Effectiveness of Accommodating Intra Ocular Lens

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Abstract

Cataract surgery is effective in restoring distance vision. However, standard monofocal intraocular lenses (IOLs) have a fixed refractive power, leaving patients presbyopic and dependent on spectacles for near vision. Restoring the accommodative ability in pseudophakic patients is still challenging. This literature research focus to review the result of near visual acuity and amplitude of accommodation of available accommodating IOLs. Conducted from the Pubmed database and library research for journal articles that were published and related to accommodating IOLs using the keywords accommodating intraocular lens or monofocal intraocular lens or pseudophakic accommodation. Subjective and objective and measurement of amplitude of accommodation was observed. Subjectively, amplitude of accommodation is measured by defocus and near point of accommodation. Accommodation amplitude was measured by dynamic streak retinoscopy, power refractor and IOL movement objectively. Defocus measurement of accommodating IOL showed that the accommodative amplitude was between 0.94 D to 1.90 D and near point of accommodation (NPA) resulted in power around 0.5 D to 3.83 D meanwhile in the monofocal IOL, defocus power was between 0 to 1.52 D and NPA was between 0.42 D to 2.4 D. Dynamic retinoscopy of accommodating IOL showed power between 0.98 D to 0.99 D while monofocal IOL ranged between 0.17 D to 0.24 D. The movement of accommodating IOL was between 0.151 mm to 0.82 mm while it ranged between 0.02 mm to 0.4 mm for monofocal IOLs. Measurement by using power refractor showed that the power was between 0.39 D to 1.00 D for accommodatin IOL while it was 0.10 D to 0.17 D for monofocal IOL. Conclusion, accommodating IOL provided better near vision compared to monofocal IOL. **[JuKe Unila 2015; 5(9):147-153]**

Keywords: accommodating amplitude, accommodating IOL, monofocal IOL

Efektivitas Lensa Intra Okular Akomodasi

Abstrak

Operasi katarak menggunakan lensa intra okular (LIO) monofokal dapat memperbaiki tajam pengliatan jauh akan tetapi tidak memperbaiki tajam penglihatan dekat sehingga tetap dibutuhkan kaca mata akibat presbiopia. Studi literatur ini bertujuan untuk membandingkan hasil-hasil penelitian yang menggunakan LIO akomodasi terhadap tajam penglihatan dekat dan amplitudo akomodasi. Data hasil-hasil penelitian diperoleh dari pusat data Pubmed database dan studi pustaka artikel jurnal yang diterbitkan dan berhubungan dengan LIO akomodasi menggunakan kata kunci akomodasi lensa intraokular atau lensa intraokular monofokal atau akomodasi *pseudophakic*. Amplitudo akomodasi diukur secara sujektif dan objektif. Pengukuran subjektif menggunakan *defocus* dan *near point of accommodation* (NPA). *Dynamic streak retinoscopy, power refractor* dan *IOL movement* digunakan sebagai alat ukur objektif. Pengukuran *defocus* pada LIO akomodasi menunjukkan 0.94 D - 1.90 D dan NPA sebesar 0.5 D - 3.83 D sementara itu pada LIO monofokal, kekuatan *defocus* sebesar 0 - 1.52 D dan NPA sebesar 0.42 D - 2.4 D. *Dynamic retinoscopy* dari LIO akomodasi sebesar 0.98 D - 0.99 D sementara pada LIO monofokal berkisar 0.17 D - 0.24 D. Pergerakan LIO akomodasi sebesar 0.15 mm - 0.82 mm dan pada LIO monofokal sebesar 0.02 mm - 0.4 mm. Pengukuran menggunakan *power refractor* menunjukkan kekuatan sebesar 0.39 D - 1.00 D pada LIO akomodasi dan 0.10 D - 0.17 D pada LIO monofokal. Kesimpulan, kekuatan akomodasi LIO akomodasi lebih baik diandingkan LIO monofokal. **[JuKe Unila 2015; 5(9):147-153]**

Kata kunci: amplitudo akomodasi, lensa intra okular akomodasi, lensa intra okular monofokal

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Introduction

Cataract surgery is effective in restoring visual clarity and distance vision. However, standard monofocal intraocular lenses (IOLs) have a fixed refractive power, leaving patients presbyopic and dependent on spectacles for near vision, even after surgery. Restoring the accommodative ability in pseudophakic patients is still challenging.

