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# A comparative assessment of three planes of implant placement in breast augmentation: A Bayesian analysis



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## KEYWORDS

Mammoplasty;  
Breast implants;  
Implant placement;  
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Bayesian network  
meta-analysis

**Summary Background:** Techniques based on three planes of implant placement, including the subglandular (SG), subpectoral (SP), and subfascial (SF) planes are used for breast augmentation. The placement that offers the greatest balance of risks and benefits is unclear. This study presents a systematic review with a Bayesian network meta-analysis to compare different implant placement techniques for augmentation mammoplasty.

**Methods:** A systematic literature search was performed. We estimated the odds ratios (ORs) for capsular contractures, hematomas, seromas, infections, reoperation rates, rippling, nipple numbness, malplacements, ruptures, and asymmetry among the different interventions. Muscle movement events and satisfaction rates were also evaluated.

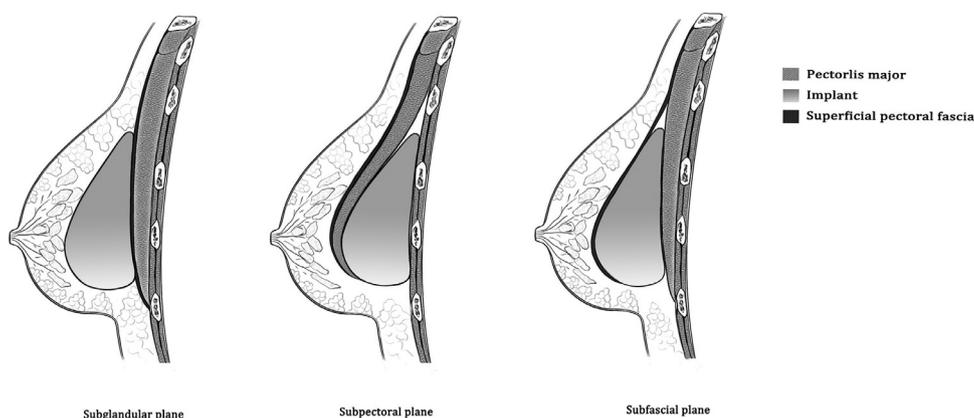
**Results:** A total of 19 studies (25,744 cases) were included. SG placement significantly increased the incidence of capsular contractures (SP vs. SG: OR 0.42; 95% credible interval [CrI] 0.28-0.63; SF vs. SG: OR 0.41; 95% CrI 0.17-0.97), hematomas (SF vs. SG: OR 0.22; 95% CrI 0.06-0.63), and seromas (SF vs. SG: OR 0.04; 95% CrI 0.00-0.81) compared to other placement techniques. Muscle movement only occurred in the SP group, but it did not increase the risk of subsequent malplacements, asymmetries, or ruptures. Most patients were highly satisfied with their surgical results. Comparisons did not show significant differences in the remaining results.

**Conclusions:** Our evidence suggests that SG placement increases the risk of capsular contractures, hematomas, and seromas. The SP and SF planes were safe and effective for controlling total complication rates and achieving high satisfaction rates; however, the long-term benefits of the SF technique require further research.

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**Figure 1** A graphic model of the different planes of implant placement.

## Introduction

Augmentation mammoplasty, which is designed to increase the cup size and change breast shape, is the most popular aesthetic surgical procedure performed worldwide. In the United States alone, more than 300,000 women underwent breast augmentation surgery in 2018,<sup>1</sup> and it has become an increasing course of action among Asian women, who have a high incidence of breast hypoplasia due to genetic and nutritional factors. The aesthetic results of this procedure are influenced by choices of implant shape, content, surface, incision location, and implant placement.<sup>2,3</sup> Placement choice is one of the many variables considered in presurgical planning.

Almost all implant augmentations are performed in one of the three locations, the classical subglandular (SG) and subpectoral (SP) planes, which have been used for over 5 decades<sup>4-23</sup> and the more recently used subfascial (SF) plane since the beginning of this century (Figure 1).<sup>9,10,14,20,24-26</sup> In the initial stages of breast augmentation surgery, implants were placed in the SG cavity, which involved a relatively simple and precise dissection process with minimal bleeding.<sup>4,27,28</sup> However, this approach was likely to reveal implant edges, lead to rippling in women with thin soft-tissues,<sup>21,26</sup> and was reported to be associated with a high risk of capsular contracture (CC) and nipple numbness.<sup>17,20</sup> Most plastic surgeons prefer SP rather than SG implant placements because they allow for a more natural appearance and potentially reduce the rate of CC.<sup>2,29-31</sup> However, patients who were treated using the SP technique, presented later with implant distortion when the pectoral muscles began to contract.<sup>14,20,22</sup> In the SF plane, the implant is located below the pectoralis major fascia. The technical advantages of the SF plane technique are controversial because the clinical distinction between the SF and SG planes can be difficult; however, proponents have reported that the SF method can provide great tissue coverage and improves implant position maintenance.<sup>32-34</sup>

