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Pars Plana Vitrectomy versus Scleral Buckling for Primary Rhegmatogenous Retinal Detachment Repair in Phakic Eyes: A Contemporary Systematic Review and Meta-Analysis of Anatomical and Functional Outcomes

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A B S T R A C T

Introduction: The optimal surgical approach for primary rhegmatogenous retinal detachment (RRD) in phakic patients remains a subject of ongoing debate. Both pars plana vitrectomy (PPV) and scleral buckling (SB) possess distinct advantages and disadvantages, particularly concerning anatomical success, visual outcomes, and the integrity of the crystalline lens. This systematic review and meta-analysis aimed to compare the anatomical and functional outcomes of PPV versus SB for primary RRD repair exclusively in phakic eyes. **Methods:** A systematic literature search was conducted across PubMed, Scopus, Embase, and the Cochrane Library databases for studies published between January 1st, 2013, and December 31st, 2023. We included comparative studies (Randomized Controlled Trials [RCTs] and non-randomized comparative studies [NRCSs]) reporting outcomes of primary PPV versus primary SB in phakic patients with RRD. Data extraction and quality assessment (using Cochrane Risk of Bias tool 2 for RCTs and Newcastle-Ottawa Scale for NRCSs) were performed independently by two reviewers. Primary outcomes were primary anatomical success rate and final anatomical success rate. The secondary outcome was the change in Best Corrected Visual Acuity (BCVA) from baseline, converted to LogMAR. Meta-analysis was performed using a random-effects model to calculate pooled Odds Ratios (OR) for anatomical outcomes and Mean Differences (MD) for BCVA change, with 95% Confidence Intervals (CI). Heterogeneity was assessed using the I^2 statistic. **Results:** 7 studies met the inclusion criteria, encompassing a total of 1,258 phakic eyes (615 PPV, 643 SB). The overall quality of included studies ranged from moderate to high risk of bias, primarily due to potential selection bias and lack of blinding in NRCSs. The pooled analysis revealed no statistically significant difference in the primary anatomical success rate between PPV and SB (OR 0.92, 95% CI [0.68, 1.24], P=0.58; I^2=35%). Similarly, the final anatomical success rate was comparable between the two groups (OR 1.05, 95% CI [0.70, 1.57], P=0.81; I^2=15%). Regarding functional outcomes, the analysis of BCVA change (LogMAR) at final follow-up showed no statistically significant difference between PPV and SB groups when considering the reported final acuities (MD -0.03 LogMAR, 95% CI [-0.12, 0.06], P=0.51; I^2=55%). **Conclusion:** This study found no significant difference in primary or final anatomical success rates between PPV and SB for primary RRD repair. Similarly, overall final BCVA improvement was comparable, although significant heterogeneity was noted. The major differentiating factor remains the substantially higher rate of subsequent cataract formation following PPV. The choice between PPV and SB for phakic RRD should be individualized, considering specific RRD characteristics, patient age, baseline lens status, surgeon expertise, and patient preferences after thorough counseling regarding the distinct postoperative sequelae, particularly the near-inevitability of cataract surgery after PPV.

1. Introduction

Rhegmatogenous retinal detachment (RRD) is a serious ocular condition that can lead to significant vision loss. It occurs when the neurosensory retina separates from the underlying retinal pigment epithelium (RPE), typically due to liquefied vitreous

passing through a retinal break. This separation disrupts the normal functioning of the retina, which is crucial for vision. The incidence of RRD varies across different geographical locations, but it is generally estimated to affect between 10 and 18 individuals per 100,000 each year. The importance of prompt surgical intervention in cases of RRD cannot be overstated. Timely surgery is essential to re-attach the retina, prevent permanent damage to photoreceptor cells, and preserve or restore the patient's vision. The surgical treatment of RRD has undergone significant advancements over the last century. Scleral buckling (SB) was the primary surgical method for many decades after its introduction by Custodis in the late 1940s and its popularization by Schepens in the 1950s. The SB procedure involves several key steps. First, all retinal breaks are identified and treated using cryotherapy or laser photocoagulation. Following this, a silicone element, which may be a band or sponge, is attached to the sclera by sutures. The purpose of this element is to indent the sclera, choroid, and RPE, which in turn supports the retinal break(s) and relieves vitreoretinal traction by altering the shape of the eye. In many cases, SB is combined with the drainage of subretinal fluid (SRF). The goal of SB is to close the retinal breaks, allowing the RPE pump to absorb any remaining SRF and achieve retinal reattachment. Scleral buckling offers several advantages. Because it is an extraocular procedure, it avoids intraocular surgery, thus preserving the crystalline lens in phakic patients. This can be particularly important, as it potentially reduces the risk of endophthalmitis compared to intraocular procedures. However, SB is also associated with certain disadvantages and potential complications. It can induce significant postoperative refractive errors, including myopic shift and astigmatism. Patients may also experience ocular motility disturbances, leading to diplopia, as well as pain. Furthermore, SB carries risks of choroidal detachment, buckle extrusion, or infection.[1-4]

In the early 1970s, Machemer pioneered an alternative surgical approach with the development and refinement of pars plana vitrectomy (PPV). PPV involves the removal of the vitreous humor, which is often the source of traction that causes retinal tears and detachment. This removal allows for direct visualization and treatment of retinal breaks under microscopic control. Additional steps in PPV include internal drainage of SRF and relief of vitreous traction, followed by the injection of an internal tamponade agent, such as gas or silicone oil. The tamponade agent supports the retina while chorioretinal adhesion forms around the breaks. The introduction of smaller gauge instrumentation (23-gauge, 25-gauge, and 27-gauge) has further advanced PPV, making it a less invasive procedure. These smaller gauges can potentially lead to faster recovery and reduced postoperative inflammation. PPV is particularly beneficial in cases where there is significant media opacity, such as vitreous hemorrhage, or in the presence of giant retinal tears, posterior breaks, or established proliferative vitreoretinopathy (PVR). Despite the growing popularity and wider use of PPV worldwide, the choice between PPV and SB for the treatment of primary, uncomplicated RRD, especially in phakic eyes, remains a topic of debate among vitreoretinal surgeons. The presence of a phakic lens introduces specific considerations that influence this decision. While PPV offers excellent visualization and direct management of vitreoretinal pathology, it is strongly associated with the development or acceleration of nuclear sclerotic cataract. This often necessitates subsequent cataract surgery within months to years after the PPV procedure, adding to the overall cost, potential risks, and potentially delaying the patient's final visual rehabilitation.[5-7]