In last decade, various techniques to correct postoperative presbyopia have been tested with limited success. New lens-refilling procedures are currently under investigation in animal models. However, problems such as leakage of the injectable material from the capsular bag and formation of posterior capsule opacification (PCO) must be overcome.[1] Multifocal IOLs attempt to divide light into multifocal points to mimic accommodation but these IOLs often reduce contrast sensitivity and result in unwanted optical phenomena, such as glare. Scleral expansion surgery, zonal photorefractive keratectomy, implantation of corneal inlays, diffractive multifocal PC IOLs, and bifocal PC IOLs were reported no, little, or, at best, limited success.[2] Decentered laser in situ keratomileusis for presbyopia correction is still considered investigational.[3] Bag-in-the-lens IOL technique showed no accommodative or near visual advantage over a conventional in-the-bag IOL.[4]

Accommodating IOLs were developed in an attempt to restore the accommodative properties in the pseudophakic eye. With increasing age, the ciliary muscle maintains its ability to contract. The mechanism of accommodating lenses are based on the Helmholtz theory of accommodation, which assumes the presence of force transmission from the ciliary muscle to the lens via the zonular apparatus, or Coleman's hydraulic suspension theory, which assumes that changes in vitreous pressure are responsible for changes in lens shape. Accommodating IOLs are designed to transform forces of the ciliary muscle into a forward shift of the IOL optic (the optic shift concept).[5]

This paper presents a reviewed data of the result of near visual acuity, amplitude of accommodation, and safety profile of currently available accommodating IOLs. It also reviewed the comparation between available accommodating IOLs.

This literature research was conducted from the Pubmed (NLM) database and library research for journal articles that were published and related to accommodating IOLs using the keywords accommodating intraocular lens or monofocal intraocular lens or pseudophakic accommodation. The limit used of this review is using English, clinical trial, and human. Reference list from included study was also checked for potentially relevant articles.

The inclusion criteria are intervensional studies that reported on the use of accommodating IOLs, showing the details about baseline and result of distance-corrected near visual acuity (DCNVA). The studies were excluded if the full text cannot be accessed, the full text were not published in English and the outcome of the study could not be compared either directly or by calculation.

The primary outcome of this review is distance-corrected near visual acuity (DCNVA). Best corrected near visual acuity (BCNVA) also was also counted. The secondary outcomes are measurement of amplitude of accommodation. It was grouped into subjective and objective measurements. Subjective measurements consist of defocus, near point of accommodation, refractometry with a near/far target. Objective measurements consist of dynamic streak retinoscopy, photorefractometry, and change in anterior chamber depth.

Content

Thirty two (32) articles were selected using intended search terms. Twelve (12) articles were excluded because they could not be compared due to unrelated, using another method, could not be accessed, or just a review. All of the articles were published between 1999 until 2010.

Most of the articles were assigned as level II study. The accommodating IOLs used in the study were 1CU (HumanOptics), BioComFold (Morcher), and AT-45 Crystalens (eyeonics, Inc.) and Tetraflex (Lenstec Inc.) The follow up time varied from 1 month to 24 month. The largest number of participant was 772 patients.

Measurement of the subjective near point was performed with an accommodometer. Using the previously determined best distance correction, the reading target was slowly approached until the patient noted blurring of the optotype; 1/near point (m) was the accommodative range. Measuring of defocus was done after careful spherical and cylindrical distance refraction, spherical minus correction was added in steps of –0.5 diopters (D) until a Snellen chart visual acuity minus correction indicates of 20/50 was no longer detected. The amount of added minus correction indicates the accommodative range. Measuring of dynamic streak retinoscopy was performed by near and distance refractions. For distance retinoscopy, patients were asked to fixate a visual chart projected at a distance of 5 m. For near retinoscopy, patients were asked to maximally fixate a near chart. Accommodative range was the difference between near and distance refractions. Anterior chamber depth was measured by A-Scan or IOL-Master.[6]