To the best of our knowledge, there have been no previous comparisons of these three surgical options (SG, SP, and SF). To guide clinicians and patients in choosing optimal implant placements, we conducted this systematic review of the current literature with a Bayesian network meta-analysis comparing data on CC, hematoma,

seroma, infection, reoperation, rippling, nipple numbness, malplacement, rupture, asymmetry, muscle movement, and satisfaction among the SG, SP, and SF groups. Different from traditional meta-analysis, network meta-analysis allows direct and indirect comparisons to assess multiple interventions. The Bayesian network is one of the most efficient models in the uncertain knowledge and reasoning field. We aimed to assess the postoperative complication and satisfaction rates as well as summarize the characteristics of these three commonly used placement techniques.

## Methods

### Search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension statement for network meta-analyses and the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines.<sup>35-37</sup> English and Chinese databases, including PubMed/MEDLINE, EMBASE, Cochrane library, and the China National Knowledge Infrastructure were searched through the end of March 2019 for articles using the keywords “breast augmentation,” “subglandular,” “subpectoral,” “subfascial” and other associated words. Manual searches were also conducted. The search strategy is presented in Appendix 1.

### Selection criteria and outcome variables

Publications were included if they met the following criteria: (a) randomized controlled trials (RCTs) or cohorts that enrolled patients with primary breast augmentations regardless of implant size, types, and surgical incisions; (b) comparisons of any two or three implant placement (SG, SP, and SF) strategies were conducted. The most commonly applied strategy for SP implant placement was partial SP augmentation (described as “dual plane” by some surgeons) and related techniques involved the release of the inferior origin of the pectoral muscle. In the SF procedure, the fascia can be readily raised from either the axillary, periareolar, or inframammary approaches. A graphic model of the

different planes of implant placement is presented in [Figure 1](#); (c) data on outcomes including CCs, hematomas, seromas, infections, reoperation rates, rippling, nipple numbness, malplacements, ruptures, asymmetry, muscle movement, and satisfaction rates were provided. Eligible studies were published as full-length articles written in English, or in Chinese with an English abstract. Trials that enrolled patients with breast reconstruction, or revision augmentation, or the ones published in 1990 or prior were excluded. When multiple trials were reported by the same team from the same institution, only the most complete data set was included. The primary outcome was defined as the incidence of CC (mainly defined as Baker grade III/IV).<sup>38</sup> All complication outcomes were recorded as count variables and patient satisfaction assessments were reported descriptively.

### Data extraction

Using a standardized form, two investigators (Z.R.S. and J.Q.S.) independently reviewed the complete manuscripts and extracted information that included: publication data (i.e., the first author's name, year of publication, and country in which the studies were conducted), study design, and the number of patients with/without outcomes (complications) in each group. Any disagreements between the two reviewers were resolved initially through discussion. If a resolution could not be reached, a third reviewer (X.C.) was consulted.

### Assessment of methodological quality

The quality of the cohorts was assessed using the Newcastle-Ottawa Scale (NOS),<sup>39</sup> and RCT quality was assessed using the Jadad scale.<sup>40</sup> On the basis of an evaluation of the three aspects of quality (selection quality, comparability, and outcome measure), the maximum score for the NOS was 9. A score of 6 or more indicated a high-quality study with a low risk of bias. The Jadad scale covers three primary domains including randomization, blinding, and participant dropout. Studies with scores greater than or equal to 3 points (of 5 total) were considered to be of high quality.

### Statistical analyses

A network meta-analysis was conducted within a Bayesian framework provided by the Aggregate Data Drug Information System (ADDIS) software (version 1.16.8; <http://www.drugis.org/addis>). Inconsistency and node split methods were used to verify consistencies between direct and indirect evidence.<sup>41</sup> A *P* value of less than 0.05 indicated a significant inconsistency between direct and indirect effects in the node split analysis. Publication bias was measured using a Begg funnel plot or by Begg's and Egger's tests using the STATA software (version 15.0; Stata Corporation, College Station, TX, USA).<sup>42,43</sup> Odds ratios (ORs) were evaluated and reported with their corresponding credible intervals (CrIs). We also used ADDIS software to assess the probability of each intervention being the most

likely, second most likely, and third most likely to cause a complication, which may be helpful in clinical practice. Traditional meta-analyses were performed for each pairwise comparison to increase the statistical power.<sup>44</sup> Significant heterogeneity was detected when  $I^2$  was >50%. Subgroup analyses were performed on the primary outcome with regard to the study design (RCTs vs. cohorts), study region (America, Europe, and Asia), and publication year (studies published before 2010 vs. after 2010). In addition, sensitivity analyses were performed to determine the impact of any single study or study quality on the overall pooled analysis.