In contrast, SB avoids direct manipulation of the lens, but it can be technically more challenging for certain break locations, particularly posterior breaks. Additionally, SB does not address vitreous traction as effectively as PPV. Furthermore, the refractive changes induced by SB can be problematic for some patients. Several previous meta-analyses have compared PPV and SB for the treatment of RRD. However, many of these earlier studies included older research that may

have employed outdated surgical techniques. Some meta-analyses also included mixed populations of phakic and pseudophakic patients without conducting clear subgroup analyses, or they did not specifically focus on primary RRD. Given the advancements and evolution of both PPV (e.g., micro-incision techniques, wide-angle viewing systems) and SB practices, as well as the shifts in surgical trends, a contemporary reassessment that focuses specifically on the phakic population is warranted. Phakic eyes represent a distinct patient group where the implications of surgical choices on the crystalline lens are of utmost importance. Therefore, it is essential to have a clear understanding of the relative performance of modern PPV compared to SB in this specific cohort to inform evidence-based clinical decision-making and provide appropriate patient counseling.[8-10] In light of these considerations, this study aimed to conduct a systematic review and meta-analysis of contemporary comparative studies. The primary objective was to evaluate the anatomical success, including primary and final reattachment rates, and functional outcomes, specifically the change in Best Corrected Visual Acuity (BCVA), of PPV versus SB as the primary surgical intervention for RRD exclusively in phakic patients.

2. Methods

This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A detailed protocol was developed before the commencement of the search. This protocol provided a structured framework, outlining the review's objectives, specific inclusion and exclusion criteria for study selection, the comprehensive search strategy, the primary and secondary outcome measures of interest, and the planned methods for data analysis.

The selection of studies for inclusion in this review was based on the following pre-defined PICOS criteria. The population of interest consisted of adult patients, specifically those aged 18 years or older, with phakic eyes. These patients were undergoing surgical intervention for primary RRD. For the purposes of this review, primary RRD was defined as RRD that was not associated with any prior intraocular surgery, ocular trauma, or advanced proliferative vitreoretinopathy (PVR) classified as Grade C or D at the time of presentation. The primary intervention under consideration was Pars Plana Vitrectomy (PPV). This could be performed with or without adjunctive procedures, such as endolaser photocoagulation and the use of an internal tamponade, which could involve either gas or silicone oil. The review did not specify any restrictions on the gauge of PPV instrumentation used in the included studies. The comparative intervention was Scleral Buckling (SB). Similar to PPV, SB could be performed with or without adjunctive procedures, including cryotherapy or laser photocoagulation and drainage of subretinal fluid. Studies were included if they directly compared PPV and SB. Studies that compared variations within either the PPV or SB technique alone, or those that compared either technique against pneumatic retinopexy as a sole intervention, were excluded from the review. Studies were required to report on at least one of the following outcomes, with the data presented separately for the PPV and SB groups within the phakic patient population; Primary Anatomical Success: This was defined as the proportion of eyes in which the retina was successfully attached following the single initial surgical procedure, whether PPV or SB. This outcome was to be assessed at a defined follow-up point, typically at least 3 months postoperatively, and without the need for any additional vitreoretinal re-intervention for RRD recurrence; Final Anatomical Success: This outcome referred to the proportion of eyes with an attached retina at the final reported follow-up time point. This measure included eyes that may have required one or more re-operations or secondary interventions for recurrent RRD; Functional Outcome: The functional outcome of interest was the change in Best Corrected Visual Acuity (BCVA) from the baseline measurement to the final reported follow-up. Studies were included if they reported mean final

BCVA and baseline BCVA with standard deviations (SD), or if they reported the mean change in BCVA with SD. The review included both Randomized Controlled Trials (RCTs) and non-randomized comparative studies (NRCSs). The latter category encompassed prospective and retrospective comparative cohort studies. Case series, case reports, narrative reviews, letters to the editor, editorials, and studies that did not provide comparative data between PPV and SB specifically for phakic patients were excluded.

Studies were excluded based on the following criteria; Studies published before January 1st, 2013, or after December 31st, 2023; Studies not published in the English language; Studies focusing exclusively on pediatric populations, defined as patients under the age of 18 years; Studies that included cases of tractional, exudative, or complex RRD. Complex RRD was defined as RRD associated with trauma, uveitis, PVR of Grade C or D at presentation, or certain giant retinal tears; Studies that included patients with a history of previous vitreoretinal surgery in the study eye; Studies where it was not possible to extract data specifically for phakic patients, i.e., studies that included both phakic and pseudophakic or aphakic patients but did not report outcomes separately for these subgroups; Studies that did not provide sufficient data for extraction of the outcomes of interest, such as missing numerators or denominators for calculating rates, or missing SD for continuous data.

A comprehensive and systematic literature search was conducted across the following electronic databases; PubMed (MEDLINE); Scopus; Embase; Cochrane Central Register of Controlled Trials (CENTRAL). In addition to the electronic database searches, the reference lists of included studies and relevant systematic reviews were manually screened to identify any potentially eligible studies that may have been missed by the primary electronic search. This process is known as backward citation searching. No attempts were made to search grey literature. This decision was based on the inherent difficulties associated with assessing the quality of grey literature and the potential challenges in extracting reliable data from such sources.

The search strategy was meticulously developed and tailored to the specific requirements and functionalities of each database. This involved the use of a combination of Medical Subject Headings (MeSH terms in PubMed, or their equivalents in other databases, such as Emtree) and free-text keywords. The keywords were carefully chosen to encompass terms related to the population of interest, the interventions being compared, and the condition under investigation. A representative search strategy developed for PubMed is provided below to illustrate the approach; "Retinal Detachment" OR "Rhegmatogenous Retinal Detachment" OR "Retinal Break*" OR "Retinal Tear*" AND "Vitrectomy" OR "Pars Plana Vitrectomy" OR PPV OR "Vitreous Surgery" AND "Scleral Buckling" OR "Scleral Buckle" OR "Encircling Band" OR "Segmental Buckle" OR SB AND "Phakia" OR Phakic OR "Crystalline Lens".

All records identified through the electronic database searches were imported into EndNote X9 reference management software. Duplicate records were then removed to ensure that each unique study was considered only once. Two reviewers independently screened the titles and abstracts of the remaining records. This screening process was conducted based on the pre-defined eligibility criteria established a priori. The purpose of this initial screening was to identify studies that were potentially relevant to the research question. The full texts of articles deemed potentially relevant during the title and abstract screening were retrieved. These full-text articles were then independently assessed by the same two reviewers to determine their final eligibility for inclusion in the systematic review. Any disagreements that arose between the two reviewers regarding study eligibility at either the title/abstract screening stage or the full-text assessment stage were resolved through a process of discussion and consensus. In cases where a consensus could not be reached, a third reviewer was consulted to adjudicate and make the final decision on inclusion or exclusion. The entire study

selection process was carefully documented and presented in a PRISMA flow diagram. This diagram provides a transparent and step-by-step visual representation of the number of records identified, the number excluded at each stage, and the final number of studies included in the systematic review.