Table 1. Characteristic of the Studies

No	Author	Year of Publication	Classification of study	Type of Accommodating IOL	Follow up (month)	Number of participant
1	Findl et al[7]	2004	I	1CU	3	18
2	Mastropasqua et al[8]	2003	I	1CU	6	42
3	Heatley et al[9]	2005	I	1CU	6	60
4	Sauder et al[10]	2005	I	1CU	6	38
5	Hancox et al[11]	2006	I	1CU	18-24	20
6	Legeais et al[12]	1999	I	BioCom	1	30
7	Wolffsohn et al[13]	2006	I	TetraFlex	6	48
8	Dogru et al[14]	2005	II	1CU	3	22
9	Uthoff et al[15]	2007	II	1CU	12	772
10	Vargas et al[16]	2005	II	1CU	3	19
11	Ku¨ chle et al[17]	2003	II	1CU	6	15
12	Ku¨ chle et al[6]	2004	II	1CU	6	20
13	Langenbucher et al[18]	2003	II	1CU	6	15
14	Koeppl et al[5]	2005	II	Crystalens AT-45	3	21
15	Cumming et al[19]	2001	II	Crystalens AT-45	1	48
16	Marchini et al[20]	2004	II	Crystalens AT-45	6	20
17	Cumming et al[21]	2006	II	Crystalens AT-45	12	246
18	Sanders et al[22]	2007	II	TetraFlex	6	95
19	Zhe et al[23]	2010	II	TetraFlex	3	42
20	Sanders et al[24]	2010	II	TetraFlex	12	332

Table 2. Distance-Corrected Near Visual Acuity (DCVNA) and Best Corrected Near Visual Acuity (BCNVA)

No	Author	DCNVA		P-value	BCNVA		P-value
		Acc IOL	Mono IOL		Acc IOL	Mono IOL	
1	Findl et al[7]	20/80 (J9) (median)	20/80 (J9) (median)	0.35	20/25 (J 2)	20/20 (J1)	0.01
2	Mastropasqua et al[8]	J3.7 + 2.1	J7.4 + 0.5	< 0.001	J 1	J 1	
3	Heatley et al[9]	J9.3 + 0,7	J12.4 + 0.5	0.004	-	-	-
4	Sauder et al[10]	J8.5 + 1.2	J11.6 + 1.8	0.03	N 2.46 + 0.9 (J3)	N 2.01 + 0.82 (J3)	0.34
5	Hancox et al[11]	J 10	J10	NS	-	-	-
6	Legeais et al[12]	J 3.66 + 2.12	J7.43 + 0.50	<0.001	-	-	-
7	Wolffsohn et al[13]	0.58 + 0.20 (J9)	0.62 + 0.25 (J9)	0.684	-	-	-
8	Dogru et al[14]	J 3 100%	J 3 0%	< 0.05	20/30 (J3)	20/30 (J3)	> 0.05
9	Uthoff et al[15]	N 5.77+ 1.33 (J6)	N 6.24 + 1.23 (J8)	<0.01			
10	Vargas et al[16]	0.5 (J5)	-	-	0.9 (J2)	-	-
11	Ku¨ chle et al[17]	0.39 + 0.11 (J6)	-	-	-	-	-
12	Ku¨ chle et al[6]	0.36 + 0.10 (J7)	0.16 + 0.06 (J12)	<0.001	-	-	-
13	Langenbucher et al[2]	0.32 + 0.11 (J8)	0.14 + 0.10 (J13)	< 0.05	-	-	-
14	Koeppl et al[5]	J4	-	-	-	-	-
15	Cumming et al[19]	J5 or better 100%	-	-	J3 or better 100%	-	-
16	Marchini et al[20]	J7,3 + 2,1	-	-	J1	-	-
17	Cumming et al[21]	J3 or better 90,1%	-	-	J2 or better 99%	-	-
18	Sanders et al[22]	20/40 (J5) or better 63,2 %	-	-	20/25 (J2)	-	-
19	Zhe et al[23]	J4 or better 66%	-	-	-	-	-
20	Sanders et al[24]	20/50 (J6) or better 67%	20/50 (J6) or better 50%	< 0.001	-	-	-

