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The efficacy of accommodative versus monofocal intraocular lenses for cataract patients
A systematic review and meta-analysis

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Abstract

Introduction: We performed a systematic review and meta-analysis to evaluate whether accommodative intraocular lenses (AC-IOLs) are superior for cataract patients compared with monofocal IOLs (MF-IOLs).

Methods: Pubmed, Embase, Cochrane library, CNKI, and Wanfang databases were searched through in August 2018 for AC-IOLs versus MF-IOLs in cataract patients. Studies were pooled under either fixed-effects model or random-effects model to calculate the relative risk (RR), weighted mean difference (WMD), or standard mean difference (SMD) and their corresponding 95% confidence interval (CI). Distance-corrected near visual acuity (DCNVA) was chosen as the primary outcome. The secondary outcomes were corrected distant visual acuity (CDVA), pilocarpine-induced IOL shift, contrast sensitivity, and spectacle independence.

Results: Seventeen studies, involving a total of 1764 eyes, were included. Our results revealed that AC-IOLs improved DCNVA (SMD = −1.84, 95% CI = −2.56 to −1.11) and were associated with significantly greater anterior lens shift than MF-IOLs (WMD = −0.30, 95% CI = −0.37 to −0.23). Furthermore, spectacle independence was significantly better with AC-IOLs than with MF-IOLs (RR = 3.07, 95% CI = 1.06–8.89). However, there was no significant difference in CDVA and contrast sensitivity between the 2 groups.

Conclusion: Our study confirmed that AC-IOLs can provide cataract patients with DCNVA and result in more high levels of spectacle independence than MF-IOLs. Further studies with larger data set and well-designed models are required to validate our findings.

Abbreviations: AC-IOLs = accommodating IOLs, AC-IOLs = accommodative intraocular lenses, CDVA = corrected distant visual acuity, CI = confidence interval, DCNVA = distance-corrected near visual acuity, MF-IOLs = monofocal intraocular lenses, MF-IOLs = monofocal IOLs, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-analysis, RCTs = randomized controlled trials, RR = relative risk, SMD = standard mean difference, WMD = weighted mean difference.

Keywords: accommodative intraocular lenses, cataract, meta-analysis, monofocal intraocular lenses, systematic review

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1. Introduction

Cataract is the leading cause of visual impairment and blindness among elderly throughout the world.[1] With the rapidly aging of the population, cataracts are becoming a major social problem in the global scale. Apart from age, other factors such as exposure to sunlight, alcohol consumption, smoking, and some drugs have been reported to increase cataract risk.[2,3] In 2011, China had the largest number with 8 million blind and 75 million visually impaired individuals. At present, cataract is a major cause of visual disability in China.[4,5]

