Review Article

Accuracy of intraocular lens power calculation formulae in short eyes: A systematic review and meta-analysis

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This review article attempts to evaluate the accuracy of intraocular lens power calculation formulae in short eyes. A thorough literature search of PubMed, Embase, Cochrane Library, Science Direct, Scopus, and Web of Science databases was conducted for articles published over the past 21 years, up to July 2021. The mean absolute error was compared by using weighted mean difference, whereas odds ratio was used for comparing the percentage of eyes with prediction error within ±0.50 diopter (D) and ±1.0 D of target refraction. Statistical heterogeneity among studies was analyzed by using Chi-square test and I^2 test. Fifteen studies including 2,395 eyes and 11 formulae (Barrett Universal II, Full Monte method, Haigis, Hill-RBF, Hoffer Q, Holladay 1, Holladay 2, Olsen, Super formula, SRK/T, and T2) were included. Although the mean absolute error (MAE) of Barrett Universal II was found to be the lowest, there was no statistically significant difference in any of the comparisons. The median absolute error (MedAE) of Barrett Universal II was the lowest (0.260). Holladay 1 and Hill-RBF had the highest percentage of eyes within ±0.50 D and ±1.0 D of target refraction, respectively. Yet their comparison with the rest of the formulae did not yield statistically significant results. Thus, to conclude, in the present meta-analysis, although lowest MAE and MedAE were found for Barrett Universal II and the highest percentage of eyes within ±0.50 D and ±1.0 D of target refraction was found for Holladay 1 and Hill-RBF, respectively, none of the formulae was found to be statistically superior over the other in eyes with short axial length.

Key words: Cataract, intraocular lens, mean absolute error, median absolute error, power calculation formulae, short eyes

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Cataract surgery remains one of the most commonly performed ophthalmological procedures worldwide owing to the aging population and increasing life expectancy.[1,2] Even in a meticulously performed surgery, the actual visual outcome can match the expected visual outcome by accurate biometry.

The advent of optical biometry circumvented the operator-induced bias encountered in ultrasound biometry. Soon partial coherence interferometry (PCI) became the gold standard optical biometer owing to its precision in measurements along with ease of use in clinical settings.[3] Optical low coherence reflectometry (OLCR) and swept-source optical coherence tomography biometers were its successors, which although maintained the same precision of measurements, provided additive information on several parameters such as lens thickness, central corneal thickness, anterior chamber depth (ACD), horizontal white-to-white diameter, and corneal radii.[4] The incorporation of these parameters into the intraocular lens (IOL) power calculation formulae gave a better prediction of the effective lens position.

However, among the wide range of available formulae, none is completely accurate in all scenarios. Modern formulae show comparable refractive outcomes in eyes with normal axial length (AL).[5] But when we deal specifically with short eyes (AL <22 mm), they gave variable results. Hence, the deliberation for choosing the most accurate formula, so as to obtain an optimal postoperative visual outcome in the subgroup of short eyes continues. In 2018, a meta-analysis on short eyes had already been carried out by Wang *et al*.[6] With set down of protocols for conducting a study on IOL power accuracy, it was recommended to compare median absolute error (MedAE) rather than mean absolute error (MAE) and also includes the percentage of eyes with prediction error (PE) within ±0.25, ±0.50, and ±1.0 diopter (D) of target refraction.[7,8] Hence, the present meta-analysis was carried out taking into account these recommendations.

Methods

We carried out this meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[9] Ethics committee approval was not required as our review relied entirely on publicly available data that are already published. Nonetheless, the study methods adhered to the tenets of the Declaration of Helsinki.

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Search methods

Two authors independently searched PubMed, Embase, Cochrane Library, Science Direct, Scopus, and Web of Science databases for research articles published over the past 21 years, up to July 2021. Search terms used for PubMed were short eyes* OR short axial length* AND Phacoemulsification AND Calculat* OR Formula* AND IOL. The title and abstract of the retrieved literature were then screened. The selected articles were further filtered by reading the full text and assessed for eligibility. Articles cited in the reference list of these eligible articles were also screened manually.

Inclusion and exclusion criteria

The studies included in the meta-analysis met the following inclusion criteria: (1) population: (a) patients older than 18 years of age, (b) eyes with AL less than 22 mm; (2) intervention: (a) biometry done by optical method, (b) eyes that underwent uneventful phacoemulsification surgery; (3) comparison: at least two of the following IOL power calculation formulae used – Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 1, Holladay 2, and SRK/T; (4) outcome: studies that reported at least one of the three outcome measures – MAE, MedAE, or percentage of eyes with PE within ±0.50 and ±1.0 D of target refraction; (5) study design: Prospective and retrospective.

The exclusion criteria were as follows: (1) history of corneal refractive surgery; (2) any ocular pathology affecting refraction; (3) toric, multifocal, piggyback IOL, or IOLs not implanted in the bag; (4) older generation formulae such as Binkhorst II, SRK I, or SRK II used; (5) review articles, studies under trial, editorials, conference abstracts, previous meta-analysis, discussion papers, full text not available in English, or animal studies.

Data extraction

Two authors extracted data regarding study design, methodology, participant demographics, and baseline characteristics from all included studies independently and matched their results. Any discrepancy found was resolved by discussion and confirmation with the third author. If standard deviation (SD) data could not be extracted from full-text articles or even after contacting the authors, we used the mean SD of the remaining studies.

Quality assessment

The study quality was assessed by using a modified checklist adapted from the Quality Assessment of Diagnostic Accuracy Studies–2 (QUADAS-2) tool.[10] The evaluation of bias was divided into four domains: patient selection, index test, reference standard, and last, flow and timing of patients. Applicability concerns were assessed using three domains: patient selection, index test, and reference standard. Each domain could have a high risk, low risk, or unclear risk of bias.

Statistical analysis

Data were analyzed for MAE, MedAE, and percentage of eyes with PE within ±0.50 and ±1.0 D of target refraction. We analyzed the relative effect size of continuous outcomes like MAE using weighted mean difference (WMD) with 95% confidence interval (CI). The relative effect size of the percentage of eyes with PE within ±0.50 and ±1.0 D of target refraction, which was a binary outcome, was calculated as odds ratio (OR) with a 95% CI. Statistical methods utilized were inverse variance for continuous data and Mantel–Haenszel for dichotomous data. A P value less than 0.05 was considered statistically significant in both. Statistical heterogeneity among studies was analyzed by using Chi-square test and I^2 test. When the I^2 value was more than 50% and P value was less than 0.1, random-effect model was used for analysis; otherwise a fixed-effect model was used. Sensitivity analysis was conducted to identify sources of significant heterogeneity. Te funnel plot was used to assess publication bias. Only descriptive analysis was performed for MedAE as it is not suitable for meta-analysis. Statistical analysis was carried out using Review Manager software (RevMan, Version 5.4).[11]

Results

Literature selection results

The detailed process of literature search and study selection is depicted in Fig. 1. Initially, 2,094 studies were identified through a database search. After the removal of 48 duplicate studies, 2,046 eligible titles were identified and screened by review of the abstract. Of these, 28 full-text articles were retrieved. After excluding 13 studies based on predefined inclusion criteria, 15 studies were included in this meta-analysis.

Study characteristics

The characteristics of eligible studies are summarized in Table 1. A total of 2,395 eyes with AL in the range of 18.77 to 21.99 mm were included in the analysis. The sample size ranged from 15 to 608 eyes. Formulae included were Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 1, Holladay 2, and SRK/T. A few studies also used newer generation formulae such as the Full Monte method, Kane, Ladas Super formula, Olsen, and T2.

Quality of included studies

A modified checklist adapted from QUADAS-2 tool was employed to assess the study quality [Fig. 2]. Detailed assessment questionnaire and its results are provided [Additional File 1]. Ten of the 15 studies did not report whether the patient selection was consecutive or random and hence had an unclear risk of bias. On analyzing the reference standard used, 10 studies had a high risk of bias due to the use of subjective refraction for calculating postoperative spherical equivalent (SE). Most of the studies were of high quality as far as index tests, the inclusion of patients, the flow of patients, and applicability were concerned.

Outcomes

The outcome variables included in our analysis were MAE, MedAE, and the percentage of eyes with PE within ±0.50 and ±1.0 D of target refraction. This meta-analysis included 2,395 eyes, of which 1,302 eyes were analyzed for Barrett Universal II, 1,543 eyes for Haigis, 1,105 eyes for Hill-RBF, 2,192 eyes for Hoffer Q, 2,129 eyes for Holladay 1, 1,272 eyes for Holladay 2, and 2,016 eyes for SRK/T formulae.

Mean absolute error

The MAE and standard error of all the formulae included in the analysis showed the lowest value for Barrett Universal II [Fig. 3(I)]. It performed equally well as Haigis, Hoffer Q, and SRK/T with WMD and 95% CI of −0.00 (−0.04, 0.03) for the three pairs [Fig. 3IIA, B, and C]. The WMD and 95% CI of Barrett Universal II with Hill-RBF, Holladay 1, and Holladay 2 were 0.02 (−0.01, 0.06); 0.02 (−0.01, 0.06), and 0.03 (−0.01, 0.06), respectively [Fig. 3II D, E, and F]. Although the MAE of Barrett Universal II was found to be the lowest, there was no statistically significant difference in any of the comparisons.

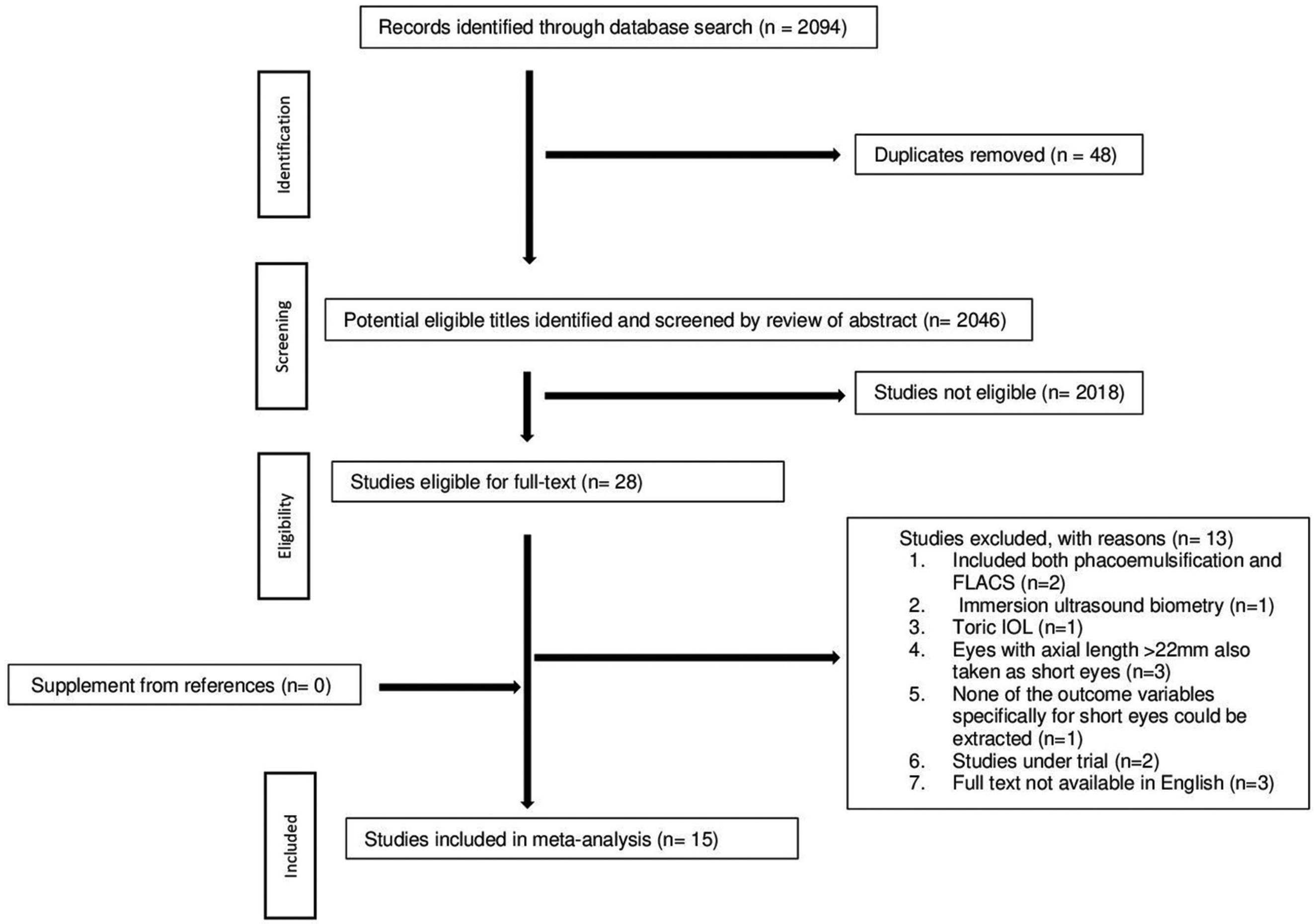

Figure 1: Flow chart of article selection. Abbreviations: FLACS = Femtosecond laser-assisted cataract surgery; IOL=Intraocular lens

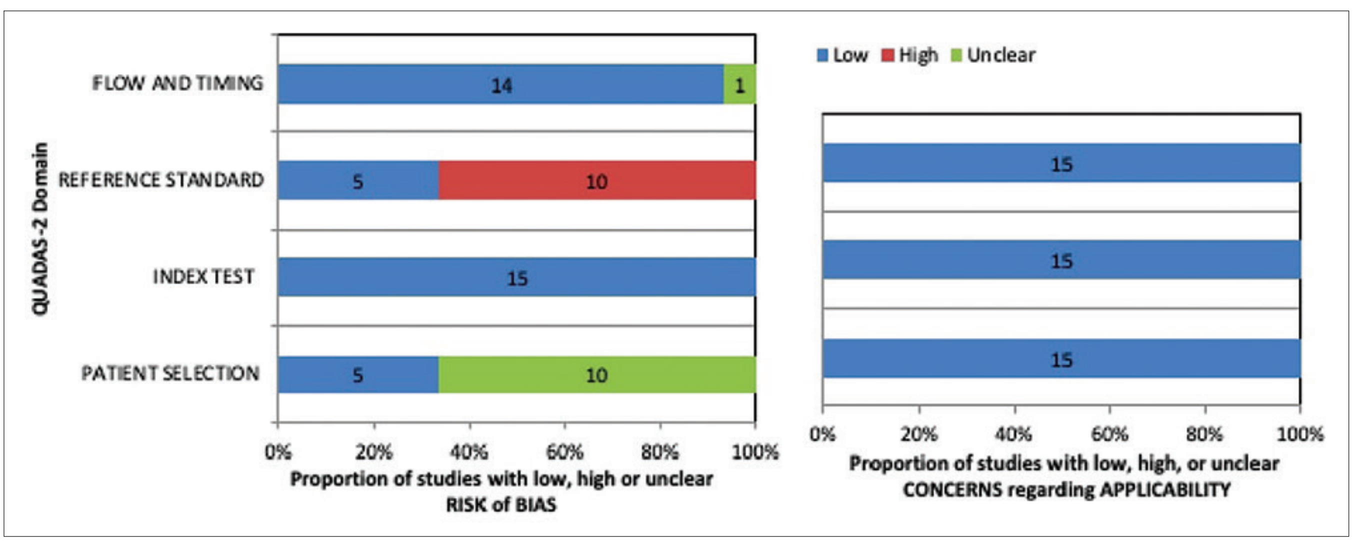

Figure 2: Quality assessment of the included studies based on modified QUADAS-2 tool. Abbreviations: QUADAS-2 = Quality Assessment of Diagnostic Accuracy Studies-2

Median absolute error

Table 2 shows the descriptive analysis of MedAE of all the formulae included in the analysis. Nine of the 15 studies have reported this parameter. The MedAE of Barrett Universal II was the lowest (0.260) followed by Hill-RBF (0.300), Holladay 1 (0.302), Haigis (0.308), Holladay 2 (0.320), SRK/T (0.327), and Hoffer Q (0.340).