## Results

### Search results

[Figure 2](#) presents a flow diagram showing the study selection process. A total of 1386 studies were identified in the primary search. After scanning the titles and abstracts, we excluded 1142 studies. After detailed evaluations of the full texts of the remaining 244 studies, 225 were excluded for various reasons as follows: reporting only one implant placement ( $n=59$ ); breast reconstruction or revision augmentation ( $n=78$ ); absence of outcome data ( $n=45$ ); articles not in the clinical trial format ( $n=33$ ); duplications ( $n=6$ ); and those published in 1990 or prior ( $n=4$ ). Finally, 19 studies met the inclusion criteria.<sup>5-10,12-14,16-21,23-26</sup>

### Study characteristics and quality

This research included 19 studies reporting 25,744 cases (cases were defined as patients or breasts in different studies) undergoing primary breast augmentation.<sup>5-10,12-14,16-21,23-26</sup> There were 2 RCTs,<sup>13,14</sup> 4 prospective cohorts,<sup>5,12,18,19</sup> and 13 retrospective cohorts.<sup>6-10,16,17,20,21,23-26</sup> Most studies were written in English, while 3 were written in Chinese with English abstracts.<sup>9,10,26</sup> Most studies ( $n=16$ ) compared the two classical placements, SG versus SP planes, and 7 studies compared the SF plane with other planes ([Figure 3](#)).<sup>9,10,14,20,24-26</sup> With the exception of one Chinese study<sup>9</sup>, all studies reported CC outcomes. The follow-up periods ranged from 6 months to 10.9 years. [Table 1](#) summarizes the characteristics of the studies included in this meta-analysis, with quality assessments provided in [Table S1](#). Only Niechajev et al. adequately described the randomization and blinding methods,<sup>13</sup> while Pereira and Sterodimas did not,<sup>14</sup> as indicated by their methodological quality scores of 4 and 2 points, respectively. Of the 17 non-randomized comparative studies, 16 had a relatively low risk of bias, scoring greater than or equal to 6 on the NOS. One cohort that did not match the incision locations or the implant surfaces and had insufficient follow-up durations, scored 5 on the NOS and had a higher risk of bias.<sup>9</sup>

### Publication bias and inconsistency

No evidence of asymmetry in CC was shown in a comparison-adjusted funnel plot for the implant placement network