Cataract surgery can effectively restore visual clarity and distance vision. The design of the traditional monofocal intraocular lenses (MF-IOLs) with a single fixed focal length can provide excellent distance vision, the MF-IOL's limited depth of focus means that they cannot provide clear vision at both distance and near.[6,7] Functional near-vision is indispensable in modern society because it requires a lot of near tasks in daily life. For example, loss of reading ability can significantly reduce a person's quality of life.[8,9] Patients with traditional MF-IOLs usually require glasses during computer work or reading.[10] Accommodating IOLs (AC-IOLs) were designed to move along the visual axis to provide near, intermediate, and distance vision in pseudophakic patients.[11,12] AC-IOLs were developed with the purpose of providing some adjusting capacity and some functional near-vision after cataract extraction. AC-IOLs provide useful near-vision without glasses while maintaining good distance vision.[11,12]
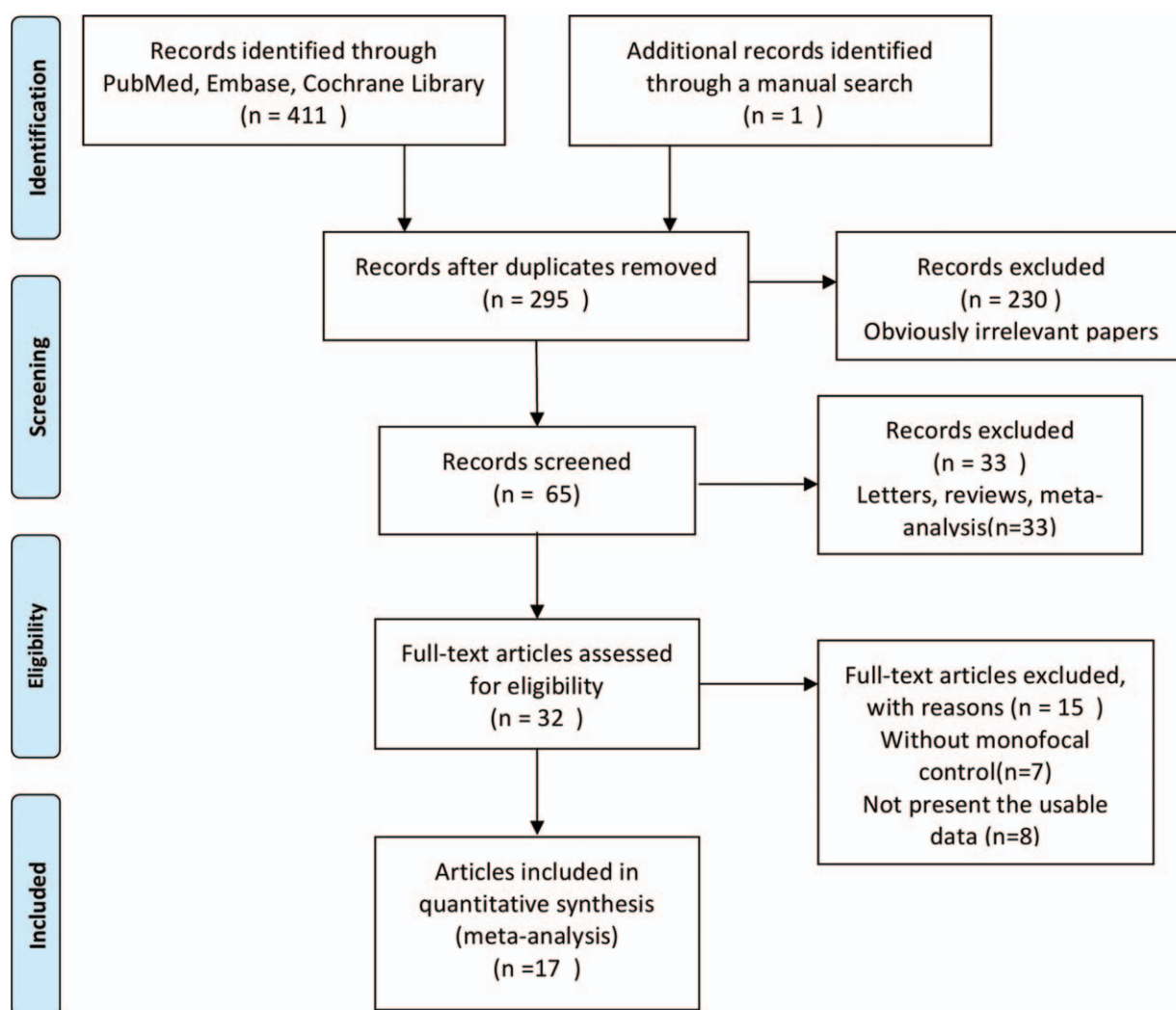
Figure 1. Flow diagram of studies identification.

Functional assessment of AC-IOLs versus MF-IOLs in cataract surgery has been investigated by 2 previous meta-analyses.[13,14] However, the results from these meta-analyses remain inconclusive and conflicting. Moreover, spectacle independence was not evaluated by systematic synthesis in the previous meta-analyses owing to the limited number of available studies. Therefore, we performed an update systematic review and meta-analysis to provide a comprehensive assessment of the visual outcomes of AC-IOLs compared with MF-IOLs after cataract surgery.

2. Methods

The present meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines.[15] All analyses were based on previous published studies, thus no ethical approval and patient consent are required.

2.1. Search strategy

We searched for relevant studies up to August 2018 through the PubMed, Embase Cochrane Library, CNKI, and Wanfang databases with the following terms and their combinations: "cataract," "intraocular lenses," "lens implantation," and "accommodative" (Table S1, http://links.lww.com/MD/C535). Two reviewers were independently performed database search and all disagreements about eligibility were resolved through discussion. We did not restrict the publication date and language. All scanned abstracts, studies, and citations were reviewed. Moreover, references of the retrieved manuscripts were also manually cross-searched for further relevant publications.