Table 1: Characteristics of study participants

Study	Year	Country	Study design	Number of eyes	Age (years±SD)	Axial length, mm±SD (Range)	Method of calculating RPE	Lens Constant Used
Aristodemou *et al.*[15]	2011	United Kingdom	Retrospective	608	NA	21.57 (20.00-21.99)	Postop SE-PR	Optimized constants
Cooke and Cooke[23]	2016	USA	Retrospective	41	NA	21.69 (20.84-22.00)	Postop SE-PR	Optimized constants
Darcy *et al.*[25]	2020	UK	Retrospective	766	NA	≤ 22	Postop SE-PR	Optimized constants For Haigis a0- optimized, a1, a2- ULIB
Day *et al.*[17]	2012	UK	Retrospective	163	57±10	21.2±0.60 (19.23-21.98)	Postop SE-PR	Optimized constants
Eom *et al.*[18]	2014	South Korea	Retrospective cross-sectional	75	70.1±6.8	21.69±0.29 (20.32-21.99)	Postop SE-PR	Optimized constants
Gavin and Hammond[16]	2008	UK	Retrospectively Prospective	41	NA	21.51 (20.29-21.96)	PR-Postop SE	Manufacturer's constants
Gökce *et al.*[19]	2017	USA	Retrospective case series	86	72±8	21.53±0.56 (18.80-22.00)	Postop SE-PR	Optimized constants
Kane *et al.*[5]	2016	Australia	Retrospective case series	156	NA	≤22	Postop SE-PR	Optimized constants
Kane *et al.*[26]	2017	Australia	Retrospective case series	137	NA	≤22	Postop SE-PR	Optimized constants
Khatib *et al.*[21]	2021	India	Retrospective observational	66	NA		Postop SE-PR	Optimized constants
Shrivastava *et al.*[20]	2018	India	Retrospective observational	50	58.54±10.36	21.61±0.27 (20.76-21.96)	Postop SE-PR	Optimized constants
Srivannaboon *et al.*[22]	2013	Thailand	Prospective comparative	15	NA	21.44 (18.77-21.94)	Postop SE-PR	ULIB constants
Terzi *et al.*[27]	2009	Germany	Retrospective	19	53±7	21.24±0.55 (20.13-21.97)	PR-Postop SE	Optimized constants
Wang *et al.*[6]	2013	China	Retrospective	33	NA	21.52±0.47	Postop SE-PR	Optimized constants
Zhao *et al.*[13]	2018	China	Retrospective	139	NA	<21	PR-Postop SE	ULIB constants

Study	Version of biometer	Method of K measurement	Follow-up	Refraction	IOL implanted	Formulae used
Aristodemou *et al.*[15]	NA	IOLMaster	1 month	Subjective	Sofport IOL and Akreos Fit IOL	Hoffer Q, Holladay 1, SRK/T
Cooke and Cooke[23]	Lenstar LS 900 (Version 3.02) and IOLMaster (Version 5.4)	Optical biometer (both OLCR and PCI)	3 weeks to 3 months	Subjective	AcrysofSN60WF	Barrett Universal II, Haigis, Hoffer Q, Holladay 1, Holladay 2No Ref, Holladay 2Pre surg Ref, Olsenstandalone, OlsenOLCR SRK-T, Super Formula, T2
Darcy *et al.*	IOLMaster (Carl Zeiss, Meditec, AG)	IOLMaster	NA	Subjective	SA60AT, Superflex Aspheric920 H, C-Flex Aspheric970C, AkreosAdaptAO	Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay1, Holladay 2, Kane, Olsen, SRK/T
Day *et al.*[17]	IOLMaster (Carl Zeiss, Meditec, Inc, Dublin, CA, USA)	IOLMaster	2-17.7 weeks	Autorefraction (Topcon KR8000 series autorefractor) Topcon, Rotterdam, The Netherlands	Akreos AO, Akreos Adapt, Corneal ACR6D, OculentisLentis L302-1	Haigis, Hoffer Q, Holladay1, SRK/T
Eom *et al.*[18]	IOLMaster (Version 5.02)	IOLMaster	3-10 weeks	Autorefractor/Keratometer (RK-F1; Canon, Tokyo, Japan)	Alcon Acrysof IQ	Haigis, Hoffer Q
Gavin and Hammond[16]	IOLMaster (Zeiss-Humphrey systems)	IOLMaster	2-3 weeks	Autorefractometer (Canon AR-2, Canon, Tokyo)	AllerganMA60	Hoffer Q, SRK/T

Contd...

Table 1: Contd...

Study	Version of biometer	Method of K measurement	Follow-up	Refraction	IOL implanted	Formulae used
Gökce *et al.*[19]	Lenstar LS900 (Version V 4.1.1, Haag Streit AG)	Lenstar	>3 weeks	Subjective	Alcon Acrysof SN60WF, SN6AT, SA60AT, Tecnis, ZCBOO, ZCT	Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 1, Holladay 2, and Olsen
Kane *et al.*[5]	IOLMaster (Version 5.4, Carl Zeiss, Meditec, AG)	IOLMaster	2 weeks	Subjective	AcrysofIQSN60WF	Barrett Universal II, Haigis, Hoffer Q, Holladay1, Holladay 2, SRK/T, T2
Kane *et al.*	IOLMaster (Version 5.4, Carl Zeiss, Meditec, AG)	IOLMaster	2 weeks	Subjective	Acrysof IQ SN60WF	Barrett Universal II, Full Monte method, Hill- RBF, Holladay 1, Ladas Super formula
Khatib *et al.*[21]	Lenstar LS 900	Lenstar	2 weeks	Subjective	Acrysof IQ SN60WF, Tecnis ZCB00	Barrett Universal II, EVO, Hill-RBF
Shrivastava *et al.*[20]	IOLMaster 500 (Version 5.4, Carl Zeiss, Meditec, AG)	IOLMaster	1 month	Autorefractometer (Accuref K-900/R-800, Rexxam Co. Ltd.)	Acrysof SN6CWS	Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 2, SRK/T
Srivannaboon *et al.*[22]	IOLMaster (Carl Zeiss, Meditec, Jena, Germany)	IOLMaster	3 months	Subjective	Hoya PY60AD	Haigis, Hoffer Q, Holladay 2 with LT, Holladay 2 without LT
Terzi *et al.*	IOLMaster (Carl Zeiss, Meditec, AG)	AL by PCI, Keratometry not clear	1 month	Subjective	Acrysof SA60AT, Sensar AR40e	Haigis, Hoffer Q, Holladay 2, SRK/T
Wang *et al.*[6]	IOLMaster (Carl Zeiss, Jena, Germany)	IOLMaster	3 months	Autorefractometer (Topcon AR, Tokyo, Japan)	Acrysof SA60AT	Haigis, Hoffer Q, Holladay 1, SRK/T
Zhao *et al.*[13]	Zeiss IOLMaster (Version 4.02)	AL- IOLMaster, Manual keratometry	1-3 months	Subjective	AA4203	Haigis, Hoffer Q, Holladay 1, Holladay 2, SRK/T

Postop SE=postoperative spherical equivalent; PR=predicted refraction; ULIB=User Group for Laser Interference Biometry; AL=axial length; OLCR=optical low-coherence reflectometry; PCI=partial coherence interferometry

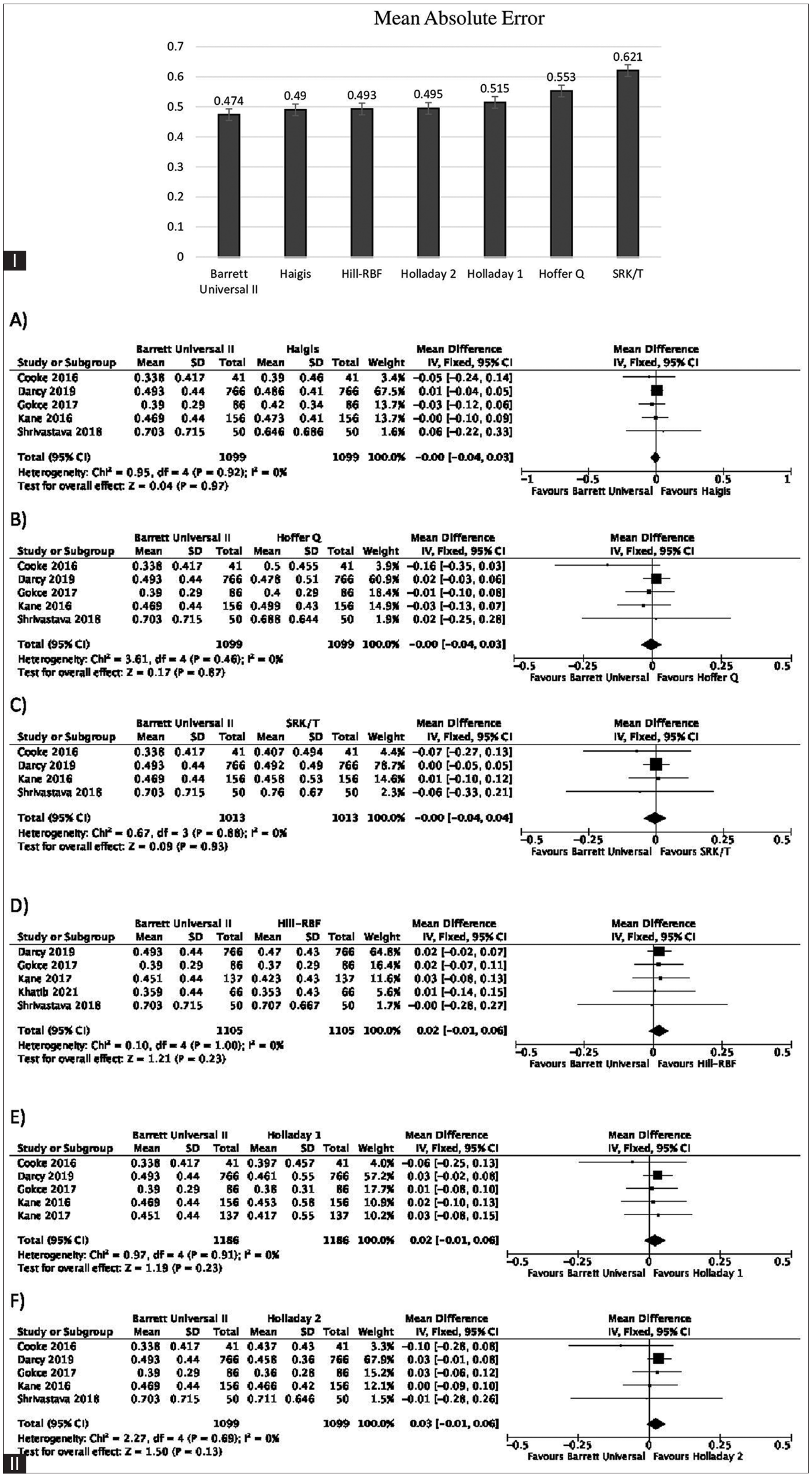

Figure 3: (I) The overall MAE and standard error of all formulae included in analysis. (II) Forest plots showing comparison of MAE between Barrett Universal II and Haigis (A), Hoffer Q (B), SRK/T (C), Hill-RBF (D), Holladay 1 (E), and Holladay 2 (F). Abbreviations: MAE = Mean absolute error; D = Diopter; PE = Prediction error

