, while 92.3% of eyes were within one line of CDVA. The binocular distance-corrected intermediate and near visual acuities are shown in Figure 4b.

Table 3. Pre- and postoperative visual acuities (distance, intermediate, near) ¹.

Visual Acuity (logMAR)	Preop	Month 3	Year 1	Preop vs. Month 3 <i>p</i> =	Month 3 vs. Year 1 <i>p</i> =
Monocular					
UDVA	0.54 ± 0.30	0.02 ± 0.08	−0.01 ± 0.12	<0.0001	0.0861
CDVA	0.01 ± 0.07	−0.02 ± 0.05	−0.05 ± 0.12	0.0898	0.4126
UIVA	n.m.	0.18 ± 0.20	0.19 ± 0.16	n.a.	0.8438
CIVA	n.m.	0.02 ± 0.09	−0.01 ± 0.11	n.a.	>0.9999
UNVA	0.31 ± 0.42	0.19 ± 0.12	0.21 ± 0.13	0.0007	0.7051
CNVA	0.17 ± 0.11	0.15 ± 0.08	0.17 ± 0.10	0.4442	0.6133
Binocular					
CDVA	n.m.	−0.05 ± 0.11	−0.06 ± 0.09	n.a.	0.3125
DCIVA	n.m.	0.05 ± 0.08	0.04 ± 0.13	n.a.	0.3613
DCNVA	n.m.	0.11 ± 0.09	0.03 ± 0.11	n.a.	0.0176

¹ Results are presented as mean ± SD. n.m. = not measured; n.a. = not applicable. *p* values are the significance values from the Wilcoxon matched-pairs signed-rank tests. *p* values of not more than 0.05 were considered statistically significant. UDVA: Uncorrected Distance Visual Acuity; CDVA: Corrected Distance Visual Acuity; UIVA: Uncorrected Intermediate Visual Acuity; CIVA: Corrected Intermediate Visual Acuity; UNVA: Uncorrected Near Visual Acuity; CNVA: Corrected Near Visual Acuity; DCIVA: Distance-corrected Intermediate Visual Acuity; DCNVA: Distance-corrected Near Visual Acuity.

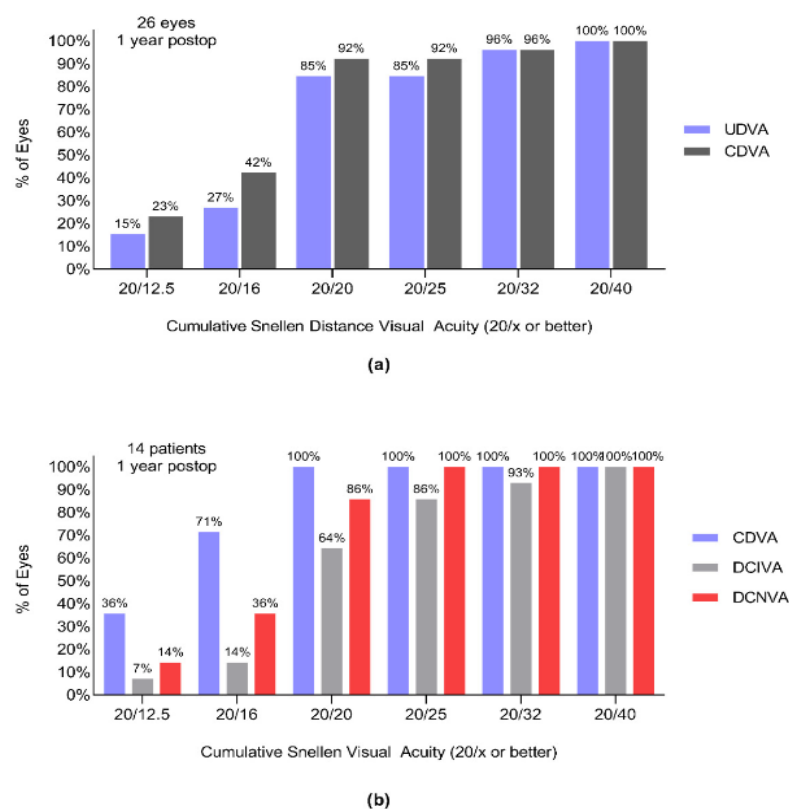


Figure 4. (a) Cumulative histogram of monocular uncorrected and corrected distance visual acuity. (b) Cumulative histogram of binocular distance-corrected visual acuities at multiple distances measured 1 year postoperatively.

Binocular visual acuity defocus curves were maintained during the one-year follow-up (Figure 5a). During the last visit, the mean VAs were 0.1 logMAR or better from +1.75 D to −3.25 D defocus (5.0 D wide defocus range). Contrast sensitivity defocus curves, which are reported to be more precise in reflecting small changes in optical quality than VA [15,16], show a non-significant improvement in the far and intermediate ranges between the third and twelfth postoperative months (Figure 5b).