A standardized data extraction form was developed to ensure consistency and completeness in the data collected from each included study. The form was pilot-tested on three initial studies. Following the pilot test, the form was refined to address any ambiguities or issues that arose during the testing phase. Two reviewers independently extracted data from each included study using the finalized data extraction form. The following key data items were extracted; Study Characteristics: This category included details such as the first author's name, the publication year, the country of origin where the study was conducted, the study design (i.e., RCT, prospective NRCS, or retrospective NRCS), the study period during which data was collected, and the follow-up duration (reported as mean or median, along with the range); Patient Characteristics: Data related to the study participants included the total number of phakic eyes included in each treatment arm (PPV and SB), the mean or median age of patients in each group, the sex distribution (percentage of male patients in each group), and baseline RRD characteristics. The baseline RRD characteristics included macula status (the percentage of detachments with macula-on and macula-off), the number and location of retinal breaks, the extent of detachment (measured in quadrants), the presence of PVR Grade A or B, and the baseline BCVA; Intervention Details: Specific details about the surgical interventions were extracted. For PPV, this included the gauge of instrumentation used, the use of chandelier illumination, the type of vitrectomy performed (core or total), whether fluid-air exchange was performed, the use of endolaser, and the type of tamponade agent used (SF6, C3F8, or Silicone Oil) and its duration. For SB, details extracted included the type of buckle used (segmental, encircling, or a combination), whether cryotherapy or laser was used, and whether subretinal fluid drainage was performed; Outcome Data: For dichotomous outcomes, specifically primary and final anatomical success, the number of events (eyes with successful retinal reattachment) and the total number of eyes in each group were extracted. For the continuous outcome of BCVA, the mean and SD of baseline BCVA and final BCVA were extracted for each group. If studies reported the mean change in BCVA and its SD, this data was extracted directly. If studies reported median and range or interquartile range for BCVA, methods for estimating the mean and SD were planned to be used, where appropriate and feasible. BCVA reported in Snellen fractions was converted to the LogMAR scale for consistency in analysis. Information on postoperative complications was also extracted. This included, in particular, data on cataract progression or the need for cataract surgery in the PPV group, and data on refractive changes or motility issues in the SB group. This information was extracted for narrative synthesis. Any discrepancies or disagreements that arose between the two reviewers during the data extraction process were resolved by consensus. This involved revisiting the original articles and discussing the discrepancies until an agreement was reached. If necessary, a third reviewer was involved in the discussion to help resolve the disagreement. The authors of the primary studies were not contacted to obtain missing data.

The methodological quality and potential risk of bias of each included study were independently assessed by two reviewers. This assessment was conducted using validated tools that were appropriate for the specific study designs; Randomized Controlled Trials (RCTs): The Cochrane Risk of Bias tool 2 (RoB 2) was used to assess the risk of bias in RCTs. This tool evaluates bias across five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in the measurement of the outcome, and bias in the selection of the reported result. Each domain was judged as being at 'Low risk' of bias, having 'Some concerns', or being at 'High risk' of bias;

Non-Randomized Comparative Studies (NRCSs): The Newcastle-Ottawa Scale (NOS) was used to assess the risk of bias in NRCSs. The NOS evaluates studies across three domains: the selection of the study groups, the comparability of the groups, and the ascertainment of the exposure or outcome. Studies were awarded stars for each item within these domains, with a maximum possible score of 9 stars. Studies scoring 7 or more stars were considered to be of high quality (low risk of bias), studies scoring 5-6 stars were considered to be of moderate quality, and studies scoring less than 5 stars were considered to be of low quality (high risk of bias). Any disagreements that arose during the risk of bias assessment process were resolved through discussion and consensus between the two reviewers. The results of the risk of bias assessment were summarized descriptively and presented in tables. The potential impact of bias on the results of the meta-analysis was considered in the discussion section of the review and was explored further through sensitivity analyses.

The meta-analysis was performed using Review Manager (RevMan) software, version 5.4; Effect Measures: For dichotomous outcomes, specifically primary and final anatomical success, the Odds Ratio (OR) with 95% Confidence Intervals (CI) was calculated. The OR was chosen as the effect measure over the Risk Ratio (RR) because it is less dependent on baseline risk prevalence. The OR is often preferred when pooling data from studies that have varying baseline risks or different study designs. For the continuous outcome, change in BCVA, the Mean Difference (MD) in LogMAR units with 95% CI was calculated. If studies reported final BCVA without reporting the change from baseline, the MD was calculated based on the difference in mean final BCVA between the PPV and SB groups, assuming that the baseline BCVA was comparable between the groups. If studies did not report the standard deviations of the change in BCVA, these were calculated from the baseline and final SDs using methods described by Cochrane, assuming a correlation coefficient of 0.5; Meta-analysis Model: Due to the anticipated clinical and methodological heterogeneity among the included studies, a random-effects model was employed for all primary analyses. The random-effects model, using the DerSimonian and Laird method, was chosen because it assumes that the true effect size varies across studies. This model provides a more conservative estimate of the pooled effect, with wider confidence intervals, compared to a fixed-effect model. The potential influence of using a fixed-effect model was explored in a sensitivity analysis; Heterogeneity Assessment: Statistical heterogeneity across studies was assessed using Cochran's Q test (Chi-squared test) and the I^2 statistic. A p-value of less than 0.10 for the Q test was considered to indicate statistically significant heterogeneity. The I^2 statistic was used to quantify the percentage of the total variation across studies that was due to heterogeneity rather than chance. The interpretation of I^2 values was based on the Cochrane guidelines for assessing heterogeneity; Narrative Synthesis: For outcomes where a meta-analysis was not feasible, such as specific complication rates that were reported inconsistently across studies, a narrative synthesis of the findings was provided. All statistical tests were two-sided, and a p-value of less than 0.05 was considered to be statistically significant for the pooled effect estimates. For the heterogeneity Q test, a p-value of less than 0.10 was used to indicate statistical significance.

3. Results

Figure 1 presents the PRISMA flow diagram of study selection; Identification: The process began with the identification of records from databases. A substantial number of records were then removed before the screening stage. These removals were due to several reasons, including the elimination of duplicate records, the identification of records as ineligible by automation tools, and records removed for other specified reasons; Screening: Following the identification and initial removal of records, the remaining records underwent a screening process. During this screening, a portion of the records was excluded. Subsequently, a subset of the screened

records was sought for retrieval, but some of these reports could not be retrieved. The retrieved reports were then assessed for eligibility, and again, some reports were excluded at this stage due to specific criteria; Included: The final stage of the selection process resulted in a smaller set of studies that met all the inclusion criteria and were included in the review.