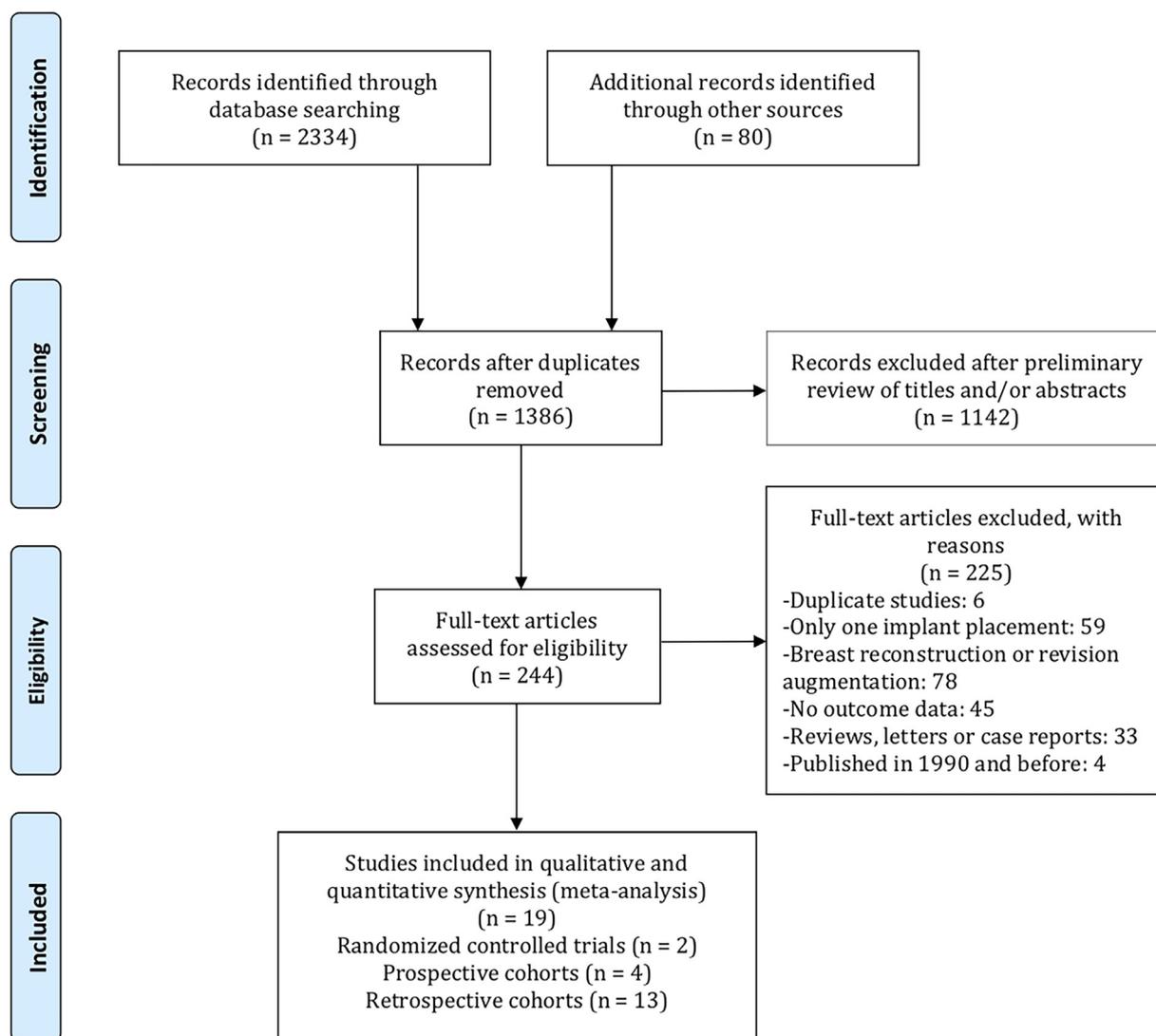


Figure 2 Flow chart showing the literature search strategy.

(Figure 4C and Table S2). Less than 10 studies were included for each secondary outcome, so the Begg's and Egger's tests were used to test publication bias. There was no evidence of statistical significance in any of the test comparisons (Table S2), which indicated minimal publication bias. The inconsistency and node split analyses showed no significant inconsistencies in the outcomes within the network (Table S3), with one exception, the infection outcome ( $P < 0.05$  for SF vs. SG, SF vs. SP, and SG vs. SP).

### Results of the network meta-analyses

Figure 4A summarizes the results of the random effects network meta-analyses of CC, hematoma, seroma, infection, reoperation, rippling, nipple numbness, malplacement, and rupture. Placement of SG implants significantly increased the CC rate compared to SP (SP vs. SG: OR 0.42; 95% CrI 0.28 to 0.63) and SF (SF vs. SG: OR 0.41; 95% CrI 0.17 to 0.97) placements. The probabilities of each intervention

being the worst placement with the highest complication rate were ranked (Figure 4B and Fig. S1). SG placement was ranked as the worst of the interventions with regard to CC and was associated with a significantly higher incidence of hematoma (SF vs. SG: OR 0.22; 95% CrI 0.06 to 0.63) and seroma (SF vs. SG: OR 0.04; 95% CrI 0.00 to 0.81) compared to SF. The comparisons did not show significant differences in the remaining results.

### Results of pairwise comparison by traditional meta-analysis

A traditional meta-analysis was conducted for direct comparisons (Table 2). The results of these analyses revealed a significantly higher incidence of CC in the SG group compared to that in the SP group (SP vs. SG: OR 0.43; 95% confidence interval [CI], 0.32 to 0.57) with high heterogeneity ( $I^2 = 60.5\%$ ). There were no statistically significant differences in the incidence of CC in other comparisons (SG