2.2. Selection criteria

The studies had to meet the following criteria to be eligible for inclusion in the present meta-analysis: enrolled cataract patients; provide ≥2 comparison groups, one group received AC-IOLs, another group received MF-IOLs; provide outcomes: distance-corrected near visual acuity (DCNVA), corrected distant visual acuity (CDVA), pilocarpine-induced IOL shift, contrast sensitivity, and spectacle independence. If multiple studies from the same population were identified, we included the one that provides more relevant information.
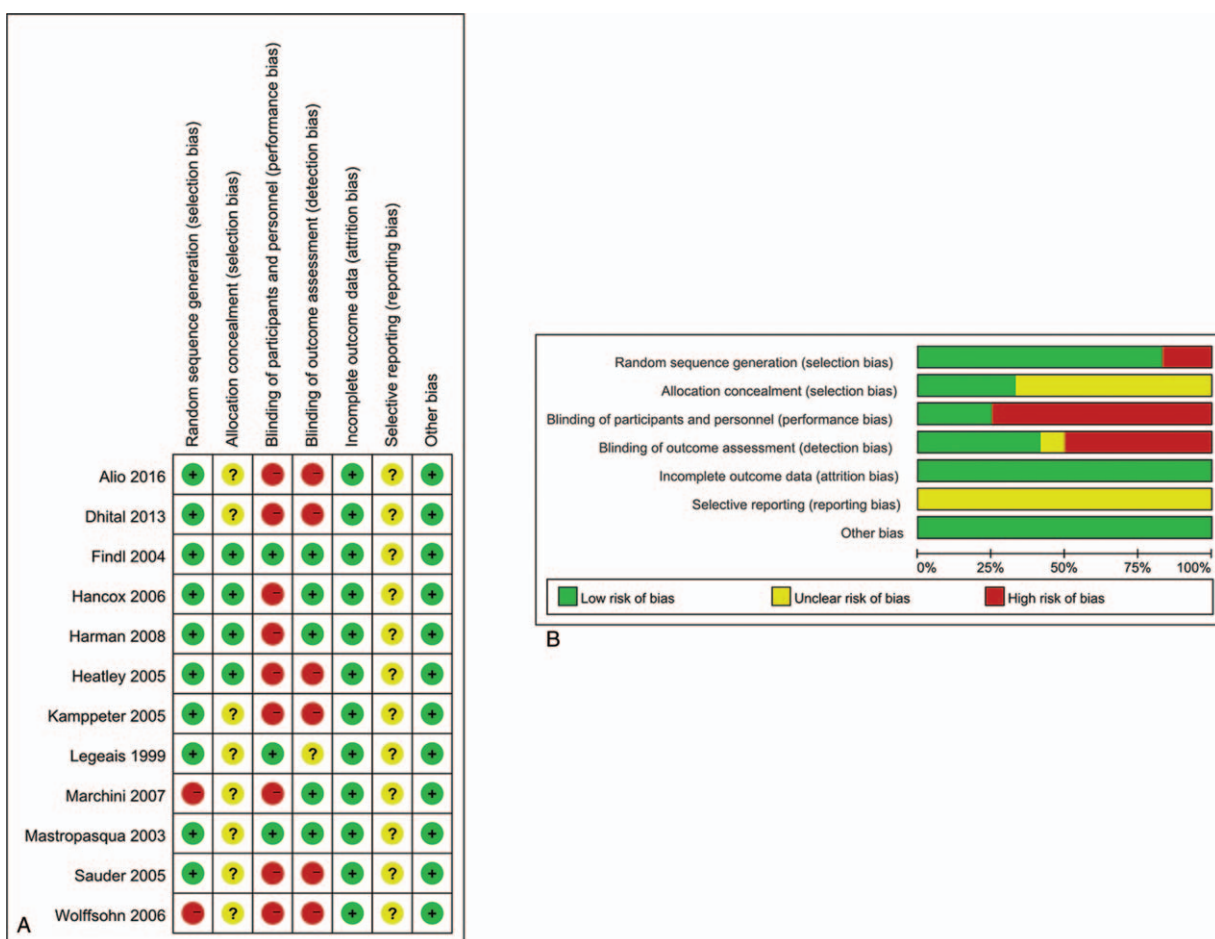
Figure 2. Risk of bias assessments for the randomized trials included in the meta-analysis. (A) Risk of bias summary; (B) risk of bias graph. +: low risk of bias; ?: unclear risk of bias; −: high risk of bias.