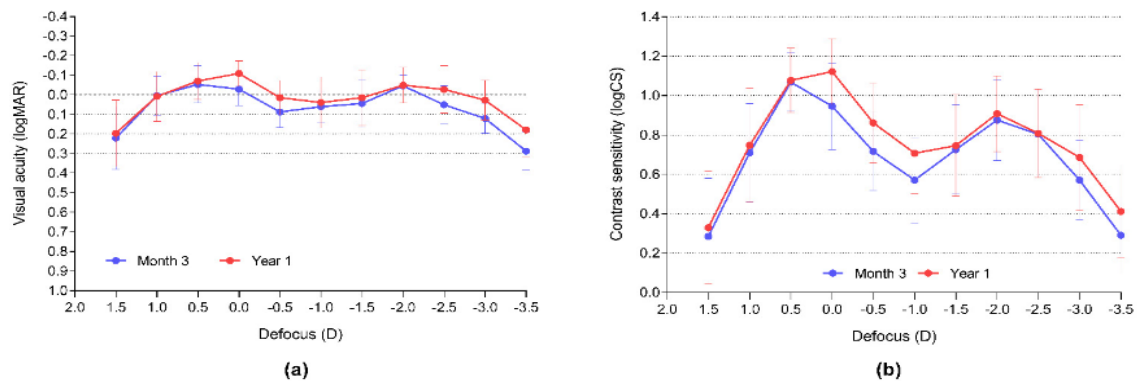


Figure 5. Binocular visual acuity (a) and contrast sensitivity (b) defocus curves confirm stable visual outcomes.

3.5. Visual Quality

Contrast sensitivities measured under different light conditions were stable post-surgery; no significant change could be revealed between the 3-month and 1-year results (data not shown; Figure 6).

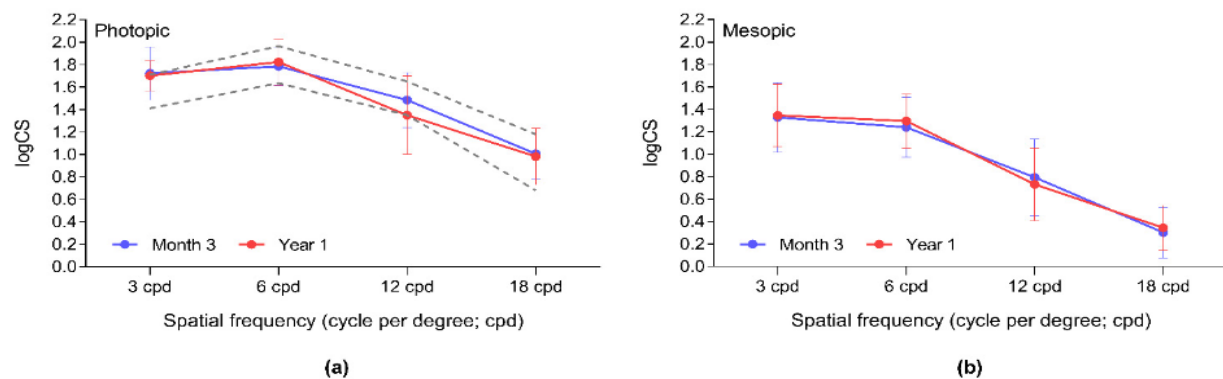


Figure 6. Photopic (a) and mesopic (b) contrast sensitivity is stable during the first postoperative year. Results are within the age-defined population normal values for the older age group (50–75 years of age) [17]. logCS: logarithm of Contrast Sensitivity; cpd: Cycle per degree.

The majority of patients had no, or only mild, difficulties performing their usual daily activities (Figure 7a), and all of them were highly satisfied with their vision (mean rating of 9.14 ± 1.23 on a scale from 1 to 10, where 10 represents the highest level of satisfaction; Figure 7b).