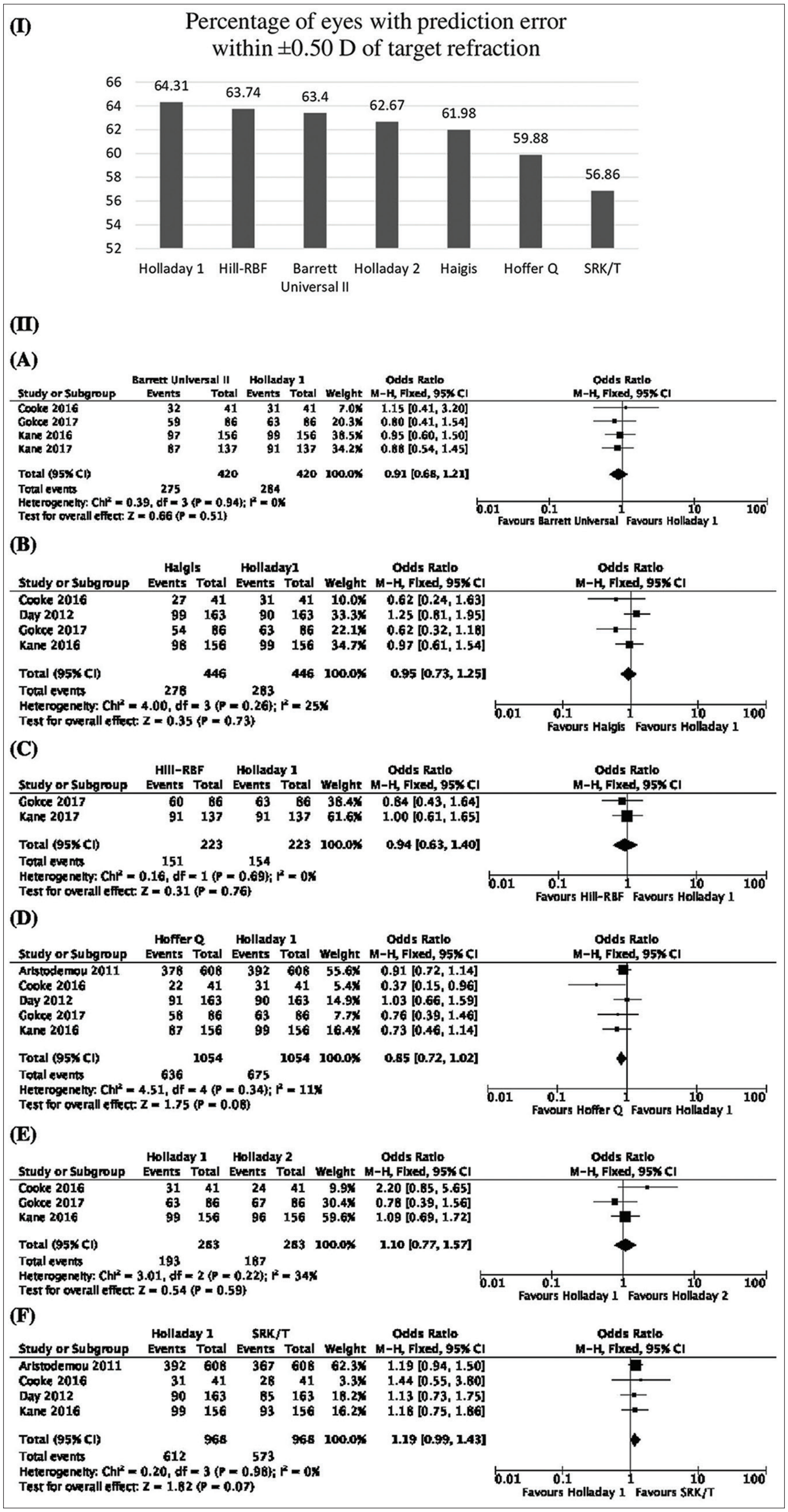

Figure 4: (I) Percentage of eyes with prediction error within ±0.50 D of target refraction of all the formulae included in the analysis. (II) Forest plots showing comparison between Holladay 1 and Barrett Universal II (A), Haigis (B), Hill-RBF (C), Hoffer Q (D), Holladay 2 (E), and SRK/T (F). Abbreviations: D = Diopter; PE = Prediction error

Table 2: Descriptive analysis of median absolute error of all the formulae included in the analysis

Formula	Number of studies	Range
Barrett Universal II	7	0.260-0.540
Full Monte	1	0.462
Haigis	11	0.308-0.570
Hill-RBF	5	0.300-0.520
Hoffer Q	13	0.340-0.580
Holladay 1	9	0.302-0.630
Holladay 2	8	0.320-0.560
Olsen	3	0.325-0.350
Super formula	2	0.320-0.370
SRK/T	10	0.327-0.690
T2	2	0.341-0.415

Percentage of eyes with prediction error within ±0.50 D of target refraction

Fig. 4(I) shows the percentage of eyes with PE within ±0.50 D of target refraction of all the formulae included in the analysis. Holladay 1 had the highest percentage of eyes. On analyzing the forest plots, OR and 95% CI of Holladay 1 as compared with Barrett Universal II, Haigis, Hill-RBF, Hoffer Q, Holladay 2, and SRK/T formulae were 0.91 (0.68,1.21), P value = 0.51, 0.95 (0.73, 1.25), P value = 0.73, 0.94 (0.63, 1.40), P value = 0.76, 0.85 (0.72, 1.02), P value = 0.08, 1.10 (0.77, 1.57), P value = 0.59, and 1.19 (0.99, 1.43), P value = 0.07, respectively, as shown in Fig. 4(II). None of the comparisons showed statistically significant results [Additional file 3].

Percentage of eyes with prediction error within ±1.0 D of target refraction

Hill-RBF had the highest value when the percentage of eyes with PE within ±1.0 D of target refraction was considered [Additional file 4 (I)]. On analyzing the forest plots none of the comparisons yielded statistically significant results [Additional file 4 (II)].

There was only one study that reported the percentage of eyes with PE within ±0.50 and ±1.0 D for comparison between Hill-RBF and SRK/T formulae, and hence forest plots were not made according to the Cochrane Collaboration guidelines.[12]

Heterogeneity and I^2

Additional file 2 (B, C, D, and E) shows both substantial as well as statistical heterogeneity on comparison of MAE of Haigis with Hoffer Q, Holladay 1, Holladay 2, and SRK/T. A random-effect model was chosen in these cases. On doing a sensitivity analysis [Additional file 5], it was observed that I^2 reduced to 0% in all the four comparisons by omitting the study by Zhao *et al*.[13] The result was more in favor of Holladay 2, although not statistically significant when the above-mentioned study was excluded from the comparison between Haigis and Holladay 2. However, the results were not altered in the rest of the comparisons.

Publication bias

The funnel plot drawn for comparison between Haigis and Hoffer Q, which included 11 studies, showed that the study by Zhao *et al*.[13] was outside the funnel [Additional file 6].

Discussion

MAE had long been reported as a parameter for comparing formula accuracy. As suggested by Hoffer *et al*.,[7] absolute error does not follow normal Gaussian distribution; so reporting and comparing MedAE gives a better idea about formula accuracy. MedAE, by negating the effect of outliers, had an added advantage. The reporting percentage of eyes within ±0.50 and ±1.0 D of target refraction is also recommended as this parameter is most closely related to patient satisfaction after surgery. With this background present, meta-analysis was carried out by comparing all the recommended parameters, that is, MAE, MedAE, and percentage of eyes with PE within ±0.50 and ±1.0 D of target refraction, to find the best-performing formula in short AL eyes.

Studies conducted in various parts of the world have advocated different formulae for eyes with short AL. Hoffer Q, a preferred formula for short eyes, has been reported as the most accurate in the study done by Hoffer[14]; although the study included only 10 short eyes and used ultrasound biometry. Also a study by Aristodemou *et al*.[15] considered it to give the best refractive outcome in eyes shorter than 21.00 mm; while between 21.00 and 21.49 mm, it was found to be equally good as Holladay 1. It is worthwhile to mention here that MAE was the only parameter compared in this study. Gavin and Hammond[16] considered Hoffer Q as an accurate formula in short eyes, but the comparison was done only against SRK/T. In a study by Day *et al*.,[17] although Hoffer Q had the lowest MAE on using manufacturer's constants; all formulae performed equally well after lens constant optimization.

Contrary to this, Haigis has been described as the most accurate formula in short eyes by some authors. Zhao *et al*.[13] found optimized Haigis formula more accurate than other formulae in eyes with AL less than 21 mm. A study done by Eom *et al*.[18] found it to be more accurate as compared with Hoffer Q when ACD was less than 2.4 mm. The meta-analysis carried out by Wang *et al*.[6] has also recommended Haigis as the formula of choice for short eyes. But a general consensus regarding the formula of choice in short eyes is still missing.

In the present analysis, although Barrett Universal II had the lowest MAE and MedAE, the results were not statistically significant when compared with the rest of the formulae. Holladay 1 and Hill-RBF had the highest percentage of eyes within ±0.50 and ±1.0 D of target refraction, respectively. Yet their comparison with the rest of the formulae also did not yield statistically significant results. Our results were in concordance with that of Kane *et al*.[5] who found no statistical difference between the formulae analyzed, thus making it difficult to choose any one IOL power calculation formula over the other, in eyes with short AL. The study results of Gökce *et al*.,[19] Shrivastava *et al*.,[20] and Khatib *et al*.[21] were in agreement with this.

Over a period of years, there have been continuous developments in the field of IOL power calculation. It is an established fact now that optimization of lens constant has to be mandatorily done for conducting any study on IOL calculation accuracy. In this analysis, Gavin and Hammond[16] used the manufacturer's constant and found Hoffer Q better, whereas Srivannaboon *et al*.[22] and Zhao *et al*.[13] used User Group for Laser Interference Biometry constants. The results of Srivannaboon *et al*.[22] showed no statistically significant difference between the formulae, whereas Zhao *et al*.[13] found Haigis formula to be more appropriate. It is interesting to note that in studies using optimized constants, none of the formulae was found to be statistically superior over the other. Second, the method of calculating refractive prediction error (RPE) also influences the results. Although most studies have calculated RPE as postoperative SE minus predicted refraction (PR), there are also a few, which have taken PR minus postoperative SE as RPE. Hence, this fact has to be considered before statistical analysis and comparing formula accuracy. Third, the difference in version and make of the optical biometers also affects the study results. This fact has been clearly established in the study by Cooke and Cooke[23] who showed that, in the subgroup of short eyes, Barrett Universal II achieved the best results when PCI measurements were used, whereas Olsen outperformed other formulae on using OLCR values. The strength of the current meta-analysis is that we have contemplated on all the above-mentioned facts and hence put forth a complete picture by analyzing the recommended parameters of formula accuracy, that is, MAE, MedAE, and percentage of eyes with prediction errors within ±0.50 and ±1.0 D of target refraction rather than only MAE as done by Wang *et al*.[6]

As an effort to minimize heterogeneity and reduce bias, our meta-analysis excluded studies where optical biometry was not used. The random-effect model was used in cases with substantial as well as statistical heterogeneity. Sensitivity analysis showed that I^2 reduced to 0% in all the four pairs of comparison (Haigis with Hoffer Q, Holladay 1, Holladay 2, and SRK/T) by omitting the study of Zhao *et al*.[13] On analyzing, we found that in a study by Zhao *et al.*,[13] although AL measurement was done by IOLMaster; keratometry was done manually. The subgroup analysis of the keratometry method showed that the difference is statistically significant ($P = 0.03$), which was accounted for the source of heterogeneity. It is also a well-known fact that racial differences can affect the accuracy of IOL calculations.[24] The studies included in this meta-analysis are from various regions of the world, thus making our results more generalized rather than pertaining to a particular subcontinent.

Conclusion

Thus, to conclude, in the present meta-analysis, although lowest MAE and MedAE were found for Barrett Universal II and highest percentage of eyes within ±0.50 D and ±1.0 D of target refraction was found for Holladay 1 and Hill-RBF, respectively, none of the formulae was found to be statistically superior over the other in eyes with short AL.

Availability of data and materials

All data analyzed in this study are included in the article and its additional files.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Additional file 1

Modified check-list adapted from the QUADAS-2 tool

Assessment of risk of bias

Domain 1: Patient selection

Question 1: Was a consecutive or random sample of patients enrolled?
- 'yes' → low risk of bias
- 'unclear' → unclear risk of bias
- 'no' → high risk of bias.

Question 2: Did the study avoid inappropriate exclusions?
- 'no' for < 10% of patients or 'yes' → low risk of bias
- 'unclear' → unclear risk of bias
- 'no' for ≥ 10% of patients → high risk of bias.

Domain 2: Index test

Were the index test result read without knowing the result of the reference standard?
- 'yes' → low risk of bias
- 'unclear' → unclear risk of bias
- 'no' → high risk of bias

Domain 3: Reference standard

Could the calculation of refractive prediction error have introduced bias?
- Objective Refraction → low risk of bias
- 'unclear' → unclear risk of bias
- Subjective refraction → high risk of bias

Domain 4: Flow and timing

Question 1: Did all patients receive the same reference standard?
- 'no' but for < 10% of patients or 'yes' → low risk of bias
- 'unclear' → unclear risk of bias
- 'no' for ≥ 10% of patients → high risk of bias.

Question 2: Was there an appropriate interval between the index test and reference standard?
- post-operative refraction done two weeks or later after surgery → low risk of bias
- 'unclear' → unclear risk of bias
- post-operative refraction done within two weeks of surgery → high risk of bias.

Assessment of applicability concerns

Domain 1: Patient selection

Is there concern that included patients do not match review question?
- 'no' → low risk of bias
- 'unclear' → unclear risk of bias
- 'yes' → high risk of bias

Domain 2: Index test

Is there concern that index test, its conduct or interpretation differ from review question?
- 'no' → low risk of bias
- 'unclear' → unclear risk of bias
- 'yes' → high risk of bias.

Domain 3: Reference standard

Is there concern that target condition as defined by the reference standard does not match the review question?
- 'no' → low risk of bias
- 'unclear' → unclear risk of bias
- 'yes' → high risk of bias.