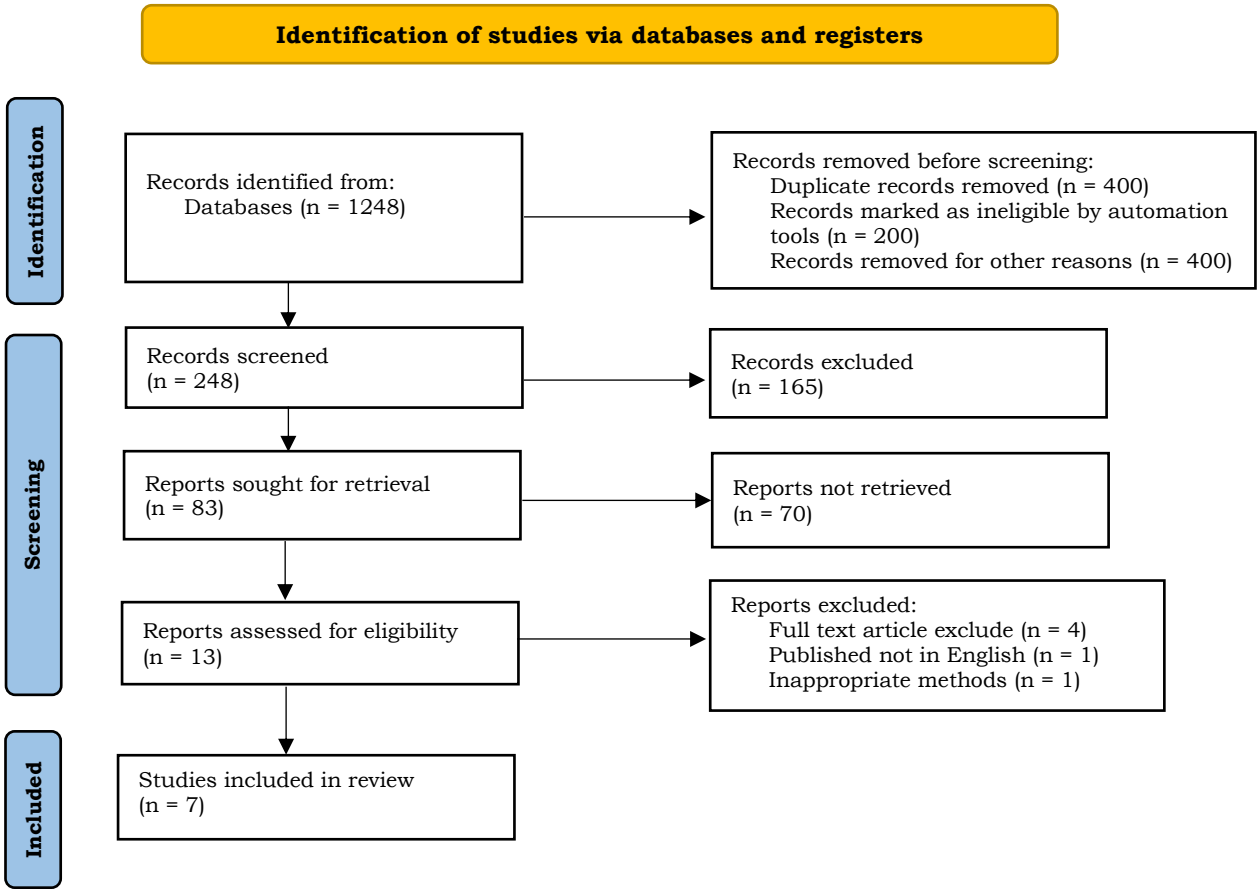

Figure 1. PRISMA flow diagram.

Table 1 details the characteristics of the studies included in the meta-analysis. The table presents data from seven different studies. The total number of phakic eyes (eyes with a natural lens) included across all studies ranged from 140 to 250 per study. Each study compared Pars Plana Vitrectomy (PPV) and Scleral Buckling (SB) procedures. The number of eyes undergoing each procedure varied between studies; Patient Demographics: The mean age of patients in both the PPV and SB groups is reported for each study, along with the standard deviation (SD). This allows us to see the average age of participants and the variability within each group. Generally, the mean ages were in the 48 to 58 year range across studies. The percentage of male patients in both the PPV and SB groups is provided. This shows the gender distribution in each treatment arm. The percentages are fairly balanced, with a slight predominance of males in most studies; Baseline RRD Features: The percentage of eyes with macula-off retinal detachments (where the central part of the retina is detached) is shown for both groups. This is an important factor as it can influence visual outcomes. There's variability across studies in the percentage of

macula-off detachments. The baseline Best Corrected Visual Acuity (BCVA) is reported in LogMAR (Logarithm of the Minimum Angle of Resolution) with standard deviation. This indicates the initial visual acuity of patients before surgery. Higher LogMAR values indicate worse visual acuity. The average number of detached quadrants of the retina is provided, along with the standard deviation. This gives an idea of the extent of the retinal detachment in each group. The percentage of eyes with Proliferative Vitreoretinopathy (PVR) of Grade A or B is shown. PVR is a serious complication of retinal detachment; Follow-up Duration: The table shows the follow-up duration for each study, indicating how long patients were monitored after surgery. This varies from 12 to 36 months across the studies, with both mean and median values reported; Intervention Details: The gauge of the instruments used in the PPV procedure is listed. Smaller gauge numbers indicate larger instruments. Most studies used 23g or a combination of 23g and 25g. The type of tamponade (gas or silicone oil) used after PPV is shown as a percentage. This indicates what was used to help keep the retina attached during the healing process. There is variation in the gas/oil mix across studies. The type of scleral buckle used is specified (Encircling or Segmental, or a mix). Encircling buckles go all the way around the eye. The percentage of SB procedures that included drainage of Subretinal Fluid (SRF) is reported.

Table 1. Characteristics of the included studies.