**Table 1** Characteristics of included studies.

Author (year)	Country	Design	Language	Comparison placements a/b(/c)	No. of cases placements a/b(/c)	No. of CCs placements a/b(/c)	Follow-up (months)
Benito-Ruiz et al. (2017) <sup>24</sup>	Spain	Retrospective cohort	English	SP/SF	113/260	3/10	60
Brown (2012) <sup>25</sup>	Australia	Retrospective cohort	English	SG/SF	83/200	1/1	6-50
Calobrace et al. (2018) <sup>19</sup>	USA	Prospective cohort	English	SG/SP	2266/2856	231/100	120
Henriksen et al. (2005) <sup>5</sup>	Denmark	Prospective cohort	English	SG/SP	1351/3133	18/21	19.5
Jacobson et al. (2012) <sup>23</sup>	USA	Retrospective cohort	English	SG/SP	24/312	0/6	13
Khan (2013) <sup>6</sup>	UK	Retrospective cohort	English	SG/SP	751/1024	6/2	≥36
Kjøller et al. (2001) <sup>7</sup>	Denmark	Retrospective cohort	English	SG/SP	41/1435	6/100	≥24
Kulmala et al. (2004) <sup>8</sup>	Finland	Retrospective cohort	English	SG/SP	39/548	18/80	130.8
Li et al. (2013) <sup>10</sup>	China	Retrospective cohort	Chinese	SG/SP/SF	183/154/113	11/8/7	6-24
Li et al. (2013) <sup>9</sup>	China	Retrospective cohort	Chinese	SG/SP/SF	NR	NR	≥9
Namnoum et al. (2013) <sup>12</sup>	USA & Canada	Prospective cohort	English	SG/SP	1213/7588	104/209	37±32
Niechajev et al. (2007) <sup>13</sup>	Sweden	RCT	English	SG/SP	92/36	19/10	60
Pereira and Sterodimas (2009) <sup>14</sup>	Brazil	RCT	English	SG/SP/SF	18/17/18	1/0/0	6-36
Seify et al. (2005) <sup>16</sup>	USA	Retrospective cohort	English	SG/SP	15/29	5/4	34
Shi et al. (2015) <sup>17</sup>	China	Retrospective cohort	English	SG/SP	35/89	3/5	32
Spear et al. (2014) <sup>18</sup>	USA	Prospective cohort	English	SG/SP	135/317	36/50	120
Stoff-Khalili et al. (2004) <sup>20</sup>	USA	Retrospective cohort	English	SG/SP/SF	105/154/75	21/4/1	35-43
Stutman et al. (2012) <sup>21</sup>	USA	Retrospective cohort	English	SG/SP	261/356	22/25	28.8
Yang et al. (2013) <sup>26</sup>	China	Retrospective cohort	Chinese	SG/SF	31/25	4/2	10.6

NR: not reported; RCT: randomized controlled trial; CC: capsular contracture; SP: subpectoral plane; SF: subfascial plane; SG: subglandular plane.

vs. SF and SP vs. SF). SG placement was ranked the worst of the interventions for hematoma formation, whereas SF placement was ranked the best (SP vs. SG: OR 0.49; 95% CI, 0.27 to 0.89; SF vs. SG: OR 0.34; 95% CI, 0.17 to 0.68; SF vs. SP: OR 0.20; 95% CI, 0.06 to 0.61) with low heterogeneity ( $I^2 = 0-29.1\%$ ). Patients in the SF group had a significantly lower rippling rate compared with those in the SG group (SF vs. SG: OR 0.17; 95% CI, 0.03 to 0.92), without heterogeneity. No statistically significant differences in the remaining outcomes were detected in the group comparisons. Subgroup analyses showed no significant differences in the CC rate between the SG and SP groups in RCTs and in Asia. There was no heterogeneity between the subgroups regarding the publication year (Table S4). A leave-one-out

sensitivity analysis of the outcomes showed that none of the exclusions altered the results of the previous analyses or reduced the heterogeneity (Table S5).

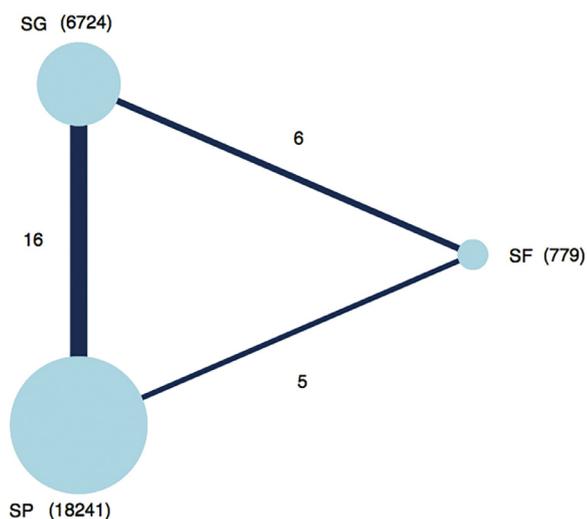
## Descriptive results

Some trials also reported muscle movement and satisfaction outcomes. Implant distortions with muscle contractions were reported only in the SP group. In total, 19 responders of 284 cases in 3 trials reported muscle movement.<sup>14,20,24</sup> The degrees of satisfaction were assessed in five studies (Table 3).<sup>9,10,14,18,25</sup> High satisfaction rates were achieved in all groups (SG, SP, and SF) with no significant differences.