Quality assessment of the included studies based on modified QUADAS- 2 tool

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Aristodemou 2011	☺	☺	☹	☺	☺	☺	☺
Cooke 2016	☺	☺	☹	☺	☺	☺	☺
Darcy 2020	☺	☺	☹	?	?	☺	☺
Day 2012	☺	☺	☺	☺	☺	☺	☺
Eom 2014	?	☺	☺	☺	☺	☺	☺
Gokce 2017	?	☺	☹	☺	☺	☺	☺
Gavin 2008	?	☺	☺	☺	☺	☺	☺
Kane 2016	?	☺	☹	☺	☺	☺	☺
Kane 2017	?	☺	☹	☺	☺	☺	☺
Khatib 2021	?	☺	☹	☺	☺	☺	☺
Shrivastava 2018	?	☺	☺	☺	☺	☺	☺
Srivannaboon 2013	☺	☺	☹	☺	☺	☺	☺
Terzi 2009	?	☺	☹	☺	☺	☺	☺
Wang 2013	?	☺	☺	☺	☺	☺	☺
Zhao 2018	?	☺	☹	☺	☺	☺	☺

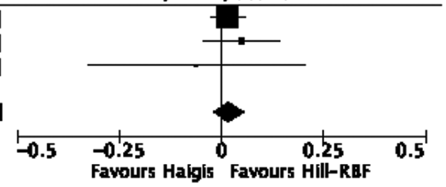
☺ Low Risk, ☹ High Risk, ? Unclear Risk

Additional file 2

Pair-wise comparison between MAE of formulae

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Hill-RBF Mean	Hill-RBF SD	Hill-RBF Total	Weight	Mean Difference IV, Fixed, 95% CI
Darcy 2019	0.486	0.41	766	0.47	0.43	766	81.7%	0.02 [−0.03, 0.06]
Gokce 2017	0.42	0.34	86	0.37	0.29	86	16.2%	0.05 [−0.04, 0.14]
Shrivastava 2018	0.646	0.686	50	0.707	0.667	50	2.1%	−0.06 [−0.33, 0.20]
Total (95% CI)			902			902	100.0%	0.02 [−0.02, 0.06]

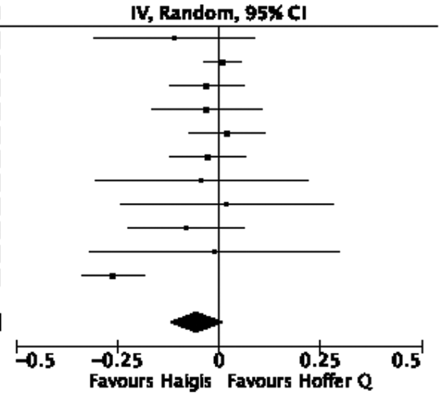
Heterogeneity: $Chi^2 = 0.78$, $df = 2$ ($P = 0.68$); $I^2 = 0\%$
Test for overall effect: $Z = 1.03$ ($P = 0.30$)



A

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Hoffer Q Mean	Hoffer Q SD	Hoffer Q Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.5	0.455	41	6.6%	−0.11 [−0.31, 0.09]
Darcy 2019	0.486	0.41	766	0.478	0.51	766	14.1%	0.01 [−0.04, 0.05]
Day 2012	0.5	0.41	163	0.53	0.44	163	11.8%	−0.03 [−0.12, 0.06]
Eom 2014	0.46	0.41	75	0.49	0.43	75	9.5%	−0.03 [−0.16, 0.10]
Gokce 2017	0.42	0.34	86	0.4	0.29	86	11.7%	0.02 [−0.07, 0.11]
Kane 2016	0.473	0.41	156	0.499	0.43	156	11.8%	−0.03 [−0.12, 0.07]
Shrivastava 2018	0.646	0.686	50	0.688	0.644	50	4.7%	−0.04 [−0.30, 0.22]
Srivannaboon 2013	0.44	0.4	15	0.42	0.33	15	4.6%	0.02 [−0.24, 0.28]
Terzi 2009	0.34	0.23	19	0.42	0.22	19	9.0%	−0.08 [−0.22, 0.06]
Wang 2013	0.66	0.68	33	0.67	0.59	33	3.7%	−0.01 [−0.32, 0.30]
Zhao 2018	0.58	0.28	139	0.84	0.38	139	12.6%	−0.26 [−0.34, −0.18]
Total (95% CI)			1543			1543	100.0%	−0.05 [−0.12, 0.01]

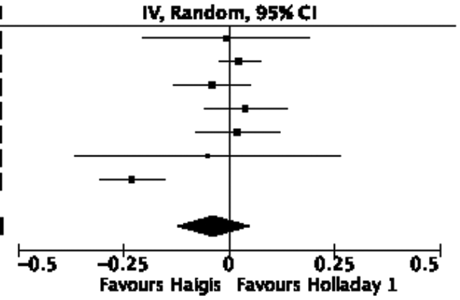
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 36.92$, $df = 10$ ($P < 0.0001$); $I^2 = 73\%$
Test for overall effect: $Z = 1.58$ ($P = 0.11$)



B

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Holladay1 Mean	Holladay1 SD	Holladay1 Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.397	0.457	41	10.0%	−0.01 [−0.21, 0.19]
Darcy 2019	0.486	0.41	766	0.461	0.55	766	18.7%	0.02 [−0.02, 0.07]
Day 2012	0.5	0.41	163	0.54	0.44	163	16.3%	−0.04 [−0.13, 0.05]
Gokce 2017	0.42	0.34	86	0.38	0.31	86	16.0%	0.04 [−0.06, 0.14]
Kane 2016	0.473	0.41	156	0.453	0.48	156	15.9%	0.02 [−0.08, 0.12]
Wang 2013	0.66	0.68	33	0.71	0.62	33	5.7%	−0.05 [−0.36, 0.26]
Zhao 2018	0.58	0.28	139	0.81	0.37	139	17.3%	−0.23 [−0.31, −0.15]
Total (95% CI)			1384			1384	100.0%	−0.04 [−0.12, 0.05]

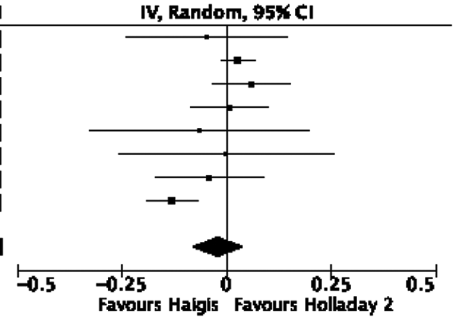
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 33.82$, $df = 6$ ($P < 0.00001$); $I^2 = 82\%$
Test for overall effect: $Z = 0.78$ ($P = 0.43$)



C

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Holladay 2 Mean	Holladay 2 SD	Holladay 2 Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.437	0.43	41	7.3%	−0.05 [−0.24, 0.15]
Darcy 2019	0.486	0.41	766	0.458	0.36	766	21.5%	0.03 [−0.01, 0.07]
Gokce 2017	0.42	0.34	86	0.36	0.28	86	15.4%	0.06 [−0.03, 0.15]
Kane 2016	0.473	0.41	156	0.466	0.42	156	15.5%	0.01 [−0.09, 0.10]
Shrivastava 2018	0.646	0.686	50	0.711	0.646	50	4.6%	−0.06 [−0.33, 0.20]
Srivannaboon 2013	0.44	0.4	15	0.44	0.31	15	4.7%	0.00 [−0.26, 0.26]
Terzi 2009	0.34	0.23	19	0.38	0.17	19	11.8%	−0.04 [−0.17, 0.09]
Zhao 2018	0.58	0.28	139	0.71	0.24	139	19.1%	−0.13 [−0.19, −0.07]
Total (95% CI)			1272			1272	100.0%	−0.02 [−0.08, 0.04]

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 21.26$, $df = 7$ ($P = 0.003$); $I^2 = 67\%$
Test for overall effect: $Z = 0.62$ ($P = 0.54$)

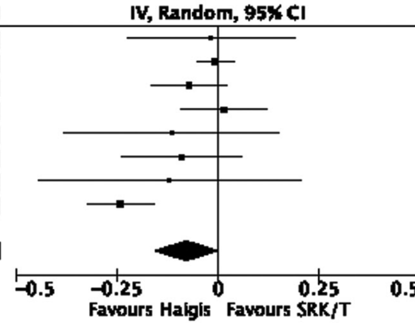


D

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	SRK/T Mean	SRK/T SD	SRK/T Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.407	0.494	41	8.8%	−0.02 [−0.22, 0.19]
Darcy 2019	0.486	0.41	766	0.492	0.49	766	19.4%	−0.01 [−0.05, 0.04]
Day 2012	0.5	0.41	163	0.57	0.45	163	16.2%	−0.07 [−0.16, 0.02]
Kane 2016	0.473	0.41	156	0.458	0.53	156	15.3%	0.01 [−0.09, 0.12]
Shrivastava 2018	0.646	0.686	50	0.76	0.67	50	6.4%	−0.11 [−0.38, 0.15]
Terzi 2009	0.34	0.23	19	0.43	0.24	19	12.1%	−0.09 [−0.24, 0.06]
Wang 2013	0.66	0.68	33	0.78	0.66	33	4.8%	−0.12 [−0.44, 0.20]
Zhao 2018	0.58	0.28	139	0.82	0.4	139	17.1%	−0.24 [−0.32, −0.16]
Total (95% CI)			**1367**			**1367**	**100.0%**	**−0.08 [−0.16, 0.00]**

Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 26.94$, df = 7 (P = 0.0003); $I^2 = 74\%$
Test for overall effect: Z = 1.86 (P = 0.06)

Mean Difference IV, Random, 95% CI

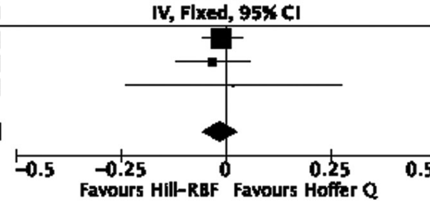


E

Study or Subgroup	Hill-RBF Mean	Hill-RBF SD	Hill-RBF Total	Hoffer Q Mean	Hoffer Q SD	Hoffer Q Total	Weight	Mean Difference IV, Fixed, 95% CI
Darcy 2019	0.47	0.43	766	0.478	0.51	766	75.1%	−0.01 [−0.06, 0.04]
Gokce 2017	0.37	0.29	86	0.4	0.29	86	22.3%	−0.03 [−0.12, 0.06]
Shrivastava 2018	0.707	0.667	50	0.688	0.644	50	2.5%	0.02 [−0.24, 0.28]
Total (95% CI)			**902**			**902**	**100.0%**	**−0.01 [−0.05, 0.03]**

Heterogeneity: $Chi^2 = 0.25$, df = 2 (P = 0.88); $I^2 = 0\%$
Test for overall effect: Z = 0.59 (P = 0.56)

Mean Difference IV, Fixed, 95% CI

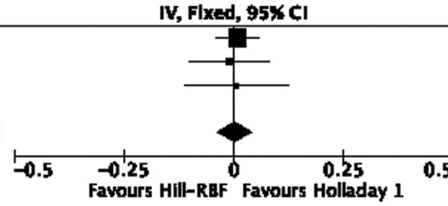


F

Study or Subgroup	Hill-RBF Mean	Hill-RBF SD	Hill-RBF Total	Holladay 1 Mean	Holladay 1 SD	Holladay 1 Total	Weight	Mean Difference IV, Fixed, 95% CI
Darcy 2019	0.47	0.43	766	0.461	0.55	766	67.5%	0.01 [−0.04, 0.06]
Gokce 2017	0.37	0.29	86	0.38	0.31	86	20.5%	−0.01 [−0.10, 0.08]
Kane 2017	0.423	0.43	137	0.417	0.55	137	12.1%	0.01 [−0.11, 0.12]
Total (95% CI)			**989**			**989**	**100.0%**	**0.00 [−0.04, 0.05]**

Heterogeneity: $Chi^2 = 0.13$, df = 2 (P = 0.94); $I^2 = 0\%$
Test for overall effect: Z = 0.23 (P = 0.82)

Mean Difference IV, Fixed, 95% CI

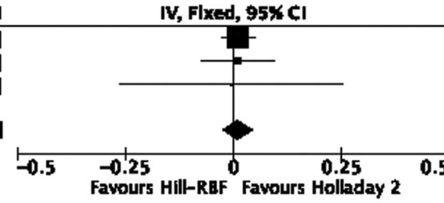


G

Study or Subgroup	Hill-RBF Mean	Hill-RBF SD	Hill-RBF Total	Holladay 2 Mean	Holladay 2 SD	Holladay 2 Total	Weight	Mean Difference IV, Fixed, 95% CI
Darcy 2019	0.47	0.43	766	0.458	0.36	766	80.6%	0.01 [−0.03, 0.05]
Gokce 2017	0.37	0.29	86	0.36	0.28	86	17.5%	0.01 [−0.08, 0.10]
Shrivastava 2018	0.707	0.667	50	0.711	0.646	50	1.9%	−0.00 [−0.26, 0.25]
Total (95% CI)			**902**			**902**	**100.0%**	**0.01 [−0.02, 0.05]**

Heterogeneity: $Chi^2 = 0.02$, df = 2 (P = 0.99); $I^2 = 0\%$
Test for overall effect: Z = 0.62 (P = 0.53)

Mean Difference IV, Fixed, 95% CI

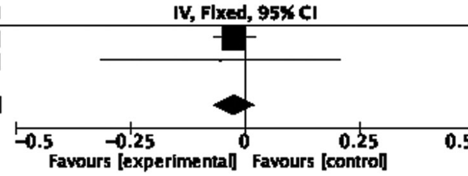


H

Study or Subgroup	Hill-RBF Mean	Hill-RBF SD	Hill-RBF Total	SRK/T Mean	SRK/T SD	SRK/T Total	Weight	Mean Difference IV, Fixed, 95% CI
Darcy 2019	0.47	0.43	766	0.492	0.49	766	97.0%	−0.02 [−0.07, 0.02]
Shrivastava 2018	0.707	0.667	50	0.76	0.67	50	3.0%	−0.05 [−0.32, 0.21]
Total (95% CI)			**816**			**816**	**100.0%**	**−0.02 [−0.07, 0.02]**

Heterogeneity: $Chi^2 = 0.05$, df = 1 (P = 0.82); $I^2 = 0\%$
Test for overall effect: Z = 0.99 (P = 0.32)

Mean Difference IV, Fixed, 95% CI

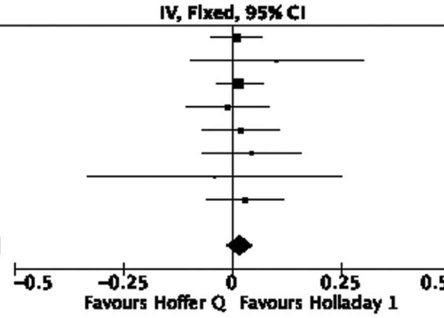


I

Study or Subgroup	Hoffer Q Mean	Hoffer Q SD	Hoffer Q Total	Holladay 1 Mean	Holladay 1 SD	Holladay 1 Total	Weight	Mean Difference IV, Fixed, 95% CI
Aristodemou 2011	0.48	0.51	608	0.47	0.55	608	25.3%	0.01 [−0.05, 0.07]
Cooke 2016	0.5	0.455	41	0.397	0.457	41	2.3%	0.10 [−0.09, 0.30]
Darcy 2019	0.478	0.51	766	0.461	0.55	766	31.8%	0.02 [−0.04, 0.07]
Day 2012	0.53	0.44	163	0.54	0.44	163	9.8%	−0.01 [−0.11, 0.09]
Gokce 2017	0.4	0.29	86	0.38	0.31	86	11.2%	0.02 [−0.07, 0.11]
Kane 2016	0.499	0.43	156	0.453	0.58	156	7.0%	0.05 [−0.07, 0.16]
Wang 2013	0.67	0.59	33	0.71	0.62	33	1.1%	−0.04 [−0.33, 0.25]
Zhao 2018	0.84	0.38	139	0.81	0.37	139	11.6%	0.03 [−0.06, 0.12]
Total (95% CI)			**1992**			**1992**	**100.0%**	**0.02 [−0.01, 0.05]**

Heterogeneity: $Chi^2 = 1.57$, df = 7 (P = 0.98); $I^2 = 0\%$
Test for overall effect: Z = 1.17 (P = 0.24)