2.3. Data extraction and quality assessment

Two investigators independently extracted the characteristics of the included studies. Any disagreement was subsequently resolved by discussion with the third author. The following information was extracted from each article: first author, year of publication, country, sex, mean age, duration of follow-up, study design, the type of AC-IOLs and MF-IOLs, outcomes assessed. We evaluate the quality of randomized controlled trials (RCTs) with the Cochrane Collaboration's tool for assessing risk of

bias.[16] We used the Newcastle-Ottawa Scale for assessing the quality of cohort studies, the full score was 9 stars, and the high-quality study was defined as a study with ≥7 stars.[17]

2.4. Statistical analysis

We calculated the weighted mean difference (WMD)/standard mean difference (SMD) and 95% confidence intervals (CIs) for the continuous data, and calculate the risk ratio (RR) and 95%

Table 1

Methodological quality of observational studies included in the meta-analysis[*].

First author	Representativeness of the exposed cohort	Selection of the unexposed cohort	Ascertainment of exposure	Outcome of interest not present at start of study	Control for important factor or additional factor	Outcome assessment	Follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	Total quality scores
Alio, 2010	☆	☆	☆	☆	☆	☆	☆	—	7
Mesci, 2010	☆	☆	☆	☆	☆	☆	☆	☆	8
Sanders, 2010	☆	☆	☆	☆	☆	☆	☆	☆	8
Zamora-Alejo, 2013	☆	☆	☆	☆	☆	☆	☆	—	7
Tan, 2014	☆	☆	☆	☆	☆	☆	☆	☆	8