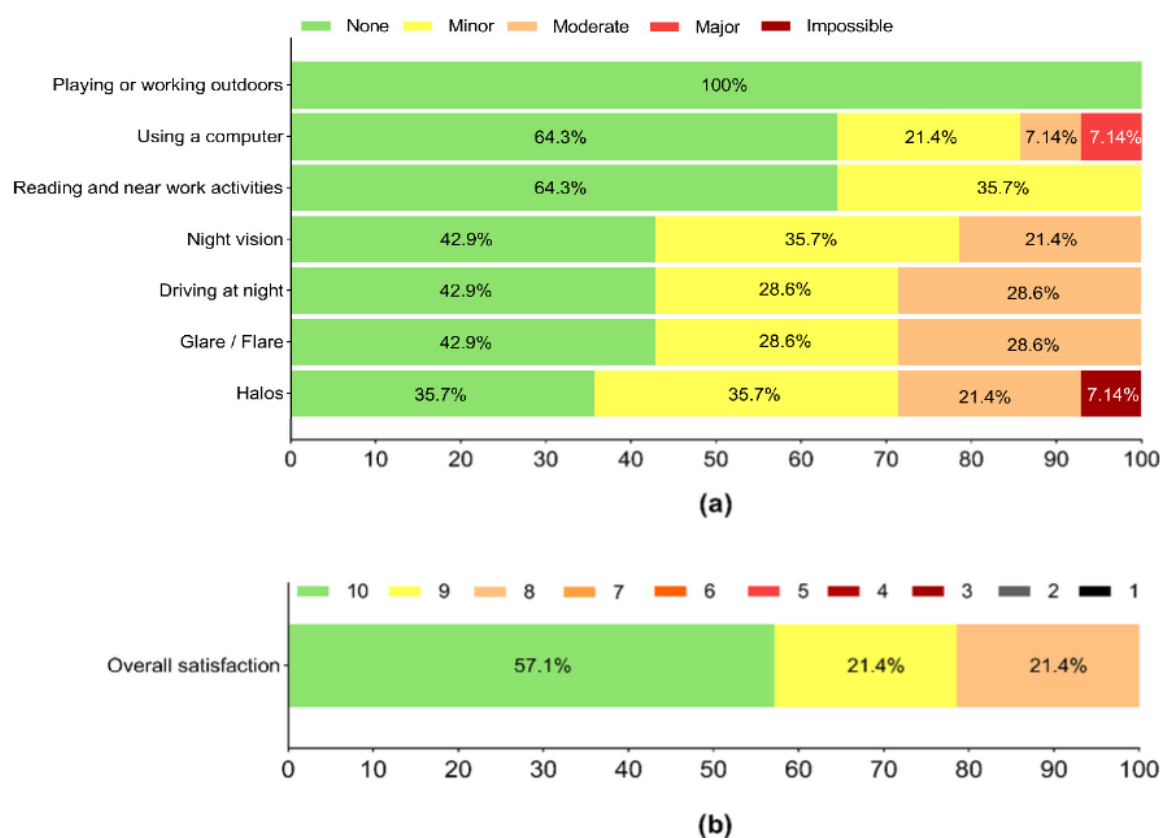


Figure 7. Visual function questionnaires reflected no or minor difficulties while performing general daily activities (a,b), and high patient satisfaction on a scale of 1 to 10 (1 = lowest satisfaction, 10 = highest satisfaction). Horizontal axes represent the percent (%) of patient responses, while colours represent the possible responses.

4. Discussion

Our current work aimed to evaluate the refractive and visual outcomes, including the assessment of visual quality and visual functions, and the astigmatism-correcting efficiency of the astigmatism correction Bi-Flex Liberty 677MTY trifocal toric capsular bag IOL.

The pre- and postoperative data of 15 cataract patients recorded during the first year following surgery were collected and evaluated. Implantation and the investigated IOL were shown to be safe, as no persistent complication directly related to the intervention could be registered.

Astigmatism correction was found to be efficient: the majority of eyes achieved postoperative refraction close to or at the target refraction, emmetropia. Our figures are similar to those we reported earlier following the implantation of the Bi-Flex 677TAY monofocal toric IOL [11] and are somewhat better than those reported by Bachernegg et al. for the same monofocal toric lens [18]. As expected, the current residual SEQ is lower than that observed after the implantation of the Bi-Flex Liberty 677MY trifocal non-toric IOL model [19], as additional astigmatism correction improved the final refractive outcomes. The predictability of the results is found to be higher than that reported for other TTIOLs such as the FineVision Pod FT [20], and AT LISA tri 939MP [21,22]. In contrast to the findings of Vanderkerckhove et al. [23], who found that 81.1% of the eyes were within

0.5 D from the target refraction 6 months following the implantation of the FineVision PodFT IOL, but only 65% 1 year postoperatively, our results remained unchanged during the one-year follow-up (89% and 92%, respectively), suggesting refractive stability. Vector analysis confirmed the efficiency of astigmatism correction, and our findings are in good agreement with those of the same but monofocal IOL model [11].

Rotational stability was high and similar to that reported on the monofocal toric model of the same lens [11,18]. Mean IOL-rotations were comparable with those published on TTIOs with modified L- or double C-loop haptic designs [24]; however, unlike with AT LISA tri 939MP and FineVision PodFT, no IOL-repositioning was required [19,20]. A stable IOL position contributed to the maintained refractive and visual outcomes. Our findings are in agreement with the previous reports [25,26], claiming that toric IOL rotations of less than 10 degrees do not change the eye's refraction by less than 0.50 D.

Visual outcomes reflect the refractive results. Visual acuities and defocus curves confirm efficient presbyopia correction. The mean binocular distance-corrected visual acuities were 0.1 logMAR or better from +1.25 to −3.25 D defocus values, which are equal to infinite to cc. 30 cm reading distance. This range is wider than that reported for the PanOptix Toric and FineVision Pod FT IOLs (3.75 D range) [24,27], or for the AT LISA Tri Toric model (3.00 D range) [28].

Photopic contrast sensitivities were within the normal range for the elderly population [29]. Mesopic CS values were close to the normal values for lower spatial frequencies except for 18.0 cpd, which was within the normal range, similar to that reported on a plate-haptic TTIO [27]. Both our photopic and mesopic measures are comparable with those reported on the non-toric Bi-Flex 677TAY model [19,30]. Although CS measurements are difficult to compare due to their subjective nature and various scales used in reporting the results, we could not detect remarkably lower CS values at higher spatial frequencies as was seen with other TTIOs [22,24,31].

Similar to previous findings with other TTIOs in the literature [27,28], our patients were able to perform their daily visual tasks without any, or only minor difficulties. High satisfaction was reported in each case. The limitation of our investigation is that we did not perform a detailed dysphotopsia evaluation; however, none of our patients complained about intolerable photic disturbances. Previous works with the non-toric trifocal 677MY IOL reported rare and minor occurrences of dysphotopic phenomena [19,30,32,33].

Our work has several limitations. We evaluated patient records collected retrospectively, and due to the COVID-19 pandemic, several patients could not attend all pre-scheduled visits. Hence, only a limited number of patients could be enrolled in the analysis. Visual functions were tested with our regularly used, but non-validated, questionnaire; therefore, the comparison of the results with other results published in the scientific literature is difficult.

The main advantage of our investigation might be the relatively long (one-year) follow-up period, which is rare among the scientific papers published on TTIOs. Only four publications with similar longitudinal monitoring could be found in the literature [21,23,31,34]. Moreover, according to our knowledge, this is the first paper published on the refractive and visual outcomes following the implantation of the Bi-Flex 677MTY lens.

5. Conclusions

Our findings suggest that the TTIO in focus is safe and efficient in the simultaneous correction of presbyopia and preoperative corneal astigmatism. The patients' vision is restored in a wide defocus range, and good visual quality enables them to perform various tasks independently of the required distance. The IOL position and hence the refractive and visual outcomes are found to be stable, which is the key to long-term patient satisfaction. Further examinations and a larger number of subjects are required to confirm the present findings, but our results suggest that the examined TTIO is a good option for astigmatic patients with high visual expectations.