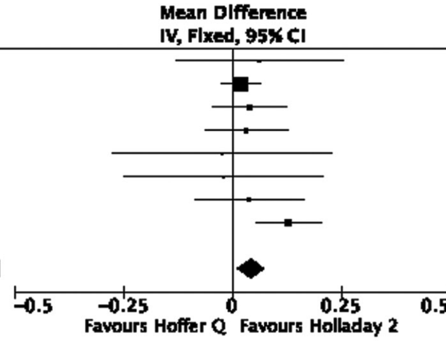
Mean Difference IV, Fixed, 95% CI



J

Study or Subgroup	Hoffer Q Mean	SD	Total	Holladay 2 Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Cooke 2016	0.5	0.455	41	0.437	0.43	41	2.6%	0.06 [−0.13, 0.25]
Darcy 2019	0.478	0.51	766	0.458	0.36	766	48.0%	0.02 [−0.02, 0.06]
Gokce 2017	0.4	0.29	86	0.36	0.28	86	12.9%	0.04 [−0.05, 0.13]
Kane 2016	0.499	0.43	156	0.466	0.42	156	10.5%	0.03 [−0.06, 0.13]
Shrivastava 2018	0.688	0.644	50	0.711	0.646	50	1.5%	−0.02 [−0.28, 0.23]
Srivannaboon 2013	0.42	0.33	15	0.44	0.31	15	1.8%	−0.02 [−0.25, 0.21]
Terzi 2009	0.42	0.22	19	0.38	0.17	19	6.0%	0.04 [−0.09, 0.17]
Zhao 2018	0.84	0.38	139	0.71	0.24	139	16.8%	0.13 [0.06, 0.20]
Total (95% CI)			**1272**			**1272**	**100.0%**	**0.04 [0.01, 0.07]**

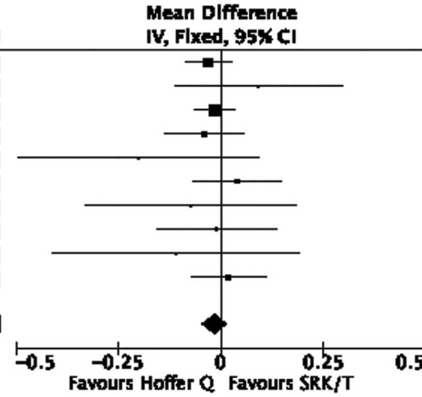
Heterogeneity: $Chi^2 = 6.89$, df = 7 (P = 0.44); $I^2 = 0\%$
Test for overall effect: Z = 2.78 (P = 0.005)



K

Study or Subgroup	Hoffer Q Mean	SD	Total	SRK/T Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Aristodemou 2011	0.48	0.51	608	0.51	0.49	608	27.8%	−0.03 [−0.09, 0.03]
Cooke 2016	0.5	0.455	41	0.407	0.494	41	2.1%	0.09 [−0.11, 0.30]
Darcy 2019	0.478	0.51	766	0.492	0.49	766	35.1%	−0.01 [−0.06, 0.04]
Day 2012	0.53	0.44	163	0.57	0.45	163	9.4%	−0.04 [−0.14, 0.06]
Gavin 2007	0.78	0.654	41	0.98	0.701	41	1.0%	−0.20 [−0.49, 0.09]
Kane 2016	0.499	0.43	156	0.458	0.53	156	7.7%	0.04 [−0.07, 0.15]
Shrivastava 2018	0.688	0.644	50	0.76	0.67	50	1.3%	−0.07 [−0.33, 0.19]
Terzi 2009	0.42	0.22	19	0.43	0.24	19	4.1%	−0.01 [−0.16, 0.14]
Wang 2013	0.67	0.59	33	0.78	0.66	33	1.0%	−0.11 [−0.41, 0.19]
Zhao 2018	0.84	0.38	139	0.82	0.4	139	10.5%	0.02 [−0.07, 0.11]
Total (95% CI)			**2016**			**2016**	**100.0%**	**−0.01 [−0.04, 0.02]**

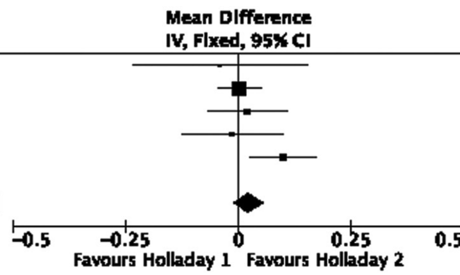
Heterogeneity: $Chi^2 = 5.30$, df = 9 (P = 0.81); $I^2 = 0\%$
Test for overall effect: Z = 0.95 (P = 0.34)



L

Study or Subgroup	Holladay 1 Mean	SD	Total	Holladay 2 Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Cooke 2016	0.397	0.457	41	0.437	0.43	41	3.1%	−0.04 [−0.23, 0.15]
Darcy 2019	0.461	0.55	766	0.458	0.36	766	52.3%	0.00 [−0.04, 0.05]
Gokce 2017	0.38	0.31	86	0.36	0.28	86	14.5%	0.02 [−0.07, 0.11]
Kane 2016	0.453	0.58	156	0.466	0.42	156	9.0%	−0.01 [−0.13, 0.10]
Zhao 2018	0.81	0.37	139	0.71	0.24	139	21.1%	0.10 [0.03, 0.17]
Total (95% CI)			**1188**			**1188**	**100.0%**	**0.02 [−0.01, 0.06]**

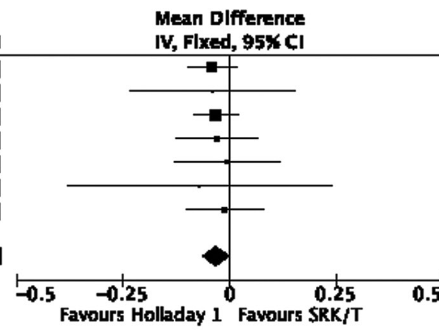
Heterogeneity: $Chi^2 = 5.76$, df = 4 (P = 0.22); $I^2 = 31\%$
Test for overall effect: Z = 1.35 (P = 0.18)



M

Study or Subgroup	Holladay 1 Mean	SD	Total	SRK/T Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Aristodemou 2011	0.47	0.55	608	0.51	0.49	608	29.4%	−0.04 [−0.10, 0.02]
Cooke 2016	0.397	0.457	41	0.437	0.43	41	2.7%	−0.04 [−0.23, 0.15]
Darcy 2019	0.461	0.55	766	0.492	0.49	766	37.1%	−0.03 [−0.08, 0.02]
Day 2012	0.54	0.44	163	0.57	0.45	163	10.8%	−0.03 [−0.13, 0.07]
Kane 2016	0.453	0.58	156	0.458	0.53	156	6.6%	−0.01 [−0.13, 0.12]
Wang 2013	0.71	0.62	33	0.78	0.66	33	1.1%	−0.07 [−0.38, 0.24]
Zhao 2018	0.81	0.37	139	0.82	0.4	139	12.3%	−0.01 [−0.10, 0.08]
Total (95% CI)			**1906**			**1906**	**100.0%**	**−0.03 [−0.06, 0.00]**

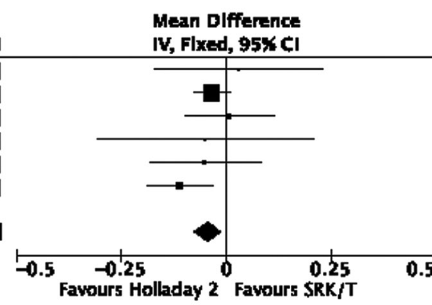
Heterogeneity: $Chi^2 = 0.53$, df = 6 (P = 1.00); $I^2 = 0\%$
Test for overall effect: Z = 1.84 (P = 0.07)



N

Study or Subgroup	Holladay 2 Mean	SD	Total	SRK/T Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Cooke 2016	0.437	0.43	41	0.407	0.494	41	2.8%	0.03 [−0.17, 0.23]
Darcy 2019	0.458	0.36	766	0.492	0.49	766	60.5%	−0.03 [−0.08, 0.01]
Kane 2016	0.466	0.42	156	0.458	0.53	156	10.0%	0.01 [−0.10, 0.11]
Shrivastava 2018	0.711	0.646	50	0.76	0.67	50	1.7%	−0.05 [−0.31, 0.21]
Terzi 2009	0.38	0.17	19	0.43	0.24	19	6.4%	−0.05 [−0.18, 0.08]
Zhao 2018	0.71	0.24	139	0.82	0.4	139	18.7%	−0.11 [−0.19, −0.03]
Total (95% CI)			**1171**			**1171**	**100.0%**	**−0.04 [−0.08, −0.01]**

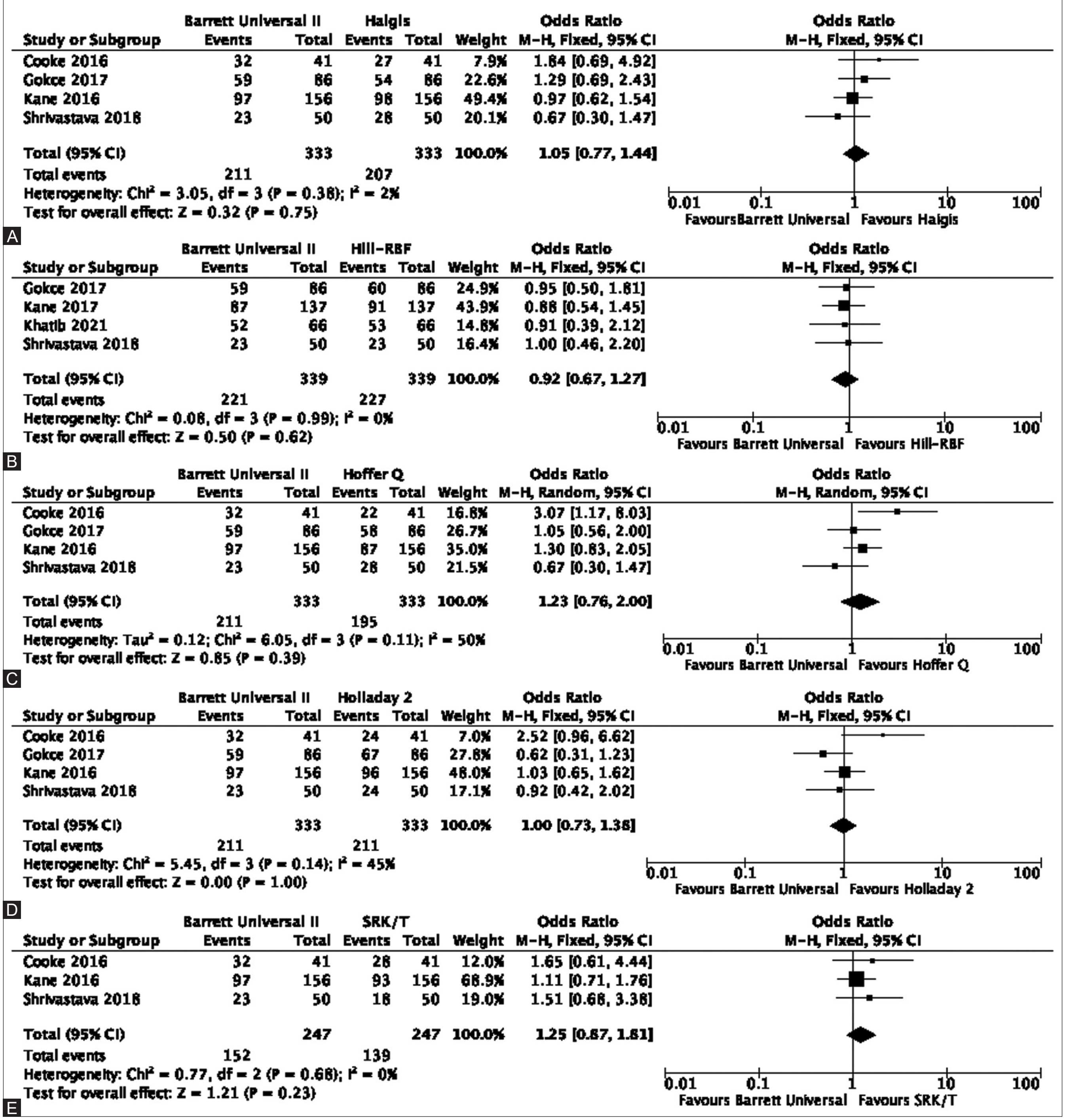
Heterogeneity: $Chi^2 = 4.44$, df = 5 (P = 0.49); $I^2 = 0\%$
Test for overall effect: Z = 2.54 (P = 0.01)



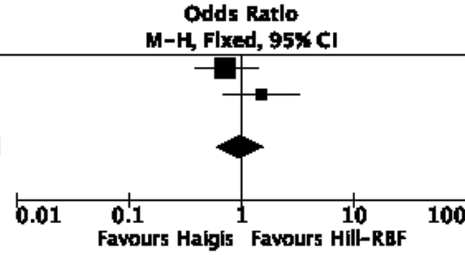
O

Additional file 3

Pair-wise comparison between formulae considering percentage of eyes with prediction error within ±0.50 D of target refraction

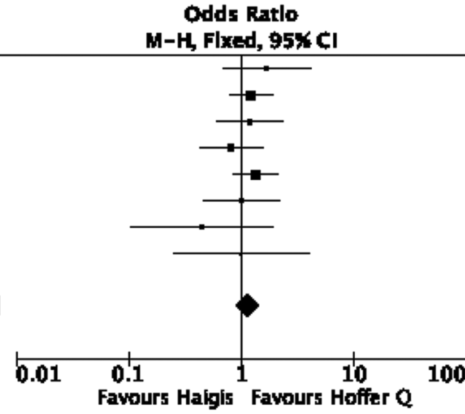


Study or Subgroup	Haigis Events	Haigis Total	Hill-RBF Events	Hill-RBF Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	54	86	60	86	68.8%	0.73 [0.39, 1.38]
Shrivastava 2018	28	50	23	50	31.2%	1.49 [0.68, 3.29]
Total (95% CI)		**136**		**136**	**100.0%**	**0.97 [0.59, 1.58]**
Total events	82		83			
Heterogeneity: Chi² = 1.92, df = 1 (P = 0.17); I² = 48%						
Test for overall effect: Z = 0.13 (P = 0.90)						