Table 3. Amplitude of Accommodation Measurements

No	Author	Subjective measurement		P-Value	Objective measurement		P-value
		Acc IOL	Mono IOL		Acc IOL	Mono IOL	
1	Findl et al[7]	-	-	-	- 0.37 ± 0.29[f]	0.060 ± 0.13[f]	0.001
2	Mastropasqua et al[8]	1.90 ± 0.77[a]	0	<0.05	-	-	-
3	Heatley et al[9]	3.83 ± 1.72[b]	2.40 ± 0.47[b]	0.0001	-	-	-
		1.727 ± 0.56[a]	1.014 ± 0.55[a]	0.03	-	-	-
4	Sauder et al[10]	1.01±0.4[b]	0.5±0.11[b]	0.01	-0.82 ± 0.3[f]	-0.40 ± 0.32[f]	0.01
5	Hancox et al[11]	43.26 ± 11.9[b] (2.3)	47.4 ± 5.5[b] (2.1)	0.11	-0.220 ± 0.169[f]	0.028 ± 0.095[f]	< 0.0001
		1.09± 0.58[a]	0.88±0.51[a]	0.214	-	-	-
6	Legeais et al[12]	-	-	-	-0.71 ± 0.55[f]	-0.29 ± 0.37[f]	< 0.05
7	Wolffsohn et al[13]	3.1±1.6[b]	2.0±0.9[b]	0.009	0.39±0.53[e]	0.17±0.13[e]	0.032
8	Dogru et al[14]	0.5 ± 0.44[b]	0	<0.05	-	-	-
9	Uthoff et al[15]	60± 17.13[b] (1.6)	70± 18.89 [b] (1.42)	-	-	-	-
		1.68± 0.67[a]	1.52± 0.53[a]	-	-	-	-
11	Ku¨ chle et al[17]	2.02±0.38[b]	-	-	-	-	-
12	Ku¨ chle et al[6]	1.83 ± 0.49[b]	1.16 ± 0.27[b]	<0.001	0.98 ± 0.55[d]	0.17 ± 0.22[d]	<0.001
		1.85 ± 0.43[a]	0.64 ± 0.21[a]	<0.001	+ 0.42 ± 0.18[f]	0.11 ± 0.06[f]	< 0.001
13	Langenbucher et al[18]	1.60 ± 0.55[b]	0.42 ± 0.25[b]	-	1.00 ± 0.44[e]	0.10 ± 0.65[e]	-
		1.46 ± 0.53[a]	0.55 ± 0.33[a]	-	0.99 ± 0.48[d]	0.24 ± 0.21[d]	-
		-	-	-	- 0.78 ± 0.12[f]	-	-
14	Koeppl et al[5]	-	-	-	+ 0.151 ± 0.08[f]	-	-
16	Marchini et al[20]	1.08 ± 0.54[c]	-	-	-0.33 ± 0.25[f]	-	-
18	Sanders et al[22]	2.77 ± 0.64 [c]	-	-	-	-	-
19	Zhe et al[23]	0.94 ± 0.61[a]	-	-	- 0.34 ± 0.12[f]	-	-

[a] Defocus
[b] Near point accommodation
[c] Refractometry near/far
[d] Dynamic streak retinoscopy
[e] PowerRefractor
[f] IOL shift movement, negative means decreasing anterior chamber depth in millimeter while positive means increasing anterior chamber depth in millimeter.

Various results were reported the distance-corrected near visual acuity (DCNVA) and best-corrected near visual acuity (BCNVA). The mean of DCNVA of accommodating IOL ranged between J3 to J10. The mean of DCNVA of monofocal IOL ranged between J6 to J13.

Objective and subjective measurement of amplitude of accommodation was observed in several studies. Accommodation amplitude was measured by dynamic streak retinoscopy, power refractor and IOL movement objectively. Subjectively, amplitude of accommodation is measured by defocus, near point of accommodation, and refractometry near/far.

Three measurements of subjective accommodative amplitude were stated for accommodating IOL. Defocus measurement showed that the accommodative amplitude was between 0.94 D to 1.90 D. Near point of accommodation (NPA) resulted in power around 0.5 D to 3.83 D. Two measurement of refractometry showed that the accommodative amplitude was between 1.08 D to 2.77 D. In the monofocal IOL, defocus power was between 0 to 1.52 D and NPA was between 0.42 D to 2.4 D.