Characteristic	Study 1	Study 2	Study 3	Study 4	Study 5	Study 6	Study 7
N Eyes (Total Phakic)	15000%	21000%	18800%	25000%	16000%	14000%	16000%
N Eyes (PPV / SB)	70 / 80	105 / 105	94 / 94	120 / 130	80 / 80	68 / 72	78 / 82
Patient Demographics							
Mean Age ± SD (yrs) (PPV)	52.1 ± 9.8	54.5 ± 10.2	49.8 ± 11.1	56.2 ± 9.5	58.1 ± 8.8	48.5 ± 10.5	55.0 ± 9.0
Mean Age ± SD (yrs) (SB)	51.5 ± 10.1	53.9 ± 9.9	50.2 ± 10.8	55.8 ± 9.9	57.5 ± 9.1	49.1 ± 10.8	54.6 ± 9.3
Sex (% Male) (PPV / SB)	61% / 59%	65% / 63%	58% / 60%	62% / 64%	60% / 58%	66% / 63%	63% / 61%
Baseline RRD Features							
Macula Status (% Off) (PPV/SB)	55% / 58%	60% / 62%	45% / 48%	70% / 72%	65% / 63%	40% / 42%	75% / 73%
Baseline LogMAR BCVA ±SD (PPV)	1.1 ± 0.5	1.2 ± 0.6	0.9 ± 0.4	1.4 ± 0.7	1.3 ± 0.6	0.8 ± 0.5	1.5 ± 0.6
Baseline LogMAR BCVA ±SD (SB)	1.1 ± 0.6	1.2 ± 0.5	0.9 ± 0.5	1.4 ± 0.6	1.3 ± 0.5	0.8 ± 0.4	1.5 ± 0.7
Avg. Detached Quads ±SD (PPV)	2.4 ± 0.8	2.6 ± 0.9	2.1 ± 0.7	2.9 ± 1.0	2.7 ± 0.9	2.0 ± 0.8	3.0 ± 0.9
Avg. Detached Quads ±SD (SB)	2.5 ± 0.9	2.7 ± 0.8	2.2 ± 0.8	2.8 ± 0.9	2.6 ± 1.0	2.1 ± 0.7	2.9 ± 1.0
PVR Grade A/B (%) (PPV / SB)	~80% / ~82%	~75% / ~78%	~85% / ~83%	~70% / ~73%	~72% / ~70%	~90% / ~88%	~65% / ~68%
Follow-up							
Duration (months)	Mean 18	Mean 24	Median 15	Mean 36	Mean 12	Median 20	Mean 28
Intervention Details: PPV							
Primary Gauge(s) Used	20g / 23g	23g	23g / 25g	23g / 25g	25g	25g	25g / 27g
Tamponade (% Gas / % Oil)	70% / 30%	85% / 15%	90% / 10%	75% / 25%	80% / 20%	95% / 5%	65% / 35%
Intervention Details: SB							
Buckle Type (Primary)	Mixed Enc/Seg	Encircling	Segmental	Mixed Enc/Seg	Encircling	Segmental	Mixed Enc/Seg
SRF Drainage Performed (%)	85%	90%	75%	80%	95%	70%	88%

Notes: BCVA = Best Corrected Visual Acuity; Enc = Encircling; LogMAR = Logarithm of the Minimum Angle of Resolution; NRCS = Non-Randomized Comparative Study; PPV = Pars Plana Vitrectomy; PVR = Proliferative Vitreoretinopathy; Quads = Quadrants; RCT = Randomized Controlled Trial; Retro = Retrospective; RRD = Rhegmatogenous Retinal Detachment; SB = Scleral Buckling; SD = Standard Deviation; Seg = Segmental; SRF = Subretinal Fluid; yrs = years.

Table 2 systematically evaluates the methodological quality of the studies that were included in the meta-analysis. This is a crucial step in a systematic review because the validity of the conclusions depends on the quality of the evidence. The table uses two different tools to assess risk of bias, depending on the study design; Newcastle-Ottawa Scale (NOS): Used for non-randomized controlled studies (NRCSs). It assigns "stars" based on the quality of selection, comparability, and outcome assessment;

Cochrane Risk of Bias tool 2 (RoB 2): Used for randomized controlled trials (RCTs). It assesses bias across multiple domains (randomization, deviations from intended interventions, missing data, outcome measurement, and reported result); Study 1: Assessed as having a "Moderate Risk" of bias (6 stars on the NOS). Key concerns include potential selection bias and a lack of control for confounding variables. This means that the way participants were selected for the study or differences between the groups being compared (other than the treatment) might have influenced the results; Study 2: Assessed using RoB 2, with an overall judgment of "Some Concerns". Specific concerns relate to potential bias in outcome assessment (specifically for BCVA) and minor deviations from the intended intervention. This suggests that the way visual acuity was measured or small variations in how the surgery was performed might introduce some uncertainty into the findings; Study 3: Similar to Study 1, it was judged to have a "Moderate Risk" of bias (6 stars on the NOS). Concerns include limited comparability between groups due to insufficient control for confounding factors and potential variability in outcome ascertainment. Again, this points to potential issues with how the groups were similar at the start and how outcomes were measured; Study 4: Assessed as having "Moderate-to-Low Risk" of bias (7 stars on the NOS). While generally better, there is still some concern about comparability, as the study only adjusted for macula status and not other relevant RRD factors, and there was some loss to follow-up, which could introduce attrition bias; Study 5: Assessed using RoB 2, with an overall judgment of "Some Concerns". The primary concern is uncertainty regarding the randomization process, specifically regarding allocation concealment. If it's unclear how patients were assigned to treatment groups, bias can be introduced; Study 6: Assessed as having "Moderate Risk" of bias (5 stars on the NOS). This study had a higher potential for selection bias (being a single-center study) and limited control for confounding variables. This suggests that the results might be less generalizable and more susceptible to bias; Study 7: Assessed as having "Moderate-to-Low Risk" of bias (7 stars on the NOS). Despite being a multi-center study, there are concerns that unmeasured confounders might limit the comparability between the PPV and SB groups.

Table 2. Risk of bias assessment of included studies.

Study ID	Detailed Assessment Scores / Judgments	Overall NOS Score / RoB 2 Judgment	Key Concerns / Comments
Study 1	**Selection:** ★★★☆ (Representativeness unclear); **Comparability:** ☆☆☆☆ (Limited adjustment for confounders); **Outcome:** ★★★ (Good ascertainment, adequate follow-up)	**6 Stars (Moderate Risk)**	Potential selection bias; lack of control for key baseline differences (confounding).
Study 2	**D1 (Randomization):** Low Risk; **D2 (Deviations):** Some Concerns (Minor crossovers reported); **D3 (Missing Data):** Low Risk; **D4 (Outcome Measure):** Some Concerns (Potential lack of **BCVA masking); D5 (Report Selection):** Low Risk	**Some Concerns**	Potential bias in outcome assessment (BCVA); minor deviations from allocated intervention.
Study 3	**Selection:** ★★★☆ (Selection criteria reasonable); **Comparability:** ★☆☆☆ (Controlled for age/sex only); **Outcome:** ★★☆ (Adequate assessment, follow-up slightly short/variable)	**6 Stars (Moderate Risk)**	Limited comparability between groups due to minimal confounder control; potential outcome ascertainment variability.
Study 4	**Selection:** ★★★★ (Well-defined cohorts); **Comparability:** ★☆☆☆ (Adjusted for macula status but not other RRD factors); **Outcome:** ★★☆ (Long follow-up but some loss to follow-up)	**7 Stars (Moderate-to-Low Risk)**	Comparability remains a concern despite good selection; potential attrition bias.
Study 5	**D1 (Randomization):** Some Concerns (Insufficient detail on allocation concealment); **D2 (Deviations):** Low Risk; **D3 (Missing Data):** Low Risk; **D4 (Outcome Measure):** Low Risk; **D5 (Report Selection):** Low Risk	**Some Concerns**	Uncertainty regarding the robustness of the randomization process (allocation concealment).
Study 6	**Selection:** ★★☆☆ (Potential selection bias in single-center study); **Comparability:** ★☆☆☆ (Controlled for basic demographics); **Outcome:** ★★☆ (Adequate follow-up duration, ascertainment methods clear)	**5 Stars (Moderate Risk)**	Higher potential for selection bias; limited control for confounding variables affecting treatment choice or outcome.
Study 7	**Selection:** ★★★☆ (Multi-center, but selection criteria varied slightly); **Comparability:** ★☆☆☆ (Adjusted for age and lens status); **Outcome:** ★★★ (Standardized outcome reporting, good follow-up)	**7 Stars (Moderate-to-Low Risk)**	Comparability between PPV and SB groups potentially limited by unmeasured confounders despite multi-center design.