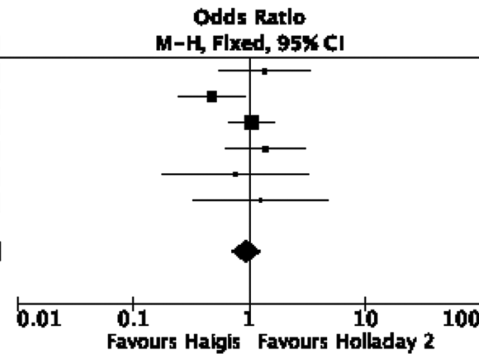
F

Study or Subgroup	Haigis Events	Haigis Total	Hoffer Q Events	Hoffer Q Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	27	41	22	41	5.6%	1.67 [0.68, 4.06]
Day 2012	99	163	91	163	26.5%	1.22 [0.79, 1.90]
Eom 2014	50	75	47	75	11.6%	1.19 [0.61, 2.33]
Gokce 2017	54	86	58	86	16.0%	0.81 [0.43, 1.53]
Kane 2016	98	156	87	156	24.0%	1.34 [0.85, 2.11]
Shrivastava 2018	28	50	28	50	9.1%	1.00 [0.45, 2.20]
Srivannaboon 2013	6	15	9	15	4.0%	0.44 [0.10, 1.92]
Terzi 2009	13	19	13	19	3.0%	1.00 [0.25, 3.93]
Total (95% CI)		**605**		**605**	**100.0%**	**1.15 [0.91, 1.45]**
Total events	375		355			
Heterogeneity: Chi² = 4.13, df = 7 (P = 0.76); I² = 0%						
Test for overall effect: Z = 1.18 (P = 0.24)						



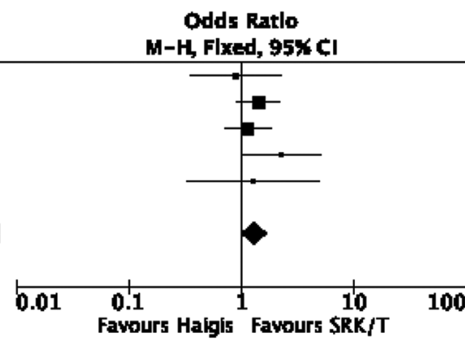
G

Study or Subgroup	Haigis Events	Haigis Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	27	41	24	41	9.4%	1.37 [0.56, 3.35]
Gokce 2017	54	86	67	86	28.5%	0.48 [0.24, 0.94]
Kane 2016	98	156	96	156	40.9%	1.06 [0.67, 1.67]
Shrivastava 2018	28	50	24	50	12.1%	1.38 [0.63, 3.03]
Srivannaboon 2013	6	15	7	15	4.8%	0.76 [0.18, 3.24]
Terzi 2009	13	19	12	19	4.3%	1.26 [0.33, 4.84]
Total (95% CI)		**367**		**367**	**100.0%**	**0.95 [0.71, 1.29]**
Total events	226		230			
Heterogeneity: Chi² = 5.97, df = 5 (P = 0.31); I² = 16%						
Test for overall effect: Z = 0.31 (P = 0.76)						



H

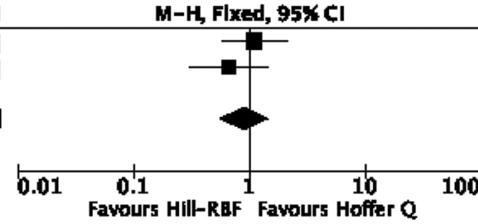
Study or Subgroup	Haigis Events	Haigis Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	27	41	28	41	10.7%	0.90 [0.36, 2.25]
Day 2012	99	163	85	163	37.4%	1.42 [0.91, 2.20]
Kane 2016	98	156	93	156	38.8%	1.14 [0.73, 1.81]
Shrivastava 2018	28	50	18	50	8.9%	2.26 [1.01, 5.05]
Terzi 2009	13	19	12	19	4.2%	1.26 [0.33, 4.84]
Total (95% CI)		**429**		**429**	**100.0%**	**1.33 [1.01, 1.74]**
Total events	265		236			
Heterogeneity: Chi² = 2.89, df = 4 (P = 0.58); I² = 0%						
Test for overall effect: Z = 2.02 (P = 0.04)						



I

Study or Subgroup	Hill-RBF Events	Hill-RBF Total	Hoffer Q Events	Hoffer Q Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	60	86	58	86	53.7%	1.11 [0.58, 2.12]
Shrivastava 2018	23	50	28	50	46.3%	0.67 [0.30, 1.47]
Total (95% CI)		**136**		**136**	**100.0%**	**0.91 [0.55, 1.49]**
Total events	83		86			

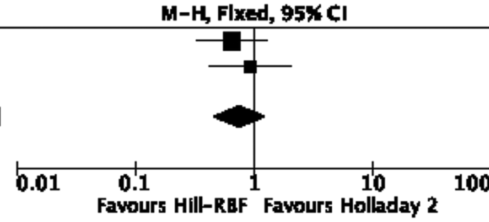
Heterogeneity: $Chi^2 = 0.96$, df = 1 (P = 0.33); $I^2 = 0\%$
Test for overall effect: Z = 0.38 (P = 0.70)



J

Study or Subgroup	Hill-RBF Events	Hill-RBF Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	60	86	67	86	61.0%	0.65 [0.33, 1.30]
Shrivastava 2018	23	50	24	50	39.0%	0.92 [0.42, 2.02]
Total (95% CI)		**136**		**136**	**100.0%**	**0.76 [0.45, 1.27]**
Total events	83		91			

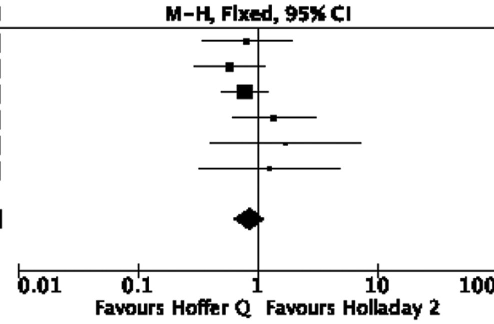
Heterogeneity: $Chi^2 = 0.42$, df = 1 (P = 0.52); $I^2 = 0\%$
Test for overall effect: Z = 1.05 (P = 0.30)



K

Study or Subgroup	Hoffer Q Events	Hoffer Q Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	22	41	24	41	12.0%	0.82 [0.34, 1.96]
Gokce 2017	58	86	67	86	23.6%	0.59 [0.30, 1.16]
Kane 2016	87	156	96	156	45.9%	0.79 [0.50, 1.24]
Shrivastava 2018	28	50	24	50	11.4%	1.38 [0.63, 3.03]
Srivannaboon 2013	9	15	7	15	3.0%	1.71 [0.40, 7.29]
Terzi 2009	13	19	12	19	4.1%	1.26 [0.33, 4.84]
Total (95% CI)		**367**		**367**	**100.0%**	**0.86 [0.64, 1.16]**
Total events	217		230			

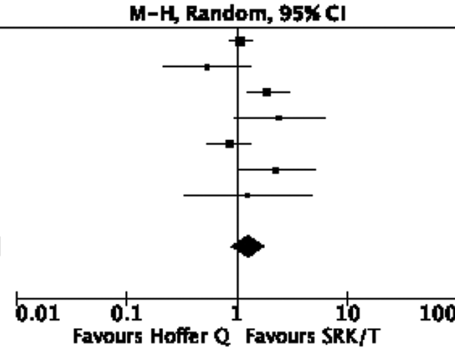
Heterogeneity: $Chi^2 = 3.93$, df = 5 (P = 0.56); $I^2 = 0\%$
Test for overall effect: Z = 0.99 (P = 0.32)



L

Study or Subgroup	Hoffer Q Events	Hoffer Q Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Random, 95% CI
Aristodemou 2011	378	608	367	608	25.4%	1.08 [0.86, 1.36]
Cooke 2016	22	41	28	41	9.8%	0.54 [0.22, 1.32]
Day 2012	91	163	65	163	19.6%	1.91 [1.23, 2.96]
Gavin 2007	18	41	10	41	9.2%	2.43 [0.95, 6.23]
Kane 2016	87	156	93	156	19.3%	0.85 [0.54, 1.34]
Shrivastava 2018	28	50	18	50	11.3%	2.26 [1.01, 5.05]
Terzi 2009	13	19	12	19	5.4%	1.26 [0.33, 4.84]
Total (95% CI)		**1078**		**1078**	**100.0%**	**1.27 [0.90, 1.80]**
Total events	637		593			

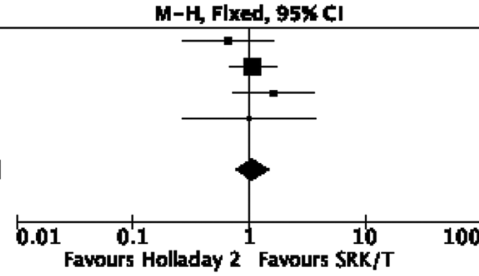
Heterogeneity: $Tau^2 = 0.11$; $Chi^2 = 14.82$, df = 6 (P = 0.02); $I^2 = 60\%$
Test for overall effect: Z = 1.36 (P = 0.17)



M

Study or Subgroup	Holladay 2 Events	Holladay 2 Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	24	41	28	41	19.0%	0.66 [0.27, 1.62]
Kane 2016	96	156	93	156	58.5%	1.08 [0.69, 1.71]
Shrivastava 2018	24	50	18	50	15.3%	1.64 [0.74, 3.66]
Terzi 2009	12	19	12	19	7.2%	1.00 [0.27, 3.74]
Total (95% CI)		**266**		**266**	**100.0%**	**1.08 [0.76, 1.53]**
Total events	156		151			

Heterogeneity: $Chi^2 = 2.23$, df = 3 (P = 0.53); $I^2 = 0\%$
Test for overall effect: Z = 0.44 (P = 0.66)

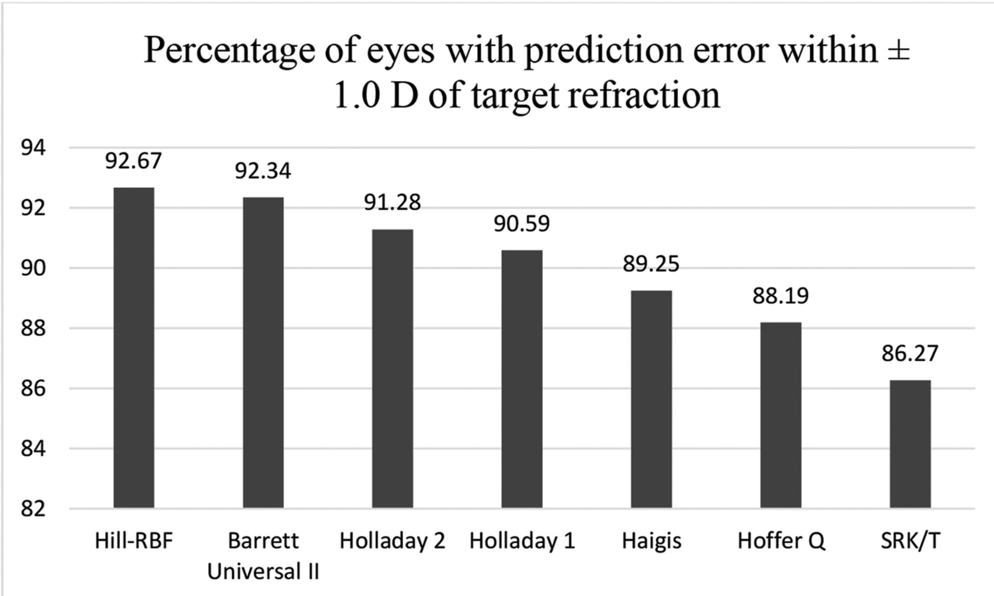


N

Additional file 4

(I) Percentage of eyes with PE within ±1.0 D of target refraction for all formulae included in the analysis (II) Forest plots showing pair-wise comparison between formulae

(I)

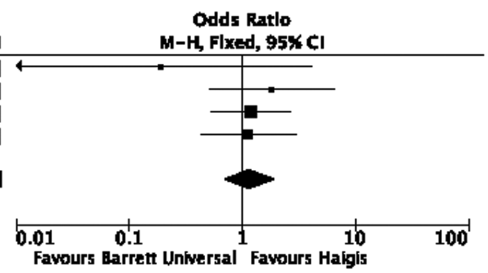


(II)

A)

Study or Subgroup	Barrett Universal II Events	Total	Haigis Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	39	41	41	41	9.9%	0.19 [0.01, 4.09]
Gokce 2017	82	86	79	86	14.8%	1.82 [0.51, 6.45]
Kane 2016	144	156	142	156	43.9%	1.18 [0.53, 2.65]
Shrivastava 2018	40	50	39	50	31.4%	1.13 [0.43, 2.96]
Total (95% CI)		**333**		**333**	**100.0%**	**1.16 [0.68, 1.98]**
Total events	305		301			

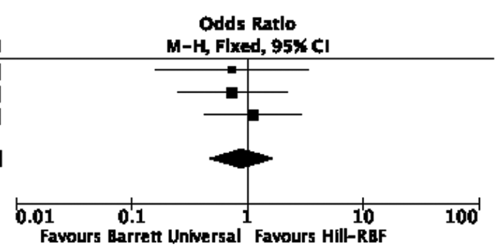
Heterogeneity: Chi² = 1.82, df = 3 (P = 0.61); I² = 0%
Test for overall effect: Z = 0.55 (P = 0.59)



B)

Study or Subgroup	Barrett Universal II Events	Total	Hill-RBF Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	82	86	83	86	20.0%	0.74 [0.16, 3.41]
Kane 2017	129	137	131	137	39.6%	0.74 [0.25, 2.19]
Shrivastava 2018	40	50	39	50	40.4%	1.13 [0.43, 2.96]
Total (95% CI)		**273**		**273**	**100.0%**	**0.90 [0.47, 1.72]**
Total events	251		253			

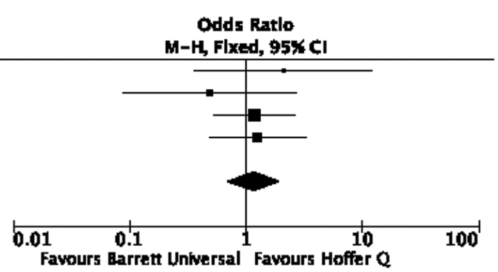
Heterogeneity: Chi² = 0.40, df = 2 (P = 0.82); I² = 0%
Test for overall effect: Z = 0.33 (P = 0.74)



C)