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Institutional Review Board Statement: The current clinical evaluation was approved by the Ethics Committee of the University Hospital Hradec Králové (Reference number: 202204 P01; 8 March 2022). The data management and the entire clinical study adhered to the principles of the Declaration of Helsinki [6].

Informed Consent Statement: The current evaluation was performed retrospectively, so there was no need to obtain informed consent from the subjects involved in the study.

Data Availability Statement: All pre- and postoperative data collected during the study are available after de-identification in the Mendeley Data depository database from <https://doi.org/10.17632/58xgbgsx8b.1> (accessed on 14 April 2022) [13].

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Research Article

Use of Simultaneous Bilateral Cataract Surgery (SBCS) to Optimize Parameters Affecting the Subjective Perception of the Procedure

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Introduction. Simultaneous Bilateral Cataract Surgery (SBCS) is still a relatively controversial procedure. The main objection is the risk of bilateral endophthalmitis or bilateral refractive error. However, SBCS has also some advantages (faster visual rehabilitation, lower risk of nosocomial infection, and lower cost). Performing surgery on both eyes in one session has one additional advantage which has not yet been described in the literature (according to the information available to authors). It allows surgeons to distinguish the effect of minor differences in the surgical protocol on the subjective perception of the procedure more accurately, which is a more suitable method than comparing two independent groups of patients. **Purpose.** To compare the effect of minor changes in the surgical protocol during SBCS on intraindividual subjective perception of surgery (pain, pressure, glare, and perception of the duration of the surgery). **Methods.** During the surgery of the right and left eyes of one patient, we randomly changed one surgical parameter (use of intracameral anesthesia, light intensity of the operating microscope, type of eyelid speculum, creation of the posterior circular capsulorhexis, and communication with the patient during surgery). Patients immediately after both surgeries subjectively evaluated the perception of pain (on the scale 0–10), pressure, and glare (on the scale 0–5) and estimated the duration of the surgery, separately for each eye. Each change was evaluated in a group of 50 patients. **Results.** In the control group with no parameters changed, we noted no difference in subjective perception of the first and second surgery. In subgroups, where we changed the protocol, we detected only minor differences in subjective perception of pain, pressure, glare, and duration of the surgery. Only one statistically significant difference in subjective pain perception was in the subgroup where we used eye intracameral anesthesia (0.34 eyes with intracameral anesthesia, 0.44 eyes with only topical anesthesia). We did not note any statistically significant differences in the perception of the time of surgery. **Conclusion.** SBCS can be used to optimize the parameters of cataract surgery. In our study, we noted a positive effect of intracameral anesthesia on subjective perception of surgery.

1. Introduction

Simultaneous Bilateral Cataract Surgery (SBCS), in the literature also known as Immediately Sequential Bilateral Cataract Surgery (ISBCS), is still a relatively controversial practice in the treatment of bilateral cataract surgery. The main opponents' argument is the risk of bilateral blindness due to severe

postoperative complications, such as endophthalmitis, toxic anterior segment syndrome, or pseudophakic bullous keratopathy [1–5]. However, it has been repeatedly reported that, with careful selection of patients and strict adherence to the protocol, this risk is minimal [6, 7].

Another argument against this is the impossibility of adjusting the calculation of the value of the intraocular lens

(IOL) in the case of refractive deviation in the first operated eye [8].

On the other hand, the SBCS has a number of advantages over the Delayed Sequential Bilateral Cataract Surgery (DSBCS), for instance, the decrease in waiting time for surgery, faster rehabilitation, patient convenience, and time savings and cost savings for healthcare providers [9–12].

However, SBCS brings another little-mentioned advantage for cataract surgery research. Performing surgery on both eyes during one stay in the operating room allows the patient to compare subjectively the course of surgery on each eye. In the case of a minor change in the surgical protocol during surgery on one and the other eye of the same person (within the limits of the guidelines), the patient can evaluate the effect of such change on subjective perception. In the case of delayed surgery of both eyes, it is very difficult for the patient to notice small changes in subjective perception. Researchers had to create two large groups of patients to compare the influence of change. In the case of the method described by us, the patients subjectively compare the difference in one and the other eye (intraindividually). This minimizes selection bias.

This study aims to compare the effect of minor changes in the surgical protocol (use of intracameral anesthesia, light intensity of the operating microscope, type of eyelid holder, creation of the posterior circular capsulorhexis, and communication with the patient during surgery) on intra-individual subjective perception of surgery (pain, pressure, glare, and perception of the duration).

2. Participants and Methods

The present study was conducted as a prospective, monocentric, randomised, blinded study. It was performed at the Somich eye clinic, Karlovy Vary, Czech Republic. Patients with bilateral cataracts who had uneventful SBCS in the period between July 2019 and March 2020 at the Somich eye clinic were consecutively enrolled. The exclusion criteria were amblyopia of one eye, the difference of the planned value of the implanted intraocular lens between both eyes greater than 1.5 D, previous intraocular surgery, a history of eye injury, severe fundus pathology, severe corneal scars, and perioperative complications. The study protocol was approved by the Ethics Committee following the Declaration of Helsinki. All participants signed an informed consent form before participation in this study.

2.1. Surgical Technique. All surgeries were done by one high volume surgeon (PS), and both surgeries were performed as two separate interventions during one patient stay in the operating room. The protocol of surgery meets the recommendation of the International Society of Bilateral Cataract Surgeons [13]. We always performed right eye surgery first, and then left eye. Immediately after the surgery, patients received standard eyedrop medication with antibiotic and nonsteroidal anti-inflammatory drops, and eyes were left uncovered. The nurse recorded the exact time of both surgeries from the time the speculum was put on and after it was removed again.