**Table 2** Pooled odds ratio and heterogeneity in pairwise meta-analysis.

Treatment comparisons		No. of trials	OR (95% CI)	I <sup>2</sup>
Capsular contracture	SP vs. SG	15	<b>0.43 (0.32, 0.57)</b>	<b>60.5%</b>
	SF vs. SG	5	0.43 (0.15, 1.22)	43.7%
	SF vs. SP	4	1.15 (0.56, 2.36)	0%
Hematoma	SP vs. SG	4	<b>0.49 (0.27, 0.89)</b>	29.1%
	SF vs. SG	4	<b>0.34 (0.17, 0.68)</b>	0%
	SF vs. SP	2	<b>0.20 (0.06, 0.61)</b>	0%
Seroma	SP vs. SG	2	0.45 (0.10, 1.93)	0%
	SF vs. SG	2	0.24 (0.03, 2.18)	0%
	SF vs. SP	3	0.30 (0.05, 1.61)	0%
Infection	SP vs. SG	4	1.06 (0.23, 4.80)	<b>58.5%</b>
	SF vs. SG	2	0.17 (0.02, 1.47)	0%
Reoperation	SP vs. SG	5	0.67 (0.33, 1.37)	<b>80.4%</b>
	SF vs. SG	2	0.50 (0.18, 1.37)	0%
Rippling	SP vs. SG	3	0.31 (0.06, 1.59)	<b>88.9%</b>
	SF vs. SG	4	<b>0.17 (0.03, 0.92)</b>	<b>73.9%</b>
	SF vs. SP	3	0.77 (0.08, 7.73)	<b>55.9%</b>
Nipple numbness	SP vs. SG	3	0.23 (0.03, 2.15)	<b>82.1%</b>
Malplacement	SF vs. SP	2	0.30 (0.09, 1.01)	0%
Asymmetry	SP vs. SG	2	1.93 (0.17, 21.81)	<b>58.3%</b>

OR: odds ratio; CI: confidence interval; I<sup>2</sup>: extent of inconsistency; SP: subpectoral plane; SF: subfascial plane; SG: subglandular plane. Significant results are shown in bold.



**Figure 3** A network of the comparisons for the Bayesian network meta-analysis. Lines connect the interventions studied via comparisons in the eligible trials. The size of the nodes is proportional to the number of cases (in parentheses) undergoing surgery. The width of the lines is proportional to the number of trials (beside the line) comparing the connected interventions. SP: subpectoral plane; SF: subfascial plane; SG: subglandular plane.

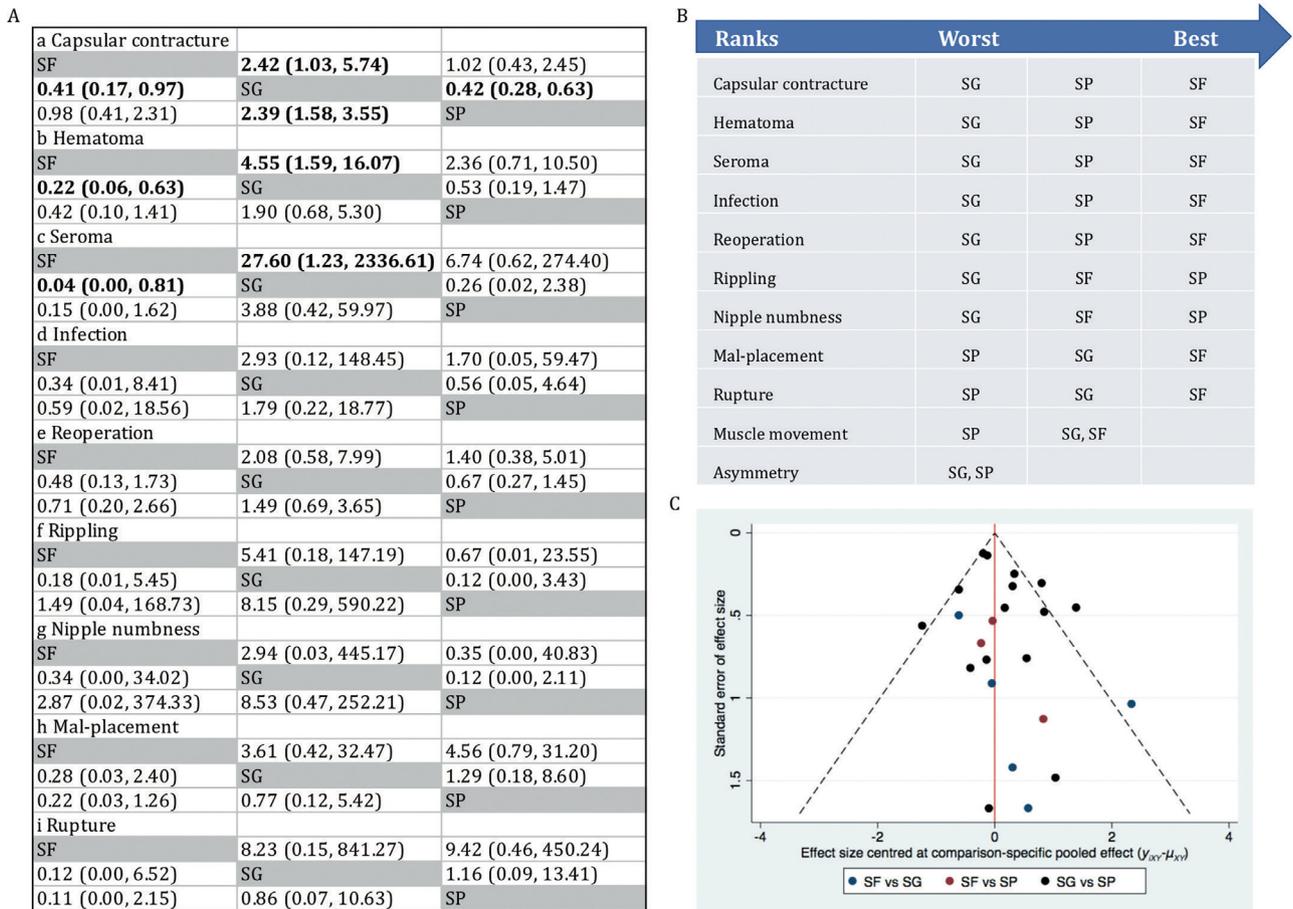
However, Li et al. (2) reported a significantly higher satisfaction rate after SF placement, which was based on less pain and lower incidences of malplacement and hematoma.<sup>9</sup>