Study or Subgroup	Barrett Universal II Events	Total	Hoffer Q Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	39	41	37	41	7.4%	2.11 [0.36, 12.20]
Gokce 2017	82	86	84	86	16.1%	0.49 [0.09, 2.74]
Kane 2016	144	156	142	156	45.1%	1.18 [0.53, 2.65]
Shrivastava 2018	40	50	38	50	31.4%	1.26 [0.49, 3.26]
Total (95% CI)		**333**		**333**	**100.0%**	**1.17 [0.68, 2.00]**
Total events	305		301			

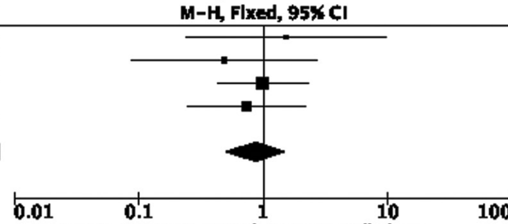
Heterogeneity: Chi² = 1.45, df = 3 (P = 0.69); I² = 0%
Test for overall effect: Z = 0.55 (P = 0.58)



D)

Study or Subgroup	Barrett Universal II Events	Total	Holladay 1 Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	39	41	38	41	7.6%	1.54 [0.24, 9.73]
Gokce 2017	82	86	84	86	16.0%	0.49 [0.09, 2.74]
Kane 2016	144	156	144	156	45.2%	1.00 [0.43, 2.30]
Kane 2017	129	137	131	137	31.2%	0.74 [0.25, 2.19]
Total (95% CI)		**420**		**420**	**100.0%**	**0.88 [0.49, 1.57]**
Total events	394		397			

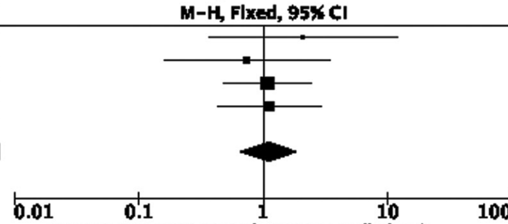
Heterogeneity: $Chi^2 = 0.99$, df = 3 (P = 0.80); $I^2 = 0\%$
Test for overall effect: Z = 0.44 (P = 0.66)



E)

Study or Subgroup	Barrett Universal II Events	Total	Holladay 2 Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	39	41	37	41	7.4%	2.11 [0.36, 12.20]
Gokce 2017	82	86	83	86	15.8%	0.74 [0.16, 3.41]
Kane 2016	144	156	143	156	45.0%	1.09 [0.48, 2.47]
Shrivastava 2018	40	50	39	50	31.9%	1.13 [0.43, 2.96]
Total (95% CI)		**333**		**333**	**100.0%**	**1.12 [0.65, 1.94]**
Total events	305		302			

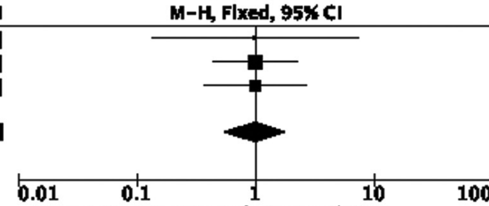
Heterogeneity: $Chi^2 = 0.78$, df = 3 (P = 0.85); $I^2 = 0\%$
Test for overall effect: Z = 0.42 (P = 0.68)



F)

Study or Subgroup	Barrett Universal II Events	Total	SRK/T Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	39	41	39	41	9.1%	1.00 [0.13, 7.46]
Kane 2016	144	156	144	156	52.8%	1.00 [0.43, 2.30]
Shrivastava 2018	40	50	40	50	38.1%	1.00 [0.38, 2.66]
Total (95% CI)		**247**		**247**	**100.0%**	**1.00 [0.55, 1.83]**
Total events	223		223			

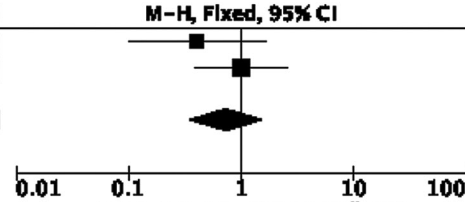
Heterogeneity: $Chi^2 = 0.00$, df = 2 (P = 1.00); $I^2 = 0\%$
Test for overall effect: Z = 0.00 (P = 1.00)



G)

Study or Subgroup	Haigis Events	Total	Hill-RBF Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	79	86	83	86	44.1%	0.41 [0.10, 1.63]
Shrivastava 2018	39	50	39	50	55.9%	1.00 [0.39, 2.58]
Total (95% CI)		**136**		**136**	**100.0%**	**0.74 [0.34, 1.59]**
Total events	118		122			

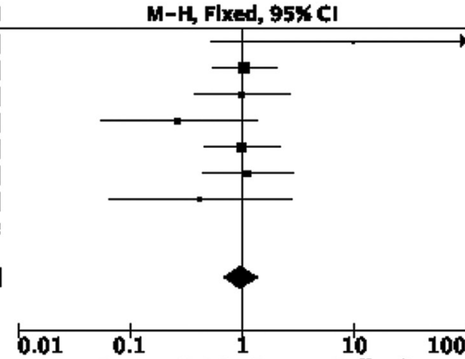
Heterogeneity: $Chi^2 = 1.10$, df = 1 (P = 0.29); $I^2 = 9\%$
Test for overall effect: Z = 0.77 (P = 0.44)



H)

Study or Subgroup	Haigis Events	Total	Hoffer Q Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	41	41	37	41	0.8%	9.96 [0.52, 191.23]
Day 2012	143	163	142	163	30.5%	1.06 [0.55, 2.04]
Eom 2014	66	75	66	75	13.8%	1.00 [0.37, 2.68]
Gokce 2017	79	86	84	86	12.0%	0.27 [0.05, 1.33]
Kane 2016	142	156	142	156	22.3%	1.00 [0.46, 2.17]
Shrivastava 2018	39	50	38	50	14.6%	1.12 [0.44, 2.84]
Srivannaboon 2013	11	15	13	15	6.1%	0.42 [0.06, 2.77]
Terzi 2009	19	19	19	19		Not estimable
Total (95% CI)		**605**		**605**	**100.0%**	**0.98 [0.68, 1.42]**
Total events	540		541			

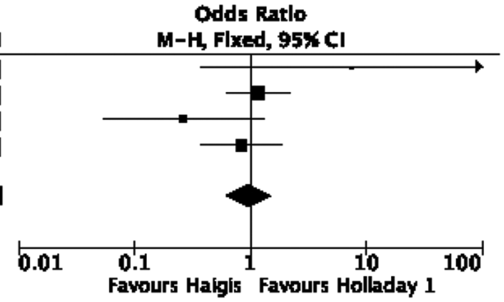
Heterogeneity: $Chi^2 = 5.78$, df = 6 (P = 0.45); $I^2 = 0\%$
Test for overall effect: Z = 0.09 (P = 0.93)



I)

Study or Subgroup	Haigis Events	Haigis Total	Holladay1 Events	Holladay1 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	41	41	38	41	1.2%	7.55 [0.38, 150.87]
Day 2012	143	163	140	163	45.9%	1.17 [0.62, 2.23]
Gokce 2017	79	86	84	86	18.3%	0.27 [0.05, 1.33]
Kane 2016	142	156	144	156	34.6%	0.85 [0.38, 1.89]
Total (95% CI)		**446**		**446**	**100.0%**	**0.97 [0.62, 1.54]**
Total events	405		406			

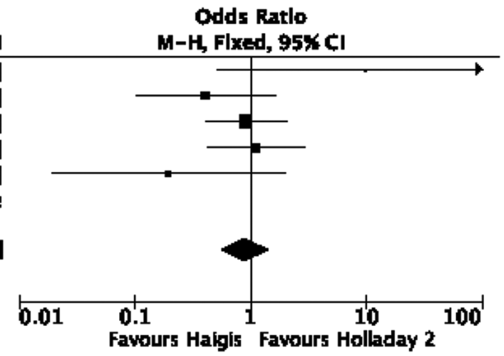
Heterogeneity: Chi² = 4.72, df = 3 (P = 0.19); I² = 36%
Test for overall effect: Z = 0.12 (P = 0.91)



J)

Study or Subgroup	Haigis Events	Haigis Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	41	41	37	41	1.4%	9.96 [0.52, 191.23]
Gokce 2017	79	86	83	86	21.4%	0.41 [0.10, 1.63]
Kane 2016	142	156	143	156	40.7%	0.92 [0.42, 2.03]
Shrivastava 2018	40	50	39	50	24.7%	1.13 [0.43, 2.96]
Srivannaboon 2013	11	15	14	15	11.8%	0.20 [0.02, 2.02]
Terzi 2009	19	19	19	19		Not estimable
Total (95% CI)		**367**		**367**	**100.0%**	**0.90 [0.55, 1.50]**
Total events	332		335			

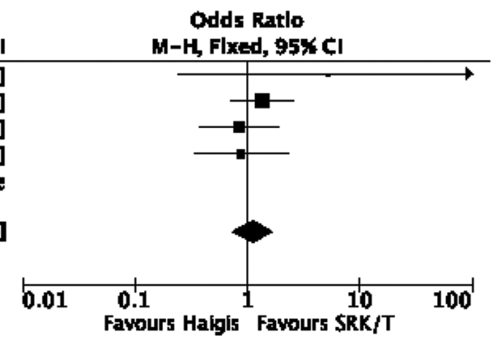
Heterogeneity: Chi² = 5.65, df = 4 (P = 0.23); I² = 29%
Test for overall effect: Z = 0.39 (P = 0.70)



K)

Study or Subgroup	Haigis Events	Haigis Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	41	41	39	41	1.2%	5.25 [0.24, 112.88]
Day 2012	143	163	137	163	43.1%	1.36 [0.72, 2.54]
Kane 2016	142	156	144	156	33.1%	0.85 [0.38, 1.89]
Shrivastava 2018	39	50	40	50	22.6%	0.89 [0.34, 2.32]
Terzi 2009	19	19	19	19		Not estimable
Total (95% CI)		**429**		**429**	**100.0%**	**1.13 [0.73, 1.74]**
Total events	384		379			

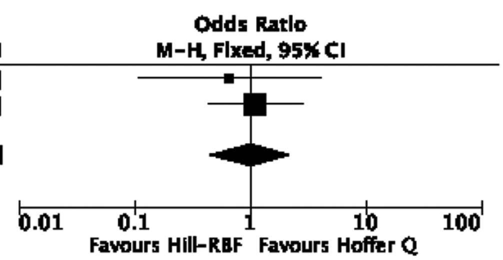
Heterogeneity: Chi² = 2.03, df = 3 (P = 0.57); I² = 0%
Test for overall effect: Z = 0.55 (P = 0.58)



L)

Study or Subgroup	Hill-RBF Events	Hill-RBF Total	Hoffer Q Events	Hoffer Q Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	83	86	84	86	26.0%	0.66 [0.11, 4.04]
Shrivastava 2018	39	50	38	50	74.0%	1.12 [0.44, 2.84]
Total (95% CI)		**136**		**136**	**100.0%**	**1.00 [0.44, 2.28]**
Total events	122		122			

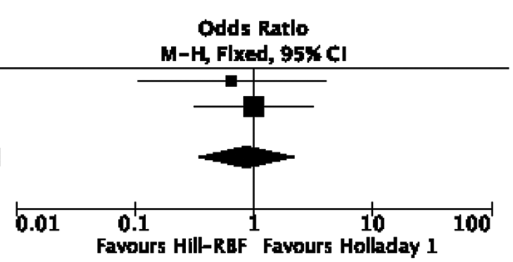
Heterogeneity: Chi² = 0.26, df = 1 (P = 0.61); I² = 0%
Test for overall effect: Z = 0.00 (P = 1.00)



M)

Study or Subgroup	Hill-RBF Events	Hill-RBF Total	Holladay 1 Events	Holladay 1 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	83	86	84	86	33.8%	0.66 [0.11, 4.04]
Kane 2017	131	137	131	137	66.2%	1.00 [0.31, 3.18]
Total (95% CI)		**223**		**223**	**100.0%**	**0.88 [0.33, 2.34]**
Total events	214		215			

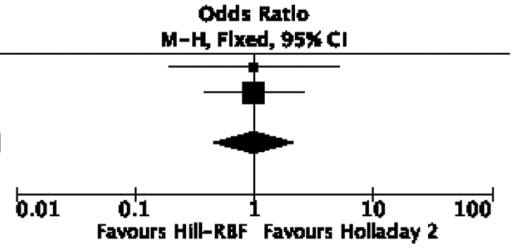
Heterogeneity: Chi² = 0.14, df = 1 (P = 0.70); I² = 0%
Test for overall effect: Z = 0.25 (P = 0.80)



N)

Study or Subgroup	Hill-RBF Events	Hill-RBF Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gokce 2017	83	86	83	86	25.2%	1.00 [0.20, 5.10]
Shrivastava 2018	39	50	39	50	74.8%	1.00 [0.39, 2.58]
Total (95% CI)		**136**		**136**	**100.0%**	**1.00 [0.44, 2.27]**
Total events	122		122			

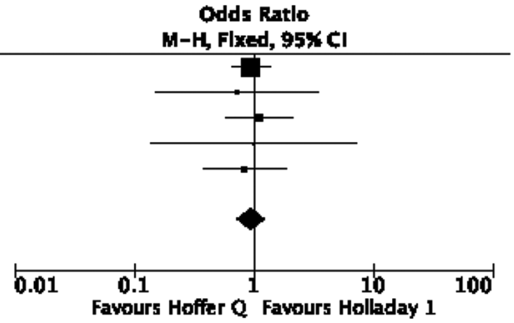
Heterogeneity: Chi² = 0.00, df = 1 (P = 1.00); I² = 0%
Test for overall effect: Z = 0.00 (P = 1.00)



O)

Study or Subgroup	Hoffer Q Events	Hoffer Q Total	Holladay 1 Events	Holladay 1 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Aristodemou 2011	539	608	542	608	62.7%	0.95 [0.67, 1.36]
Cooke 2016	37	41	38	41	3.8%	0.73 [0.15, 3.49]
Day 2012	142	163	140	163	18.4%	1.11 [0.59, 2.10]
Gokce 2017	84	86	84	86	2.0%	1.00 [0.14, 7.27]
Kane 2016	142	156	144	156	13.2%	0.85 [0.38, 1.89]
Total (95% CI)		**1054**		**1054**	**100.0%**	**0.96 [0.72, 1.27]**
Total events	944		948			