[*] A study could be awarded a maximum of one star for each item except for the item control for important factor or additional factor.
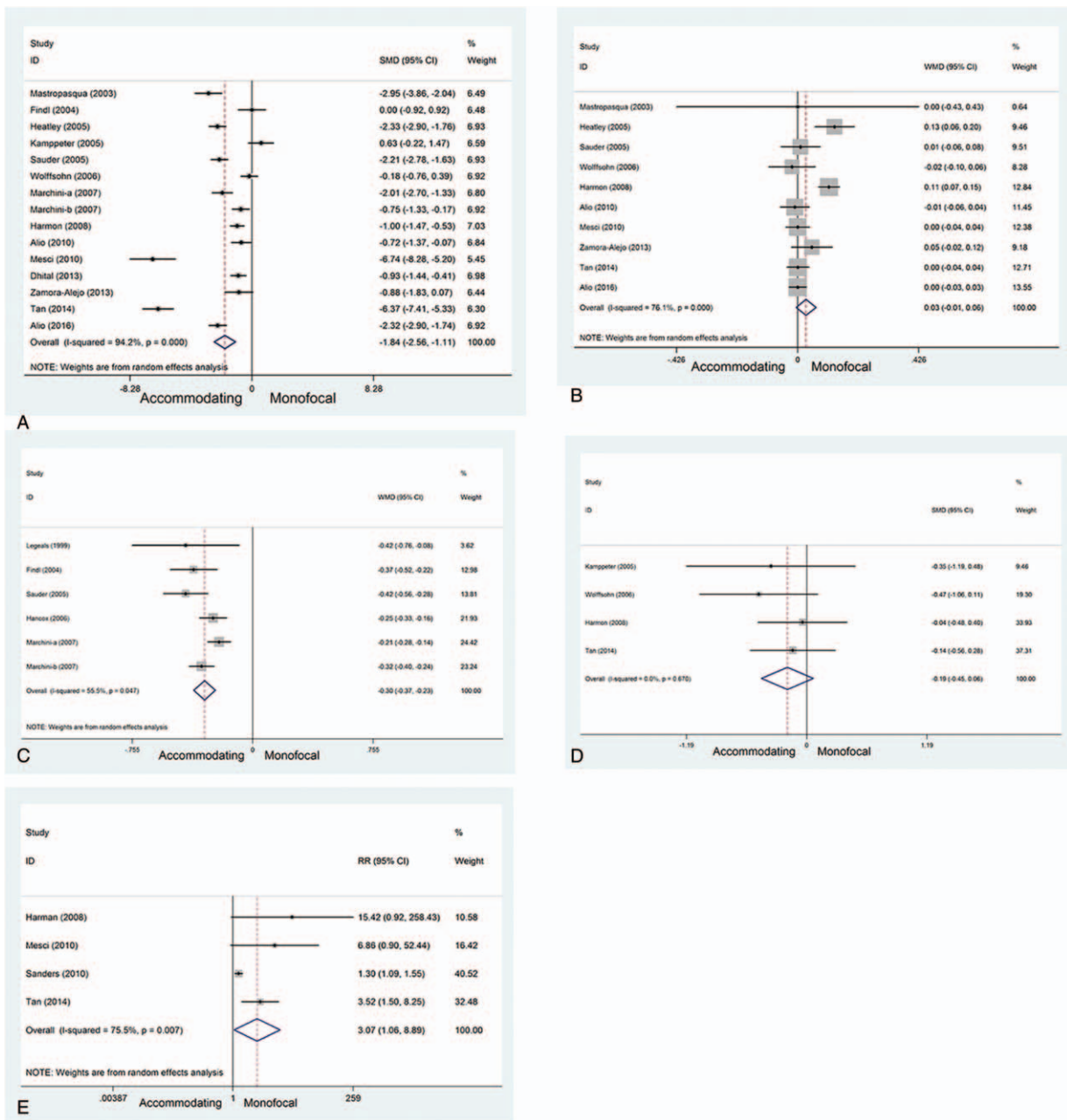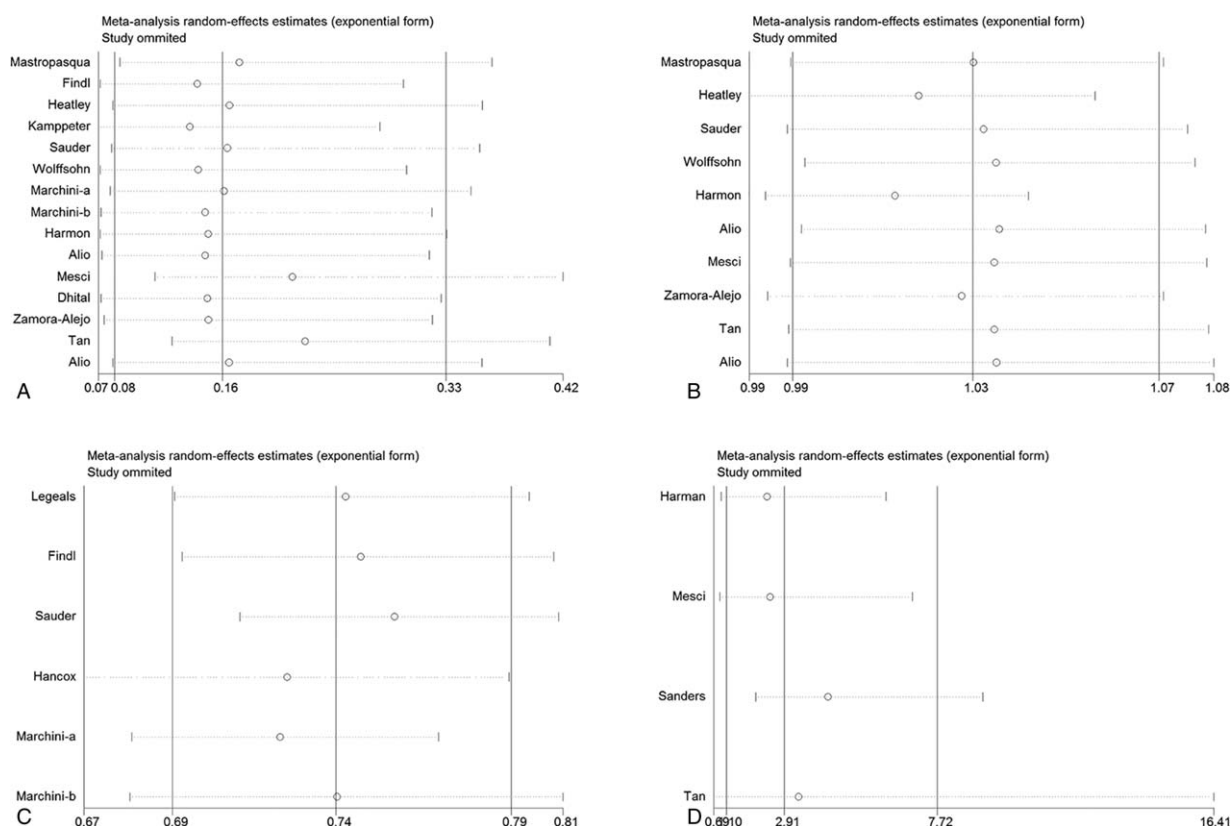
Figure 4. Sensitivity analysis of the effect of accommodating IOLs versus monofocal IOLs in patients with cataract. (A) DCNVA; (B) CDVA; (C) pilocarpine-induced IOL shift; (D) spectacle independence.