## Discussion

Since the first use of implants in augmentation mammoplasty, surgeons have been researching for the appropriate

plane for the placement of breast implants.<sup>4</sup> To the best of our knowledge, this is the first systematic review to perform a Bayesian network meta-analysis of primary breast augmentation approaches, by comparing the data of SG, SP, and SF groups on CC, hematoma, seroma, infection, reoperation, rippling, nipple numbness, malplacement, rupture, asymmetry, muscle movement, and satisfaction. In this analysis, we determined that SG placement increases the risk of capsular contractures, hematomas, and seromas. The SP and SF planes are safe and effective for controlling postoperative complications and achieving high patient satisfaction rates; however, an understanding of the long-term benefits of the SF technique requires additional research.

CC continues to be the leading complication after augmentation mammoplasty, with prevalence rates ranging from 0.6% to 17.4%.<sup>28,45-47</sup> Fibrous capsules usually form around the implants at 3 months to 1 year postoperatively.<sup>36</sup> This fibrosis is a normal physiological response that helps to maintain the implant in its proper position;<sup>48</sup> however, if the amount of fibrotic tissue is excessive and if the myofibroblasts contract, a squeezing effect results, forcing the implant to assume a hard spherical shape.<sup>49</sup> The real cause of CC is still unknown. Many risk factors have been proposed, such as cigarette smoking,<sup>50</sup> smooth surface of the implant,<sup>51</sup> the use of a silicone implant,<sup>52</sup> secondary surgery,<sup>46</sup> radiation, hematoma, and SG placement.<sup>31,53</sup> Much effort has been taken toward reducing the CC rate. Surface textured implants were created to promote adhesion to the tissues.<sup>19,24</sup> Larger implants were also reported to have a protective effect.<sup>19</sup> In the last published meta-analysis, irrigation of the implant with povidone prior to implantation was shown to produce lower rates of CC than saline irrigation (2.7% vs. 8.9%).<sup>48</sup> Most studies have demonstrated that incision location had no significant effect on the risk of CC;<sup>18,21,23,53</sup> however, one study reported that trans-axillary incisions increased the rate of CC.<sup>12</sup>



**Figure 4** Results of the network meta-analyses. (A) Pooled odds ratios (ORs) with corresponding credible intervals (CrIs) for breast augmentation complications. The ORs were estimated in upper and lower triangles, and compared between the column-defining and row-defining interventions. For complication outcomes, ORs lower than 1 suggest benefits and comparative effects for the column-defining interventions. Significant outcomes are shown in bold. (B) Ranking of the implant placements, from most likely to cause complications (worst) to least likely to cause complications (best). (C) A comparison-adjusted funnel plot for the implant placement network. The red line represents the null hypothesis - study-specific effect sizes do not differ from the respective comparison-specific pooled effect estimates. Dots in the different colors represent the different comparisons. An observation of all studies symmetrically distributed around the null effect line indicated no small sample effect in the current network. SP: subpectoral plane; SF: subfascial plane; SG: subglandular plane.