2.2. Assessment. After undergoing surgery on both eyes and leaving the operating room, patients completed a simple questionnaire with the help of a nurse who read the questions to the patients and wrote down their answers. In our questionnaire on the numerical scale, the patients expressed pain (0–10, 0 no pain, 10 maximum unsustainable pain), perception of pressure (0–5, 0 no pressure, 5 maximum pressure), and feeling of glare (0–5, no problem with glare, 5 maximum glare) and they also estimated the duration of the surgery.

2.3. Groups of Patients. At first, we examined 50 patients (100 eyes) with no change between the two surgeries, to see if subjects perceived a subjective difference in both eye surgeries, for instance, depending on whether it was the first or second eye surgery (control subgroup).

Then, we gradually changed these parameters of the surgery; for each changed parameter, we created a group of 50 patients (100 eyes):

Anesthesia—in one eye we used only topical anesthesia, in the other eye additionally was administered 0.02 ml of Mydrane (Phenylephrine hydrochloridum, Tropicamidum, Lidocaini hydrochloridum), (Laboratoires Thea, Clermont Ferrand Cedex 2, France)—subgroup 1.

Light intensity of the surgical microscope—OPMI Lumera 700 (Carl Zeiss Meditec AG, Jena, Germany), in one eye illumination was 40% of the maximal intensity, in the other eye 80%—subgroup 2.

Speculum (Lieberman type—both) with a solid (closed) blade in one eye and wire (open) blade speculum in the other—subgroup 3.

Creation of the primary posterior circular curvilinear capsulorhexis (PPCCC)—in one eye was left posterior capsule intact, in the other eye we made PPCCC—subgroup 4.

Communication during surgery—during the operation of one eye, the surgeon communicated with the patient practically all time, and during the procedure of the other eye, the communication between the surgeon and patient was minimal—subgroup 5.

The changed parameter was used randomly on the right or left eye. The patient was not informed either of which parameters were changed or in which eye.

2.4. Statistical Analysis. Statistical analysis was performed using SPSS Statistics software (version 21, IBM Corp.) The comparison was performed by Student's paired *t*-test in the case of normal distributed variables and nonparametric Wilcoxon's test in the case of nonnormal distributed variables. A *p* value less than 0.05 was considered statistically significant.

3. Results

Table 1 shows the baseline and demographic data. The mean age was 72.5 ± 8.4 years (range 46–93 years). The similar mean age was also in the different subgroups. The small differences were not statistically significant. Number of men

TABLE 1: Baseline and demographic data of the study population.

Parameter	All patients	Subgroup					
		Control	(1) Anesthesia	(2) Light	(3) Speculum	(4) PCCC	(5) Communication
Mean age (years)	72.5 ± 8.4	70.4 ± 7.5	73.2 ± 8.0	71.8 ± 8.9	72.3 ± 8.7	73.5 ± 7.4	73.7 ± 8.4
Male (N (%))	114 (38.0)	19 (38.0)	14 (28.0)	21 (42.0)	17 (34.0)	18 (36.0)	25 (50.0)
Female (N (%))	186 (62.0)	31 (62.0)	36 (72.0)	29 (58.0)	33 (66.0)	32 (64.0)	25 (50.0)
Eye (N)	600	100	100	100	100	100	100
OD (N)	300	50	50	50	50	50	50
OS (N)	300	50	50	50	50	50	50
Mean power of implanted IOL (D)	21.3 ± 3.2	20.5 ± 2.8	21.2 ± 3.3	21.3 ± 2.9	21.7 ± 3.4	22.2 ± 3.5	21.5 ± 2.7

in all groups was 114 (38%), and the number of women was 186 (62%). This ratio was similar in all subgroups, apart from subgroup 5 which had the same number of men and women. The mean power of the implanted intraocular lens (IOL) was 21.3 ± 3.2 D and this value was similar in all different subgroups (statistically not significant differences).

In the control group, in which we did not change any parameters during the surgery of the right and left eyes, we did not find any statistically significant difference between the perception of right and left eye surgery. Differences between pain, pressure, and glare perceptions were minimal, statistically not significant (Table 2). We also did not register any difference in the time perception of the surgery duration. The mean real time of surgery was 262 ± 62 seconds on the right eye and 261 ± 71 seconds. The subjectively perceived time of surgery was 259 ± 121 on the right eye and 262 ± 129 on the left eye (Table 3). This means that the patients perceived the duration of surgery on average 8 seconds longer in the right eye and 2 seconds shorter in the left eye, respectively. The difference was not statistically significant.

In the individual subgroups, we did not notice (with one exception) any difference in the perception of pain, pressure, and illumination during surgery between the two eyes. Additionally, the perception of the duration of the surgery did not differ, or the differences were not statistically significant. The only difference in the perception of pain during the surgery was noted in subgroup 1 with a changed type of anesthesia. In the eye where Mydrane was used intracamerally, the mean value of subjectively perceived pain was 0.32 ± 0.71, while in the eye where only superficial anesthesia was used, the value was 0.44 ± 0.81. This difference was statistically significant (Tables 4 and 5).