3. Results

3.1. Characteristics of the studies

Our initial database searches and manual search retrieved a total of 412 articles. After duplicate removal and abstract/title reviewed, 32 articles were eligible for full-text review. Of these, 15 were further excluded, leaving a total of 17 articles eligible to be included in the present meta-analysis. Finally, 17 studies[23–38] with 1764 eyes were incorporated into the current meta-analysis. The flow chart of selection of studies and reasons for exclusion is presented in Figure 1. The main characteristics of the eligible studies are shown in Table S2, http://links.lww.com/MD/C535. The studies were performed in various countries, and the study size ranged from 23 to 670 eyes. The mean age of patient ranged from 61.1 to 75.9 years. Twelve RCTs and 5 cohort studies were included in our study. A summary of selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias identified in each individual RCT is shown in Figure 2. All of the included RCTs studies showed moderate and high quality with acceptable and moderate risk of bias. The main features of the eligible study are shown in Table S1, http://links.lww.com/MD/C535. Methodological quality of cohort studies included in the meta-analysis is shown in Table 1. The quality of the cohort studies included in the meta-analysis was generally high; 2 studies had 8 stars, and 2 studies had 7 stars.

3.1.1. Distance-corrected near visual acuity. Fourteen studies[23,25–28,30–33,35–38] with 1694 eyes were included in

analysis of DCNVA. The pooled results showed that AC-IOLs improved DCNVA more than MF-IOLs (SMD = −1.84, 95% CI = −2.56 to −1.11, $P_{\text{heterogeneity}} < 0.001$, $I^2 = 94.2\%$) (Fig. 3A).

3.1.2. Corrected distant visual acuity. Ten trials[25,27,28,30–33,36–38] with 747 eyes were included in analysis of CDVA. No significant difference between the 2 groups (WMD = 0.03, 95% CI = −0.01 to 0.06, $P_{\text{heterogeneity}} < 0.001$, $I^2 = 76.1\%$; Fig. 3B) was observed, which indicates that the AC-IOLs and MF-IOLs were not significantly different in terms of CDVA.

3.1.3. Pilocarpine-induced IOL shift. Five studies[23,24,26,28,29] with 340 eyes were included in analysis of pilocarpine-induced IOL shift. The pooled results showed that AC-IOLs were associated with significantly greater anterior lens shift than MF-IOLs (WMD = −0.30, 95% CI = −0.37 to −0.23, $P_{\text{heterogeneity}} = 0.047$, $I^2 = 55.5\%$) (Fig. 3C).

3.1.4. Contrast sensitivity. Four trials[28,30,31,37] with 251 eyes were included in analysis of contrast sensitivity. The results are shown in Figure 3D. No significant difference between the 2 groups (SMD = −0.19, 95% CI = −0.45 to 0.06, $P_{\text{heterogeneity}} = 0.670$, $I^2 = 0\%$) was observed, which indicates that the AC-IOLs and MF-IOLs were not significantly different in terms of contrast sensitivity.