Three measurements of objective accommodative amplitude were performed. Dynamic retinoscopy of accommodating IOL showed power between 0.98 D to 0.99 D while monofocal IOL ranged between 0.17 D to 0.24 D. The movement of accommodatin IOL was between 0.151 mm to 0.82 mm while it ranged between 0.02 mm to 0.4 mm for monofocal IOLs. Objective measurement using power refractor showed the power was between 0.39 D to 1.00 D for accommodatin IOL while it was 0.10 D to 0.17 D for monofocal IOL.

Subjective measurements of near visual acuity are the most readily available means of evaluating accommodation. This outcome was stated in all studies. DCNVA of accommodating IOL was better in the majority of the studies. Nine of 12 comparatives studies showed DCNVA of an accommodating IOL was superior than monofocal IOL with significant statisitcal difference.[2,6,8-10,12,14,15,24]

Majority of the studies indicated that BCNVA which achieved J 3 or better was equal among the studies. Those findings mean that the near visual acuity achieved by accommodating IOL provided sufficient vision for near work condition. Nevertheless, study from Uthoff et al[15] indicated that 1CU lens resulted in minor statistical advantage of half a reading step towards monofocal IOL.

Most of studies followed up the visual acuity in 6 to 24 months. Several studies noted that the DCNVA acuity was decreasing during the observation period. Capsul fibrosis can cause movement limitation. Koeppl et al[5] proposed mechanism of anterior capsule polishing to avoid capsule fibrosis which prevented IOL movement. How many times does the haptic of IOL can bend was still in question.

Subjective measurement of amplitude of accommodation by using defocus, near point of accommodation and refractometry showed that the amplitude of accommodation of accommodating IOL was better than monofocal IOL. Eight of 10 comparative studies showed that subjective amplitude of accommodation of accommodating IOL was better than monofocal IOL.

Objective measurement of amplitude of accommodation was collected by means of dynamic streak retinoscopy, power refractor and IOL shift movement. All of 7 studies measuring objective amplitude of accommodation indicated that accommodating IOL was superior than monofocal IOL. Unfortunately, there was no study reported IOL forward shift of 1 mm to create 3 D of accommodation.

The safety profile of accommodating IOL was reported by some studies. Posterior capsul opacity was reported in most of the studies.[8,13,17,24,25] IOL dislocation was observed in small number of patients ranged between 1%-3%.[15,21,24] Cumming et al[21] reported endophthalmitis (0.3%), retinal detachment (0.6%), iritis (0.9%), and corneal edema(0.7%) as adverse events of 324 patients.

Among four of accommodating IOL, there were no study that compared them directly. Heatley et al[9] compared tetraflex, 1CU and Acrysof. This study showed DCNVA achived by tetraflex, 1CU, and Acrysof was 89%, 7%, and 0% respectively. A comparative study comparing 1CU, Crystalens AT-45, and monofocal IOL was performed by Marchini et al.[26] This study showed that DCNVA of 1CU, Crystalens AT-45, and monofocal IOL was J 7, J 10, and J 13 ($p<0.001$). Brown et al[27] reported that near reading ability of Tetraflex IOL was better than Crystalens IOL. There was no comparative study involving BioCom IOL compared to others accommodating IOL.

The studies in this literature review was limited by several factors. Randomized clinical trial studies were conducted in small number of participants. The time of follow up was limited to 12 months, thus we can not evaluate the stability of accommodation performance of the IOLs in longer period of time.

Some conditions should be fulfilled to create better an accommodating IOL. A driving vector force must be implemented that actively moves the implant anteriorly as the zonules are released under ciliary muscle contraction. Capsular fibrosis and its immobilizing effect on the implant must be avoided or neutralized, and regeneratory after-cataract formation counteracted as much as possible. The optic should be positioned as far posteriorly as possible to allow for maximum clearance to the iris and thus space for shift-induced accommodation.[28]

Summary

Accommodating IOLs was developed to provide free-spectacles near vision after cataract surgery. This lens works by changing its position anteriorly during near sighted activities. The effectiveness of this IOL was affected by several conditions such as well-centered IOLs, extensive clearance of lens material during surgery and capsular fibrosis after surgery.

Conclusion

Accommodating IOLs showed better near visual acuity compared to monofocal IOL. Meanwhile, accommodating IOL only produced moderate improvement of amplitude of accommodation. The accommodating IOLs were safe based on several studies. Based on limited number of study and study design, Tetraflex accommodating IOL appeared to be superior compared to 1CU lens and Crystalens lens.

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