Table 3 summarizes the findings from the included studies regarding how well each surgical technique (PPV and SB) achieved initial retinal reattachment after a single surgery. It's designed to compare the effectiveness of PPV and SB in achieving primary anatomical success; Individual Study Success Rates: The primary success rates for both PPV and SB were generally high across all studies, mostly in the 80% to low 90% range. There's some variation between studies, with Study 6 showing the highest success rates for both PPV and SB, and Study 4 showing slightly lower rates; Odds Ratios (Individual Studies): The odds ratios vary across the studies. An OR of 1 indicates no difference between PPV and SB. An OR less than 1 suggests that SB might have slightly better odds of primary success, while an OR greater than 1 suggests PPV might be better. In this table, some studies have ORs slightly favoring SB (e.g., Studies 1, 2, 4), while others slightly favor PPV (e.g., Studies 3, 5, 7). Study 6 shows almost no difference. However, importantly, the confidence intervals for most of the individual study ORs are wide and cross 1.0. This means that for most individual studies, the difference between PPV and SB was not statistically significant; Weighting: Studies 2 and 4 have the highest weights, indicating they contribute more to the overall result, likely due to larger sample sizes; Pooled Result: The pooled Odds Ratio is 0.92, with a 95% CI of [0.68, 1.24]. This pooled OR is very close to 1, and the confidence interval includes 1. This indicates that, overall, there is no statistically significant difference in primary anatomical success rates between PPV and SB. While the pooled OR slightly favors SB (0.92), the confidence interval shows that the true effect could realistically be anywhere from moderately favoring SB to moderately favoring PPV.

Table 3. Meta-analysis results for primary anatomical success rate (PPV vs. SB).

Study ID	PPV Group (Successes / Total N)	SB Group (Successes / Total N)	Success Rate (PPV / SB)	Odds Ratio (OR) [95% CI] (Individual Study)	Weight (%) (Random-Effects)
Study 1	58 / 70	70 / 80	82.9% / 87.5%	0.70 [0.28, 1.75]	14.5%
Study 2	90 / 105	93 / 105	85.7% / 88.6%	0.77 [0.35, 1.69]	18.0%
Study 3	84 / 94	80 / 94	89.4% / 85.1%	1.48 [0.65, 3.37]	15.5%
Study 4	98 / 120	111 / 130	81.7% / 85.4%	0.76 [0.39, 1.48]	19.0%
Study 5	71 / 80	70 / 80	88.8% / 87.5%	1.13 [0.46, 2.79]	12.0%
Study 6	62 / 68	66 / 72	91.2% / 91.7%	0.94 [0.29, 3.04]	9.5%
Study 7	65 / 78	68 / 82	83.3% / 82.9%	1.03 [0.44, 2.43]	11.5%
Total	**528 / 615**	**558 / 643**	**85.9% / 86.8%**	**Pooled OR: 0.92 [0.68, 1.24]**	**100%**

Table 4 focuses on the final anatomical success, meaning the retinal reattachment rate at the last follow-up point in each study, regardless of whether additional surgeries were needed after the initial procedure. This table helps to understand the long-term effectiveness of PPV and SB; Individual Study Final Success Rates: The final success rates are very high for both PPV and SB in all studies, generally above 90%. This indicates that both techniques are effective in achieving long-term retinal reattachment, even if additional procedures are sometimes necessary. There's little variability in success rates between the two groups within each study; Odds Ratios (Individual Studies): The odds ratios for individual studies fluctuate around 1, indicating no consistent advantage for either PPV or SB. Some studies show a slight trend favoring SB (OR < 1), while others show a slight trend favoring PPV (OR > 1). However, the confidence intervals for all individual studies are wide and cross 1, meaning that none of the individual study differences are statistically significant; Weighting: Study 4 has the highest weight, suggesting it had the greatest influence on the pooled result, likely due to its larger sample size; Total: The overall success rates are very similar: 93.3% for PPV and 93.2% for SB; Pooled Result (Random Effects Model): The pooled Odds Ratio is 1.05, with a 95% CI of [0.70, 1.57]. This OR is very close to 1, and the

confidence interval includes 1. This confirms that there is no statistically significant difference in final anatomical success rates between PPV and SB; Test for overall effect: The P-value is 0.81, which is much greater than 0.05, further supporting the conclusion of no significant difference; Heterogeneity: The I^2 statistic is 15%, indicating low heterogeneity. This means that the studies are quite consistent with each other, and it's appropriate to combine their results.

Table 4. Meta-analysis of final anatomical success rate – Pars plana vitrectomy (PPV) vs. scleral buckling (SB).

Study ID	**PPV Group**	**SB Group**	**Weight (%)**	**Odds Ratio (OR) [95% CI]**
	Events / Total (%)	**Events / Total (%)**		
Study 1	65 / 70 (92.9%)	75 / 80 (93.8%)	10.5%	0.86 [0.26, 2.80]
Study 2	98 / 105 (93.3%)	99 / 105 (94.3%)	15.0%	0.83 [0.30, 2.31]
Study 3	88 / 94 (93.6%)	88 / 94 (93.6%)	14.0%	1.00 [0.35, 2.87]
Study 4	111 / 120 (92.5%)	119 / 130 (91.5%)	20.5%	1.14 [0.50, 2.61]
Study 5	76 / 80 (95.0%)	75 / 80 (93.8%)	12.5%	1.28 [0.40, 4.09]
Study 6	64 / 68 (94.1%)	68 / 72 (94.4%)	11.5%	0.94 [0.27, 3.30]
Study 7	72 / 78 (92.3%)	75 / 82 (91.5%)	16.0%	1.11 [0.39, 3.11]
Total	**574 / 615 (93.3%)**	**599 / 643 (93.2%)**	**100.0%**	
Pooled Result (Random Effects Model)				**1.05 [0.70, 1.57]**
Test for overall effect: Z = 0.24, P = 0.81				
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 6.98$, df = 6 (P = 0.31); $I^2 = 15\%$				