4. Discussion

One of the earliest scientific reports of simultaneous binocular cataract in one operating session was published in 1952 [14], initially applied to ICCE operations. Over the years, surgical techniques were refined and supporters of SBCS appeared. SBCS began to become more common with the rise of small incision phacoemulsification [10]. SBCS is fully accepted in paediatric patients, or otherwise handicapped, especially if the surgeries are performed under general anesthesia. The risk of death during the second general anesthesia statistically exceeds the risk of bilateral blindness due to a serious complication [6], though in general the popularity of SBCS increases in the case of

uncomplicated bilateral surgery for age-related cataracts, under topical anesthesia.

At our clinic, we standardly perform 80–90% of procedures with the technique SBCS, so far without any serious complications. Interestingly, some patients spontaneously perceived some differences in their right and left eye surgery, despite the fact that the operation was relatively the same. In the first phase of our study, we therefore tried to register differences in the perception of surgery in both eyes.

In clinical practice, it is a common observation amongst ophthalmic surgeons that patients with bilateral cataracts often report more pain and discomfort during the second consecutive eye surgery (DSBCS). Previous studies have investigated this observation and have also reported an increase in pain in the second surgery relative to the first [15–17]. Yu et al. published the results of subjective sensation of the surgery of both eyes in the group of 127 patients with bilateral cataracts, operated as DSBCS (the interval between surgeries was approximately 1 month). Patients experienced less anxiety, a greater number of eye bulges, and greater pain during the second cataract surgery compared with the first surgery. The differences in the scores for light sensitivity between surgeries were not statistically significant [18]. Adatia et al. in their study described that of 125 patients who rated second eye surgery as the generally more unpleasant procedure, 90 (72.0%) were similarly or more relaxed during the second procedure. Second-eye cataract surgery was perceived as being a longer and/or more painful procedure by a significant number of patients (45.4%) [19]. Finally, Shi et al. published a meta-analysis of seven studies by comparing pain scores, assessed shortly after phacoemulsification under local anesthesia. This analysis showed that there were statistical differences in pain values between the first and the second eye (WMD: 0.69; 95% CI: 0.40, 0.98; $p < 0.00001$; with high heterogeneity ($I^2 = 80\%$). The pain value was lower in patients who underwent the first eye surgery [20]. Ursea et al. hypothesized that a subtle increase in pain in the second surgery relative to the first appears to be associated with decreased preoperative anxiety and may be related to the amnesic effect of intravenous sedation [16]. Also, Jiang et al. and Nijkamp et al. in their studies confirmed that greater pain in the second operated eye is related to less anxiety [21, 22]. However, according to the information available to us, so far, no one has found a difference in the perception of surgery on both eyes if they were performed on the same operation day (SBCS).

TABLE 2: Perception of pain, pressure, and glare in the control subgroup (without change of any parameter between the right and left eye): mean $\pm$ SD, median (min-max); p values of Wilcoxon signed-rank test between right and left eye.

Eye	Pain		Pressure		Glare	
	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)
Both eyes	0.72 $\pm$ 1.11	0 (0-5)	1.02 $\pm$ 0.85	1 (0-4)	1.12 $\pm$ 1.20	0 (0-4)
Right eye	0.70 $\pm$ 1.14	0 (0-5)	1.04 $\pm$ 0.92	1 (0-4)	1.10 $\pm$ 0.85	0 (0-4)
Left eye	0.74 $\pm$ 1.07	0 (0-5)	1.00 $\pm$ 0.77	1 (0-3)	1.14 $\pm$ 0.92	1 (0-4)
p value right vs. left		0.299		0.344		0.161

TABLE 3: Comparison of perception of time of surgery in the control subgroup (without change of any parameter between right and left eye): mean $\pm$ SD; p values of paired t -test between right and left eye and between real and subjectively perceived time.

Eye	Real time (sec)	Subjectively perceived time (sec)	p value real vs. perceived
	Mean $\pm$ SD	Mean $\pm$ SD	
Both eyes	261.62 $\pm$ 74.79	255.90 $\pm$ 131.20	0.686
Right eye	260.76 $\pm$ 65.48	258.26 $\pm$ 124.98	0.903
Left eye	262.48 $\pm$ 83.81	253.54 $\pm$ 138.49	0.484
p value right vs. left	0.913	0.864	

In our group of 50 patients (control subgroup), the differences between pain, pressure, and glare perceptions were minimal and statistically not significant. We also did not register any difference in the time perception of the duration of the surgery. This means that if a change is made during the surgery of one of the two eyes, that patient could register such a change in the perception of pain, pressure, glare, or in estimating of the time of surgery. We had selected five minor changes that we perform on our patients if necessary during the surgical protocol and that did not affect the outcome of the operation. In the study, we always performed a change in one of the parameters in a targeted manner in a group of patients, randomly to the first or second operated eye.

The effect of intracameral anesthesia on pain perception during surgery has been published quite frequently. Nebbioso et al. summarized that intracameral administration of lidocaine is a simple and secure method able to increase the analgesia during cataract surgery, eliminating the discomfort and increasing the cooperation of the patients during the steps of manipulation [23]. On the contrary, Crandall et al. did not find a statistically significant difference but described that patients in the lidocaine group reported being less bothered by tissue manipulation. The surgeon assessment also showed more patient cooperation in the lidocaine group [24]. Ezra and Allan published a meta-analysis, a total of eight trials comprising 1281 patients. Their data comparison showed a significantly lower intraoperative pain perception in patient groups using supplementary intracameral lidocaine, although the difference was small. No significant difference was demonstrated between the groups receiving topical anesthesia alone and topical combined with intracameral anesthesia in terms of need for supplemental anesthesia, intraoperative adverse events, or corneal toxicity [25].