3.1.5. Spectacle independence. Four studies[31,33,34,37] with 1023 eyes were included in analysis of spectacle independence. The pooled results showed that spectacle independence was significantly better with AC-IOLs than with MF-IOLs (RR = 3.07, 95% CI = 1.06–8.89, $P_{\text{heterogeneity}} = 0.007$, $I^2 = 75.5\%$) (Fig. 3E).
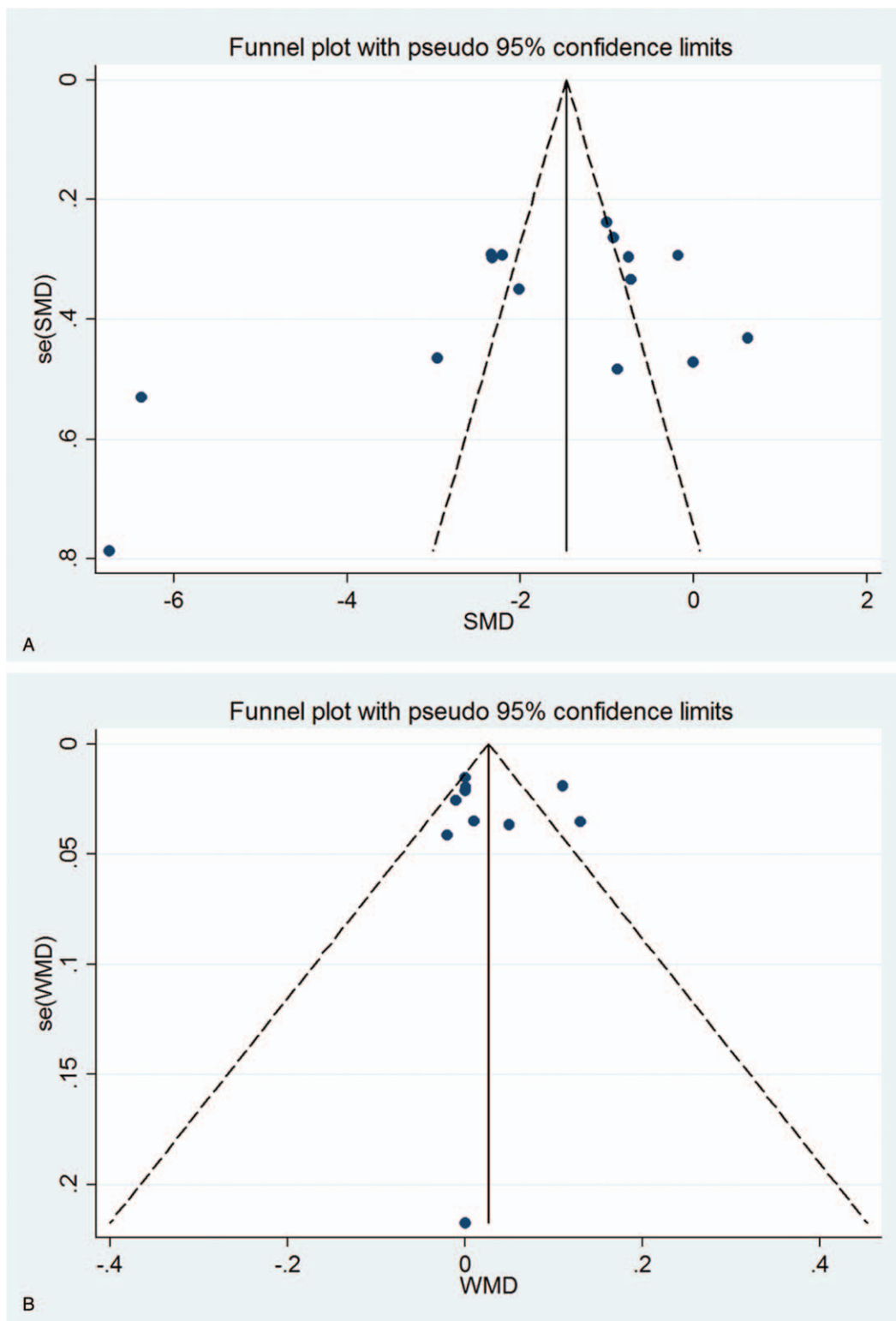
Figure 5. Funnel plot for publication bias test. Each point represents a separate study for the indicated association. (A) DCNVA; (B) CDVA.

3.2. Subgroup analyses

Subgroup analyses were performed according to the type of AC-IOLs (1CU, Crystalens HD, or other), study design (RCT or non-RCT), and follow-up time (follow-up time <12 months or ≥12 months). The results from subgroup analyses were quite consistent with the overall results for distance-corrected near visual acuity, corrected distant visual acuity, pilocarpine-induced IOL shift, and contrast sensitivity. However, in the subgroup analyses by the type of AC-IOLs, a significant different was observed in 1CU group (Table S3, http://links.lww.

com/MD/C535) for spectacle independence. All subgroup results are summarized in Table S3, http://links.lww.com/MD/C535.