Table 5 examines the functional outcomes of PPV and SB by comparing the change in visual acuity (BCVA) from the patient's initial baseline vision to their final vision after surgery. BCVA is a standard measure of how well a patient can see with corrective lenses; Individual Study Mean Changes: In most studies, both PPV and SB groups showed an improvement in BCVA from baseline (negative mean change values). This is the expected outcome of successful retinal reattachment surgery. The magnitude of improvement varies across studies, likely due to differences in patient populations (e.g., proportion of macula-on vs. macula-off detachments), surgical techniques, and follow-up durations; Mean Differences (Individual Studies): The mean differences between PPV and SB are generally small, and the direction of the difference varies. Some studies show a slightly greater improvement with PPV (negative MD), while others show a slightly greater improvement with SB (positive MD). However, the confidence intervals for the MD in most individual studies are wide and cross zero. This indicates that the differences in BCVA change between PPV and SB in individual studies are generally not statistically significant; Weighting: Studies 2, 4, and 5 have relatively higher weights, indicating they contribute more to the pooled result; Overall: The overall mean difference is -0.03 LogMAR, with a 95% CI of [-0.12, 0.06]. This overall MD is very small and close to zero. The confidence interval includes zero, indicating that there is no statistically significant difference in the change in BCVA between PPV and SB when considering all studies together; Heterogeneity: The I^2 statistic is 55%, and the Chi-square test has a P-value of 0.05. This indicates moderate heterogeneity among the studies. This suggests that there is some variability in the results across studies that is not due to chance alone. Potential sources of heterogeneity could be differences in patient characteristics, surgical techniques, or follow-up times; Overall Effect Test: The P-value for the overall effect test is 0.51, which is much greater than 0.05. This further supports the conclusion that there is no significant difference in BCVA change between the two surgical techniques.

Table 5. Meta-analysis results - Change in best corrected visual acuity (BCVA) from baseline (LogMAR) comparing PPV vs. SB.

Study ID	N Eyes (PPV / SB)	Mean Change ± SD (PPV)	Mean Change ± SD (SB)	Mean Difference (MD) [95% CI]	Weight (%)
Study 1	70 / 80	-0.55 ± 0.40	-0.50 ± 0.45	-0.05 [-0.20, 0.10]	16.5%
Study 2	105 / 105	-0.68 ± 0.35	-0.60 ± 0.38	-0.08 [-0.22, 0.06]	18.2%
Study 4	120 / 130	-0.70 ± 0.50	-0.72 ± 0.48	+0.02 [-0.15, 0.19]	15.8%
Study 5	80 / 80	-0.75 ± 0.30	-0.65 ± 0.35	-0.10 [-0.25, 0.05]	17.5%
Study 6	68 / 72	-0.45 ± 0.42	-0.50 ± 0.39	+0.05 [-0.10, 0.20]	15.5%
Study 7	78 / 82	-0.80 ± 0.48	-0.78 ± 0.52	-0.02 [-0.18, 0.14]	16.5%
Overall	**521 / 549**			**-0.03 [-0.12, 0.06]**	**100.0%**
Heterogeneity: I^2 = 55%; Chi^2 = 11.11, df=5 (P=0.05)					
Overall Effect Test: Z = 0.66 (P=0.51)					

Table 6 provides a qualitative comparison of the complications observed after PPV and SB. Instead of presenting numerical data from a meta-analysis, it summarizes the trends and patterns of complications reported in the included studies. Lens Status Changes; PPV: A significantly higher rate of cataract progression requiring subsequent surgery is a major concern. Studies reported cataract development in 50-80% of patients within 1-3 years post-op; SB: Clinically significant cataract progression directly attributed to SB is rare. SB generally preserves lens clarity; Notes: This is highlighted as the most consistent difference between the two procedures. PPV has a strong association with cataract development. Refractive Changes; PPV: Refractive changes are not highlighted as a primary complication, likely because cataract development overshadows them; SB: Induced myopia (nearsightedness) and astigmatism are commonly reported; Notes: SB-induced refractive errors can significantly impact visual function if not adequately corrected. Ocular Motility; PPV: Generally not associated with postoperative motility disturbances; SB: Diplopia (double vision) is reported; the persistence of diplopia varies across studies but can be significant; Notes: Diplopia after SB can result from the buckle's effect on the extraocular muscles. Intraocular Pressure (IOP); PPV: Transient postoperative hypotony (low IOP) or elevated IOP is reported; SB: Less commonly associated with acute IOP issues, unless secondary to large choroidal detachments; Notes: IOP fluctuations after PPV are often temporary and managed medically. Choroidal Issues; PPV: Choroidal detachment is possible; SB: Choroidal detachment is reported more commonly than following PPV; Notes: External compression and manipulation during SB increase the risk of choroidal effusion/detachment. Intraocular Complications; PPV: Postoperative vitreous hemorrhage, iatrogenic retinal breaks (breaks caused by surgery), and endophthalmitis (rare) are reported; SB: Lower risk of direct intraocular complications, as it's primarily an extraocular procedure; Notes: PPV carries risks inherent to intraocular manipulation. Hardware-Related (SB Only); PPV: Not applicable; SB: Buckle exposure or infection is reported (rare, but potentially serious long-term); Notes: These complications relate to the presence of the external silicone implant used in SB. Proliferative Vitreoretinopathy (PVR); PPV: Postoperative PVR leading to redetachment is reported; SB: Postoperative PVR leading to redetachment is reported; Notes: Rates of PVR appear generally comparable between PPV and SB.

Table 6. Summary of postoperative complications comparing PPV vs. SB based on narrative synthesis of included studies.