In our subgroup of patients with changed types of anesthesia, we noticed a statistically significant difference in the perception of pain. The pain of the surgery (or the difference between the right and left eye) was assessed by the patients in general, after surgery. We did not determine the effect of individual steps. The pain was lower in the eyes, where

intracameral anesthesia (Mydrane) was used, in addition to topical anesthesia, in comparison to eyes with topical anesthesia alone, although its use did not affect the perception of pressure, glare, or duration of the surgery.

Relatively few papers have been published on the influence of lighting intensity on the subjective perception of surgery. Most patients perceive a light sensation during surgery, while many of them describe this sensation as unpleasant. Biró and Schvöller in their prospective study noted that every patient saw lights of different and changing intensity. One hundred and twenty-six (95.5%) patients saw different colours; 13.6% patients saw a rainbow-like scale of colours; 74.2% patients could see clear shapes and forms (mainly circle, square, rectangle, and ellipse). Forty-nine (37.1%) patients could see the instruments, and 35 (26.5%) patients saw the fingers of the surgeon during surgery. Twenty-six patients (19.7%) considered the strong light of the microscope very disturbing and uncomfortable. The authors found no relation between intraoperative visual sensation and patient's age, sex, preoperative visual acuity, duration of surgery, or cataract severity [26]. Kim et al. compared the microscope illumination and intracameral illumination. They concluded that the microscope ocular illuminance and irradiance during cataract surgery were higher in the microscope illumination than in the intracameral illumination. It suggests that light exposure reaching the patient's and surgeon's retina during cataract surgery is lower in the intracameral illumination than in the microscope illumination [27]. A similar work with the same conclusion was also published by Seo et al. The authors summarized that, in view of the patients' visual experience, oblique intracameral illumination caused less subjective photostress and was preferred over coaxial microscope illumination [28].

In our group of patients, in which we operated with 40% microscope intensity illumination in one eye and in the other eye with 80%, we did not observe any effect on the subjective perception of pain, pressure, or duration of the operation. Surprisingly, the patients did not notice any

TABLE 4: Comparison of perception of pain, pressure, and glare between eyes with and without changing parameters of surgery in 5 subgroups: mean $\pm$ SD, median (min-max); *p* values of Wilcoxon signed-rank test.

Subgroup	Pain		Pressure		Glare	
	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)	Mean $\pm$ SD	Median (min-max)
<i>(1) Anesthesia</i>						
Only topic	0.44 $\pm$ 0.81	0 (0-3)	0.60 $\pm$ 0.70	0 (0-3)	0.62 $\pm$ 1.01	0 (0-3)
Intracameral	0.32 $\pm$ 0.71	0 (0-3)	0.52 $\pm$ 0.58	0 (0-2)	0.62 $\pm$ 1.05	0 (0-4)
<i>p</i> value topic vs. intr.		0.032*		0.351		1.000
<i>(2) Light intensity</i>						
40%	0.80 $\pm$ 1.50	0 (0-7)	0.88 $\pm$ 0.96	0 (0-3)	0.82 $\pm$ 1.10	0 (0-4)
80%	0.92 $\pm$ 1.83	0 (0-10)	0.82 $\pm$ 1.02	0.5 (0-4)	0.86 $\pm$ 1.11	0.5 (0-4)
<i>p</i> value 40% vs. 80%		0.444		0.537		0.598
<i>(3) Speculums</i>						
Solid	0.49 $\pm$ 0.83	0 (0-3)	0.57 $\pm$ 0.67	0 (0-2)	0.67 $\pm$ 1.09	0 (0-4)
Wire	0.50 $\pm$ 0.73	0 (0-2)	0.47 $\pm$ 0.58	0 (0-2)	0.61 $\pm$ 1.06	0 (0-4)
<i>p</i> value solid vs. wire		0.837		0.301		0.083
<i>(4) PPCCC</i>						
Intact	0.50 $\pm$ 1.28	0 (0-6)	0.90 $\pm$ 0.93	1 (0-3)	0.78 $\pm$ 1.13	0 (0-3)
PPCCC	0.46 $\pm$ 1.05	0 (0-8)	0.94 $\pm$ 0.91	1 (0-3)	0.72 $\pm$ 0.99	0 (0-4)
<i>p</i> value intact vs. PPCCC		0.659		0.699		0.444
<i>(5) Communication</i>						
No	1.18 $\pm$ 1.85	0 (0-7)	1.00 $\pm$ 1.18	1 (0-4)	1.30 $\pm$ 1.25	1 (0-4)
Speaking	1.16 $\pm$ 1.844	0 (0-10)	1.00 $\pm$ 1.16	1 (0-4)	1.30 $\pm$ 1.27	1 (0-4)
<i>p</i> value no vs. speaking		0.932		1.000		1.000

*Statistically significant results are marked in bold.

TABLE 5: Comparison of perception of time between eyes with and without changing parameters of surgery in 5 subgroups: mean $\pm$ SD; *p* values of paired *t*-test between real and subjectively perceived time.