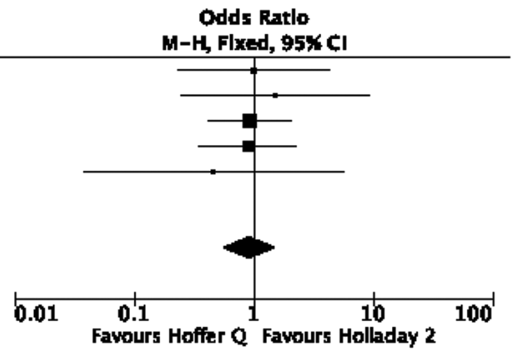
Heterogeneity: Chi² = 0.42, df = 4 (P = 0.98); I² = 0%
Test for overall effect: Z = 0.29 (P = 0.77)



P)

Study or Subgroup	Hoffer Q Events	Hoffer Q Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	37	41	37	41	12.2%	1.00 [0.23, 4.30]
Gokce 2017	84	86	83	86	6.5%	1.52 [0.25, 9.32]
Kane 2016	142	156	143	156	43.4%	0.92 [0.42, 2.03]
Shrivastava 2018	38	50	39	50	31.6%	0.89 [0.35, 2.27]
Srivannaboon 2013	13	15	14	15	6.3%	0.46 [0.04, 5.75]
Terzi 2009	19	19	19	19		Not estimable
Total (95% CI)		**367**		**367**	**100.0%**	**0.93 [0.56, 1.57]**
Total events	333		335			

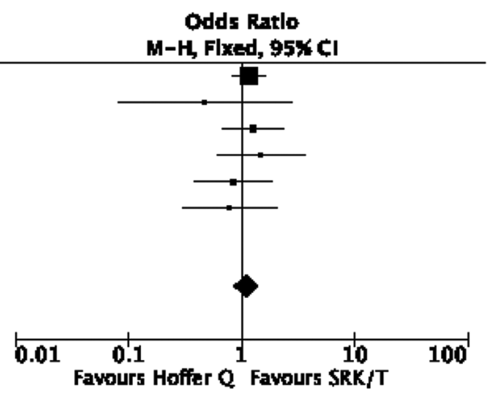
Heterogeneity: Chi² = 0.59, df = 4 (P = 0.96); I² = 0%
Test for overall effect: Z = 0.26 (P = 0.79)



Q)

Study or Subgroup	Hoffer Q Events	Hoffer Q Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Aristodemou 2011	539	608	529	608	53.6%	1.17 [0.83, 1.65]
Cooke 2016	37	41	39	41	3.4%	0.47 [0.08, 2.75]
Day 2012	142	163	137	163	15.8%	1.28 [0.69, 2.39]
Gavin 2007	26	41	22	41	7.2%	1.50 [0.62, 3.62]
Kane 2016	142	156	144	156	11.5%	0.85 [0.38, 1.89]
Shrivastava 2018	38	50	40	50	8.6%	0.79 [0.31, 2.05]
Terzi 2009	19	19	19	19		Not estimable
Total (95% CI)		**1078**		**1078**	**100.0%**	**1.12 [0.86, 1.44]**
Total events	943		930			

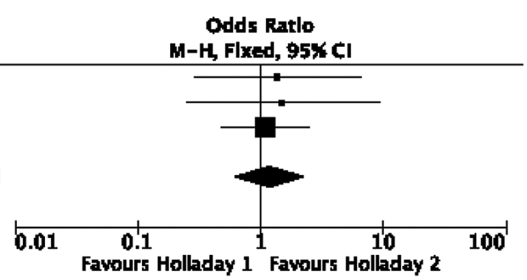
Heterogeneity: Chi² = 2.55, df = 5 (P = 0.77); I² = 0%
Test for overall effect: Z = 0.84 (P = 0.40)



R)

Study or Subgroup	Holladay 1 Events	Holladay 1 Total	Holladay 2 Events	Holladay 2 Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	38	41	37	41	17.3%	1.37 [0.29, 6.54]
Gokce 2017	84	86	83	86	12.3%	1.52 [0.25, 9.32]
Kane 2016	144	156	143	156	70.3%	1.09 [0.48, 2.47]
Total (95% CI)		**283**		**283**	**100.0%**	**1.19 [0.61, 2.33]**
Total events	266		263			

Heterogeneity: Chi² = 0.14, df = 2 (P = 0.93); I² = 0%
Test for overall effect: Z = 0.51 (P = 0.61)

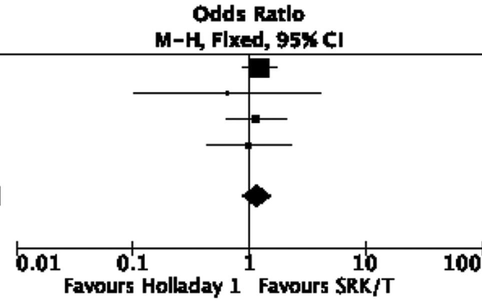


S)

Study or Subgroup	Holladay 1 Events	Holladay 1 Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Aristodemou 2011	542	608	529	608	63.3%	1.23 [0.87, 1.74]
Cooke 2016	38	41	39	41	3.1%	0.65 [0.10, 4.11]
Day 2012	140	163	137	163	21.3%	1.16 [0.63, 2.12]
Kane 2016	144	156	144	156	12.2%	1.00 [0.43, 2.30]
Total (95% CI)		**968**		**968**	**100.0%**	**1.17 [0.88, 1.54]**
Total events	864		849			

Heterogeneity: $Chi^2 = 0.60$, $df = 3$ ($P = 0.90$); $I^2 = 0\%$

Test for overall effect: $Z = 1.07$ ($P = 0.28$)

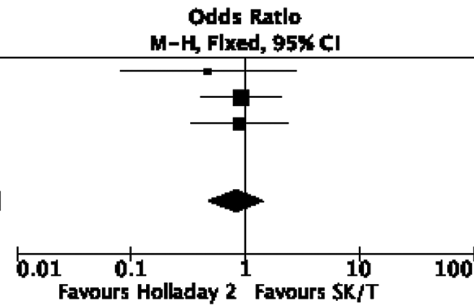


T)

Study or Subgroup	Holladay 2 Events	Holladay 2 Total	SRK/T Events	SRK/T Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Cooke 2016	37	41	39	41	15.5%	0.47 [0.08, 2.75]
Kane 2016	143	156	144	156	48.8%	0.92 [0.40, 2.08]
Shrivastava 2018	39	50	40	50	35.8%	0.89 [0.34, 2.32]
Terzi 2009	19	19	19	19		Not estimable
Total (95% CI)		**266**		**266**	**100.0%**	**0.84 [0.47, 1.50]**
Total events	238		242			

Heterogeneity: $Chi^2 = 0.46$, $df = 2$ ($P = 0.79$); $I^2 = 0\%$

Test for overall effect: $Z = 0.59$ ($P = 0.55$)



D = Diopter; PE = Prediction error

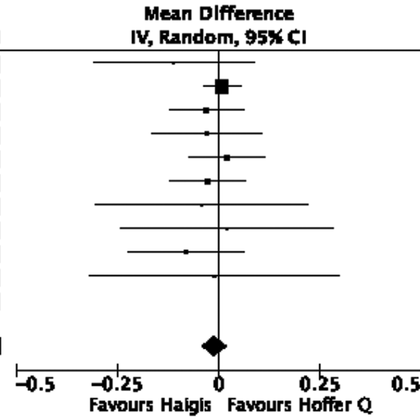
Additional file 5

Sensitivity analysis of comparison of Mean absolute error of Haigis with Hoffer Q (A), Holladay 1 (B), Holladay 2 (C) and SRK/T (D)

A)

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Hoffer Q Mean	Hoffer Q SD	Hoffer Q Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.5	0.455	41	2.6%	−0.11 [−0.31, 0.09]
Darcy 2019	0.486	0.41	766	0.478	0.51	766	47.5%	0.01 [−0.04, 0.05]
Day 2012	0.5	0.41	163	0.53	0.44	163	12.0%	−0.03 [−0.12, 0.06]
Eom 2014	0.46	0.41	75	0.49	0.43	75	5.6%	−0.03 [−0.16, 0.10]
Gokce 2017	0.42	0.34	86	0.4	0.29	86	11.4%	0.02 [−0.07, 0.11]
Kane 2016	0.473	0.41	156	0.499	0.43	156	11.7%	−0.03 [−0.12, 0.07]
Shrivastava 2018	0.646	0.686	50	0.688	0.644	50	1.5%	−0.04 [−0.30, 0.22]
Srivannaboon 2013	0.44	0.4	15	0.42	0.33	15	1.5%	0.02 [−0.24, 0.28]
Terzi 2009	0.34	0.23	19	0.42	0.22	19	5.0%	−0.08 [−0.22, 0.06]
Wang 2013	0.66	0.68	33	0.67	0.59	33	1.1%	−0.01 [−0.32, 0.30]
Zhao 2018	0.58	0.28	139	0.84	0.38	139	0.0%	−0.26 [−0.34, −0.18]
Total (95% CI)			**1404**			**1404**	**100.0%**	**−0.01 [−0.04, 0.02]**

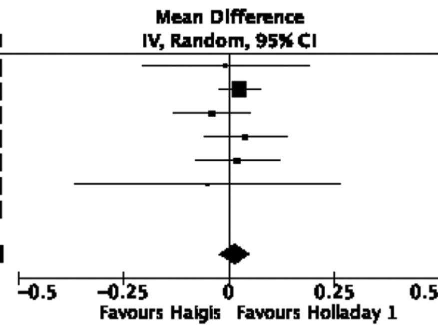
Heterogeneity: Tau² = 0.00; Chi² = 3.35, df = 9 (P = 0.95); I² = 0%
Test for overall effect: Z = 0.59 (P = 0.56)



B)

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Holladay1 Mean	Holladay1 SD	Holladay1 Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.397	0.457	41	3.2%	−0.01 [−0.21, 0.19]
Darcy 2019	0.486	0.41	766	0.461	0.55	766	54.0%	0.02 [−0.02, 0.07]
Day 2012	0.5	0.41	163	0.54	0.44	163	15.0%	−0.04 [−0.13, 0.05]
Gokce 2017	0.42	0.34	86	0.38	0.31	86	13.5%	0.04 [−0.06, 0.14]
Kane 2016	0.473	0.41	156	0.453	0.48	156	13.0%	0.02 [−0.08, 0.12]
Wang 2013	0.66	0.68	33	0.71	0.62	33	1.3%	−0.05 [−0.36, 0.26]
Zhao 2018	0.58	0.28	139	0.81	0.37	139	0.0%	−0.23 [−0.31, −0.15]
Total (95% CI)			**1245**			**1245**	**100.0%**	**0.01 [−0.02, 0.05]**

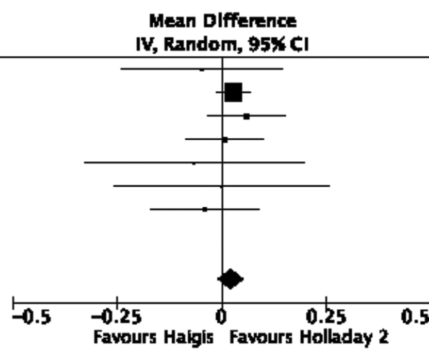
Heterogeneity: Tau² = 0.00; Chi² = 2.00, df = 5 (P = 0.85); I² = 0%
Test for overall effect: Z = 0.80 (P = 0.42)



C)

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	Holladay 2 Mean	Holladay 2 SD	Holladay 2 Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.437	0.43	41	2.6%	−0.05 [−0.24, 0.15]
Darcy 2019	0.486	0.41	766	0.458	0.36	766	65.6%	0.03 [−0.01, 0.07]
Gokce 2017	0.42	0.34	86	0.36	0.28	86	11.3%	0.06 [−0.03, 0.15]
Kane 2016	0.473	0.41	156	0.466	0.42	156	11.6%	0.01 [−0.09, 0.10]
Shrivastava 2018	0.646	0.686	50	0.711	0.646	50	1.4%	−0.06 [−0.33, 0.20]
Srivannaboon 2013	0.44	0.4	15	0.44	0.31	15	1.5%	0.00 [−0.26, 0.26]
Terzi 2009	0.34	0.23	19	0.38	0.17	19	5.9%	−0.04 [−0.17, 0.09]
Zhao 2018	0.58	0.28	139	0.71	0.24	139	0.0%	−0.13 [−0.19, −0.07]
Total (95% CI)			**1133**			**1133**	**100.0%**	**0.02 [−0.01, 0.05]**

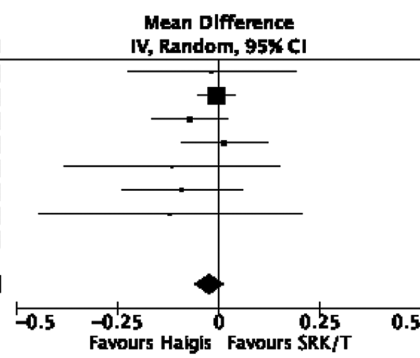
Heterogeneity: Tau² = 0.00; Chi² = 2.67, df = 6 (P = 0.85); I² = 0%
Test for overall effect: Z = 1.34 (P = 0.18)



D)

Study or Subgroup	Haigis Mean	Haigis SD	Haigis Total	SRK/T Mean	SRK/T SD	SRK/T Total	Weight	Mean Difference IV, Random, 95% CI
Cooke 2016	0.39	0.46	41	0.407	0.494	41	3.0%	−0.02 [−0.22, 0.19]
Darcy 2019	0.486	0.41	766	0.492	0.49	766	62.2%	−0.01 [−0.05, 0.04]
Day 2012	0.5	0.41	163	0.57	0.45	163	14.6%	−0.07 [−0.16, 0.02]
Kane 2016	0.473	0.41	156	0.458	0.53	156	11.5%	0.01 [−0.09, 0.12]
Shrivastava 2018	0.646	0.686	50	0.76	0.67	50	1.8%	−0.11 [−0.38, 0.15]
Terzi 2009	0.34	0.23	19	0.43	0.24	19	5.7%	−0.09 [−0.24, 0.06]
Wang 2013	0.66	0.68	33	0.78	0.66	33	1.2%	−0.12 [−0.44, 0.20]
Zhao 2018	0.58	0.28	139	0.82	0.4	139	0.0%	−0.24 [−0.32, −0.16]
Total (95% CI)			**1228**			**1228**	**100.0%**	**−0.02 [−0.06, 0.01]**

Heterogeneity: Tau² = 0.00; Chi² = 3.58, df = 6 (P = 0.73); I² = 0%
Test for overall effect: Z = 1.17 (P = 0.24)



Additional file 6

Funnel plot using data of 11 studies comparing Mean absolute error between Haigis and Hoffer Q