3.3. Sensitivity analysis

Sensitivity analysis by omitting a single study in each turn revealed that the overall results were free from the influence of a single study (Fig. 4).

3.4. Publication bias

The Begg and Egger regression test showed no significant publication bias in analyses of DCNVA (Begg test $P = .373$; Egger test $P = .109$) (Fig. 5A) and CDVA (Begg test $P = .283$; Egger test $P = .837$) (Fig. 5B).

4. Discussion

The present systematic review and meta-analysis examined RCTs and cohort studies to compare the postoperative visual performances of AC-IOLs and MF-IOLs. Our results revealed that AC-IOLs improved DCNVA and associated with significantly greater anterior lens shift than MF-IOLs. Furthermore, spectacle independence was significantly better with AC-IOLs than with MF-IOLs. However, there was no significant difference in CDVA and contrast sensitivity between the 2 groups.

DCNVA improved significantly with both groups in our study. The results of our study were consistent with 2 previous meta-analyses,[13,14] which also found slight to moderate improvement in DCNVA with AC-IOLs over MF-IOLs. However, we noted a significant statistical heterogeneity between the trials. The mixture of study designs (unilateral versus bilateral intervention) could be a cause for heterogeneity between the trials. Most participants received the same intervention to both eyes but some participants only received an intervention to one eye. A possible influence on accommodation amplitude is the patient's age. In our study, most of patients were >60 years and had a subjective amplitude of accommodation less than the young patients. In contrast, the objective accommodation amplitude seemed to correlate poorly with age. Contrast sensitivity represents a person's ability to distinguish objects with fuzzy boundaries. As previously reported, contrast sensitivity decreases with age.[39,40] The higher contrast sensitivity in younger patients might contribute to deeper depth of field, resulting in a wider range of subjective accommodation of amplitude. In this study, we discovered that the contrast sensitivity of AC-IOLs was not significantly different from that of MF-IOLs.

Functional assessment of AC-IOLs versus MF-IOLs in cataract surgery has been investigated by previous meta-analyses.[13,14] Our results also differ from previous meta-analysis because of the additional studies included. Recently, Ong et al[14] conducted a meta-analysis, which involved 256 eyes from 5 studies. Compared with Ong's work, we identified 12 additional eligible studies[24-26,28,30,32-38] and our study involved 1764 eyes from 17 studies. Our study also reported pilocarpine-induced IOL shift that was not reported in meta-analysis by Ong et al and found that AC-IOLs were associated with significantly greater anterior lens shift than MF-IOLs. A previous meta-analysis conducted by Takakura et al[13] was limited as only 12 studies were included. Compared with meta-analysis by Takura et al, we were able to include 7 additional eligible studies.[32-38] Therefore, we were able to perform more comprehensive analyses; for example, Takakura et al only analyzed one study in analysis spectacle independence, whereas we identified 3 additional eligible studies

and found that spectacle independence was significantly better with AC-IOLs than with MF-IOLs.

Some limitations should be noticed in this meta-analysis: first, the different follow-up time periods and the insufficient reporting of postoperative adverse visual events may have caused selection bias. Second, significant heterogeneity was observed across trials, suggesting that the results from the present meta-analysis should be treated with caution. Different patient selection criteria, surgery protocols, and accommodating IOL models are possible explanations for the heterogeneity. Finally, this limitation of small sample size, which raises concerns about the power to detect a statistically significant effect.

In conclusion, despite the limitations of this meta-analysis, our study confirmed that AC-IOLs can provide cataract patients with excellent DCNVA and result in more high levels of spectacle independence than MF-IOLs. Further studies with larger data set and well-designed models are required to validate our findings.

Author contributions

Investigation: Hongwei Zhou, Chongyan Zhu, Wenya Xu, Fang Zhou.
Methodology: Hongwei Zhou, Chongyan Zhu, Wenya Xu, Fang Zhou.
Validation: Hongwei Zhou.
Visualization: Hongwei Zhou.
Writing – original draft: Hongwei Zhou, Chongyan Zhu, Wenya Xu, Fang Zhou.
Writing – review and editing: Hongwei Zhou, Chongyan Zhu, Wenya Xu, Fang Zhou.

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