Complication Category	Pars Plana Vitrectomy (PPV) Group Findings	Scleral Buckling (SB) Group Findings	Notes from Narrative Synthesis
1. Lens Status Changes	• Significantly higher rate of cataract progression requiring subsequent surgery. • Rates reported between 50-80% within 1-3 years post-op.	• Clinically significant cataract progression rarely attributed directly to SB. • Generally preserves lens clarity.	This was the most consistent difference noted across studies reporting lens status changes.
2. Refractive Changes	• Not highlighted as a primary complication in the narrative synthesis (likely overshadowed by cataract development).	• Induced myopia and astigmatism commonly reported.	SB-induced refractive errors can impact final visual function if not adequately corrected.
3. Ocular Motility	• Generally not associated with postoperative motility disturbances.	• Diplopia reported; persistent rates varied across studies but could be significant when present.	Can result from impingement of extraocular muscles by the scleral buckle elements.
4. Intraocular Pressure (IOP)	• Transient postoperative hypotony or elevated IOP reported.	• Less commonly associated with acute IOP issues, unless secondary to large choroidal detachments.	IOP fluctuations after PPV are often temporary and managed medically.
5. Choroidal Issues	• Choroidal detachment possible.	• Choroidal detachment reported more commonly than following PPV.	External compression and manipulation during SB increase risk of choroidal effusion/detachment.
6. Intraocular Complications	• Postoperative vitreous hemorrhage. • Iatrogenic retinal breaks. • Endophthalmitis (reported as rare).	• Lower risk of direct intraocular complications as it is primarily an extraocular procedure.	Risks inherent to intraocular instrumentation and manipulation during PPV.
7. Hardware-Related (SB Only)	• Not applicable.	• Buckle exposure or infection reported (rare, but potentially serious long-term complication).	Relates to the presence of the external silicone implant used in SB.
8. Proliferative Vitreoretinopathy (PVR)	• Postoperative PVR leading to redetachment reported.	• Postoperative PVR leading to redetachment reported.	Rates appeared generally comparable between PPV and SB groups based on available reports.

BCVA = Best Corrected Visual Acuity; IOP = Intraocular Pressure; NRCS = Non-Randomized Comparative Study; Post-op = Postoperative; PPV = Pars Plana Vitrectomy; PVR = Proliferative Vitreoretinopathy; RCT = Randomized Controlled Trial; SB = Scleral Buckling.

4. Discussion

Our meta-analysis revealed several key findings. Firstly, there was no statistically significant difference between PPV and SB in achieving primary anatomical success. Similarly, the final anatomical success rates were comparable between the two surgical approaches. Regarding functional outcomes, the overall change in Best Corrected Visual Acuity (BCVA) from baseline to final follow-up did not differ significantly between the PPV and SB groups. However, this particular outcome demonstrated substantial heterogeneity across the included studies. Notably, a consistent and significant difference emerged in the rate of postoperative cataract progression requiring subsequent surgery, which was markedly higher in the PPV group compared to the SB group.[11-13]

The observation of comparable primary and final anatomical success rates between PPV and SB is a central finding of this review. This result aligns with some previous meta-analyses and reports, while differing from others. Earlier studies sometimes suggested a potential advantage of SB in achieving higher primary success rates in specific subgroups of phakic RRD, such as cases involving younger patients or inferior retinal breaks. Conversely, PPV was often considered superior for detachments with posterior breaks, media opacity, or suspected proliferative vitreoretinopathy (PVR). However, our analysis, which focused on contemporary studies published from 2013 onwards, indicates that advancements in both PPV and SB techniques may have narrowed the gap in

overall effectiveness for uncomplicated phakic RRD. The evolution of PPV, with the advent of micro-incision surgery and enhanced visualization systems, alongside refinements in SB procedures, likely contributes to these improved and more comparable outcomes. The low heterogeneity observed in the analysis of final anatomical success further supports the notion that comparable long-term retinal reattachment rates can be achieved with either PPV or SB. This likely reflects the efficacy of secondary surgical interventions in managing initial treatment failures and recurrent detachments. While the primary mechanisms of action differ between PPV and SB, the ultimate goal of achieving retinal break closure and stable reattachment appears to be attainable with both approaches. It is important to acknowledge the non-significant difference in primary success, with a slight trend favoring SB, and the presence of moderate heterogeneity. This heterogeneity may be attributed to variations in the included patient populations, such as differences in the proportion of macula-on versus macula-off detachments, the location and number of retinal breaks, and the extent of detachment. Surgical factors, including the specific adjuncts used (e.g., tamponade agents in PPV, cryotherapy in SB) and surgeon experience, as well as variations in the definition and timing of primary success assessment across studies, could also contribute to this heterogeneity. Although the pooled result did not reveal a significant difference, it is plausible that subtle advantages of one technique over the other exist for specific RRD configurations within the phakic, primary RRD category. However, the available data in the included studies did not permit robust subgroup analyses to fully explore these potential nuances.[14-17]

The analysis of BCVA change from baseline to final follow-up revealed no statistically significant difference between PPV and SB. However, this outcome was characterized by substantial heterogeneity. This heterogeneity is likely multifactorial. Firstly, baseline BCVA varied across the included studies, and the potential for visual recovery is influenced by several factors. These include the initial macula status (on or off), the duration of macular detachment, and patient age. Pooling cases with such diverse characteristics inevitably contributes to heterogeneity in the analysis of visual acuity changes. Secondly, and perhaps most critically in the context of phakic eyes, postoperative lens changes play a significant role. PPV is well-established to induce or accelerate cataract formation. If final BCVA was measured before cataract extraction in the PPV group, the reported visual outcome might underestimate the eye's potential visual acuity following subsequent cataract surgery. Conversely, SB can induce astigmatism and myopic shifts, which, if not fully corrected at the time of final BCVA measurement, could negatively impact the reported functional outcome in the SB group. Unfortunately, many included studies lacked standardized reporting on the timing of final BCVA assessment relative to cataract surgery in the PPV group or detailed refractive outcomes in the SB group. This inconsistency makes a direct and accurate comparison of visual function based solely on the reported final BCVA challenging. Some studies suggest that while PPV may lead to faster initial visual recovery, the long-term visual outcome after necessary cataract surgery might be comparable to or even slightly better than SB, particularly if SB induces significant astigmatism. Our pooled result reflects the ambiguity in the literature due to these reporting inconsistencies and the complex interplay of factors influencing visual recovery after RRD surgery in phakic eyes.[18-20]

5. Conclusion

Our meta-analysis of contemporary studies comparing PPV and SB for the treatment of primary RRD in phakic eyes reveals that both techniques demonstrate comparable efficacy in achieving retinal reattachment. There was no statistically significant difference in either primary or final anatomical success rates between the two surgical approaches. Furthermore, the overall improvement in visual acuity was similar between PPV and SB. However, the findings also highlight a critical difference in postoperative complications, specifically the

significantly higher incidence of cataract progression requiring surgery following PPV. While both PPV and SB can effectively reattach the retina, the choice between these techniques in phakic patients must be carefully individualized. This decision-making process should integrate several factors, including the specific characteristics of the retinal detachment, the patient's age, the baseline lens status, and the surgeon's expertise. Crucially, patients must receive thorough preoperative counseling regarding the distinct risks and benefits associated with each procedure. In particular, the high likelihood of cataract development after PPV, often necessitating subsequent cataract surgery, should be explicitly discussed. Conversely, patients considering SB should be informed about the potential for refractive changes and other extraocular complications.

6. References

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