Subgroup	Real time (sec) Mean $\pm$ SD	Subjectively perceived time (sec) Mean $\pm$ SD	<i>p</i> value real vs. perceived
(1) <i>Anesthesia</i>			
Only topic	268.82 $\pm$ 60.23	234.30 $\pm$ 90.96	0.027*
Intracameral	266.56 $\pm$ 44.47	234.68 $\pm$ 89.17	0.028*
<i>p</i> value topic vs. intracameral	0.831	0.983	
(2) <i>Light intensity</i>			
40%	281.96 $\pm$ 58.96	296.04 $\pm$ 143.45	0.457
80%	297.58 $\pm$ 70.95	286.50 $\pm$ 160.48	0.530
<i>p</i> value 40% vs. 80%	0.234	0.755	
(3) <i>Speculums</i>			
Solid	275.52 $\pm$ 49.76	276.36 $\pm$ 104.62	0.589
Wire	283.36 $\pm$ 56.86	272.20 $\pm$ 98.71	0.470
<i>p</i> value solid vs. wire	0.465	0.812	
(4) <i>PPCCC</i>			
Intact	290.68 $\pm$ 64.98	310.26 $\pm$ 147.52	0.368
PPCCC	312.36 $\pm$ 70.04	314.40 $\pm$ 155.85	0.931
<i>p</i> value intact vs. PPCCC	0.112	0.892	
(5) <i>Communication</i>			
No	303.10 $\pm$ 85.15	339.22 $\pm$ 138.56	0.111
Speaking	292.44 $\pm$ 97.45	232.32 $\pm$ 180.52	0.193
<i>p</i> value no vs. speaking	0.562	0.622	

*Statistically significant results are marked in bold.

greater difference in the degree of glare. In the eye with 40%, the mean described glare was 0.82 ± 1.10 , in the eye with 80% 0.86 ± 1.11 , but the difference was not statistically significant.

The effect of cataract density can rather be ruled out, as only patients with approximately symmetrical cataracts in both eyes were included into the study.

Very few papers have also been published on the effect of speculum on the subjective perception of surgery. Crosby et al. investigated the effect of eyelid holder on postoperative ptosis. They concluded that the different speculae have significantly different forces on patients' eyelids during surgery. The patients who experience the greatest compression of the

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Použité zkratky

CLE	výměna čiré čočky (Clear Lens Extraction)
EDOF	nitrooční čočka s prodlouženým fokusem
ERG	elektroretinogram
IOL	nitrooční čočka
KOSO	kvalita optického systému oka (je dána OSI a MTF)
MFIOL	multifokální nitrooční čočka
MFTIOL	multifokální torická nitrooční čočka
MTF	modulation tranfer function (modulační přenosová funkce)
NOT	nitrooční tlak
NKZO	nejlépe korigovaná zraková ostrost (UCVA)
NZO	nekorigovaná zraková ostrost
OCT	optická koherentní tomografie
OSI	objective scatering index (rozptylový index)
OSO	optický systém oka
PSF	Point spread Function
SEQ	sférický ekvivalent
VEP	evokovaný zrakový potenciál (Visual electric potencial)
ZRV	zbytková refrakční vada

Obrázky

Obrázek 1: Anatomická struktura lidského oka

Obrázek 2. Zrakový systém člověka, včetně projekce vláken zrakového nervu z pravého a levého oka do mozkové kůry - optická dráha (Šikl 2012, s.68)

Obrázek 3. Schéma HD analyzátoru

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Obrázek 5. HD analýza o implantované monofokální IOL se žlutým filtrem mimo mesopickou oblast za denních a nočních podmínek

Obrázek 7. HD analýza u MF IOL za denních a nočních podmínek

Obrázek 7. HD analýza u MF IOL za denních a nočních podmínek

Obrázek 8. Dotazník zachycuje žádné mírné potíže v denním životě (a,b) a vysokou spokojenost pacientů ve škále 1 až 10 (1 = nejnižší spokojenost, 10 = nejvyšší spokojenost), horizontální osa reprezentuje (%) odpovědí pacientů, zatím co barevná škála označuje spokojenost

Obrázek 9. Graf Kontrolastní citlivosti, měřena za různých světelných podmínek, 12 měsíců po operaci. (a) za fotopických podmínek. (b) za fotopických podmínek s glare (c) za mesopických podmínek

Obrázek 10. Graf odpovědí - Hlavní na (a) dysfotopisie a (b) posouzení zrakových funkcí použitím modifikovaného dotazníku 12 měsíců po operaci. 1= žádné potíže, 2 = minimální potíže, 3 = střední potíže, 4 = znatelné potíže, 5=nedokážu rozeznat-nedoprovází, žádné signifikantní rozdíly mezi oběma IOL nebyly zaznamenány

Obrázek 11. Distribuce odpovědí na dotazy položené pacientům na obtíže způsobující (a) zamlžené vidění, (b) glare/flare. Subjektivní hodnocení byl učiněn pomocí modifikovaného dotazníku (Visual Function Questionnaire form) 12 měsíců pooperačně

Obrázek 12. Celková spokojenost uváděná pacienty po implantaci IOL. Obě skupiny uváděly vysokou míru spokojenosti, přesto, že ve skupině AT LISA tri byly uváděny obtíže s větší variabilitou. 10 = nejvyšší stupeň v žebříčku, 1 = nejnižší stupeň v žebříčku

Obrázek 13. Graf procentuálního zastoupení očí, u kterých se musela provést NdYAG capsulotomie pro významnou opacifikaci zadního pouzdra, zhoršující zrakovou ostrost, Zastoupení NdYAG laserové capsulotomie v prvním pooperačním roce.

Tabulky

Tabulka 1. ukazuje refrakční výsledky ve 3 a 12 měsíci poperačně, kterých bylo mimojiné dosaženo záhy po implantaci TIOL. Porovnáním hodnot residuální refrakce (SEQ a CYL) při pooperačních kontrolách prokazujeme stabilitu v čase

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Tabulka 3. Porovnání vnímání doby zákroku oproti kontrolní skupině (beze změn parametrů mezi operací pravého a levého oka)

Tabulka 3. Porovnání vnímání doby zákroku oproti kontrolní skupině (beze změn parametrů mezi operací pravého a levého oka)