**Table 3** Summary of satisfaction.

Study (year)	Comparisons	Questionnaire	Results
Brown (2012) <sup>25</sup>	SG, SF	Satisfaction questionnaire	Patient satisfaction with their surgical experience and final aesthetic result did not differ between the groups.
Li et al. (2013) <sup>10</sup>	SG, SP, SF	Satisfactory survey referring to Breast-Q system	The difference of satisfactory among the 3 groups was not statistically significant.
Li et al. (2013) <sup>9</sup>	SG, SP, SF	Percentage questionnaire	Patients with subfascial planes achieved the highest satisfaction ( $P < 0.01$ ) with less pain and lower incidence of malplacement and hematoma.
Pereira and Sterodimas (2009) <sup>14</sup>	SG, SP, SF	NR	The rates of satisfaction of the 3 groups at the 6-month follow-up are similar.
Spear et al. (2014) <sup>18</sup>	SG, SP	Five-point scale	Subjects rated their satisfaction with implants as a mean of 4.7 on a scale. 92.9% of subjects were satisfied at 10 years.

SP: subpectoral plane; SF: subfascial plane; SG: subglandular plane; NR: not reported.

The anatomical location of the implants has generally been associated with CC. Many studies<sup>4,5,8,12,15,18,19,22</sup> and meta-analyses<sup>50,54</sup> have all suggested a significantly higher risk of CC after SG placement (Hand et al.<sup>54</sup> RR 2.18, Egeberg et al.<sup>50</sup> OR 4.77) compared to SP placement. In this research, we compared 3 implant placement techniques and observed a similar result indicating that SG placement was associated with a 2-fold greater rate of CC compared with SP or SF. It is hypothesized that microorganisms from the breast ducts that attach to the implant surface can accelerate the inflammatory response process, whereas planes with stronger blood supplies help to prevent infection and reduce the risk of CC.<sup>46,50</sup> In addition, pectoralis muscle movements contribute to a continuous massage of the implant, possibly limiting the formation of a fibrous capsule.<sup>55,56</sup> On the basis of our results, we confirmed that benefits of the SP and SF positions include greater blood flow, better muscle massaging effects, and greater protection against bacterial growth around the breast glands.<sup>57,58</sup> The SG location, which is fully exposed to the breast duct, was significantly associated with the highest CC rate. There is reason to believe that this statistically significant difference is also clinically meaningful. Our results exhibited good consistency ( $P > 0.05$ ). However, some studies, included in our analysis, used a mixture of textured and smooth-surfaced implants,<sup>7,8,12,18</sup> which might have led to the high heterogeneity ( $I^2 = 60.5\%$ ) in the traditional meta-analysis.

Furthermore, we performed subgroup and sensitivity analyses to explore the heterogeneity. Subgroup analyses showed no significant differences in the CC rate between SG and SP in RCTs and in Asia, which implied that the study design and study region had an impact on the results. However, the sample size was rather small in RCTs (163 cases in total) and in Asia (461 cases in total); thus, the confirmation of the results requires a larger sample size in RCTs. Furthermore, patients in the SG groups had much higher CC rates in American studies (OR 0.38). There was no heterogeneity between the subgroups regarding the publication year ( $I^2 = 0$ ), indicating that changes in surgical skills and implant technology over time did not cause a bias in the results. A leave-one-out sensitivity analysis of the outcomes showed that none of the exclusions altered the results of the previous analyses or reduced their heterogeneity.

The incidence of hematoma formation after breast augmentation was 1-2%.<sup>3,59</sup> In theory, hematoma and seroma rates should be lower with SG placement because that plane is biologically avascular, is easily dissected, and causes less tissue damage. However, our results indicated that the highest incidence of hematoma and seroma occurred with SG placement (with significance), and the lowest occurred with SF placement. Because of the low incidence rates of hematoma and seroma, most studies in our analysis did not identify differences in incidence rates among the different placement techniques with statistical significance. The only exception was the study presented by Li et al., which reported a significant reduction in hematoma in the SF group.<sup>9</sup> The reasons why SG placement could have been associated with unpredictable hemorrhage and inflammatory fluid production, has not been explained by previous studies.<sup>24,60,61</sup> Higher incidence rates of hematoma and seroma in the SG group may be one of the reasons for the higher CC rate in the same group as we reported. No

heterogeneity ( $I^2 = 0-29.1\%$ ) or inconsistency ( $P > 0.05$ ) was detected with these two outcomes.

Dynamic muscle action occurred only in the SP group for anatomical reasons. The “dynamic breast” is of particular concern among bodybuilders with highly developed muscles.<sup>58</sup> In such patients, the pectoralis muscle should be carefully and judiciously released from the lower sternum to minimize the animation deformity. In theory, muscle movement may have led to implant malplacement, subsequent asymmetry, and even implant rupture.<sup>24,30,47</sup> An SP pocket was identified as a significant risk factor for implant rupture in a recent case-control study.<sup>62</sup> In our findings, however, SP placement did not significantly increase the incidence of malplacement, asymmetry, and rupture compared to other groups. Partial SP augmentation (described as “dual plane” by some surgeons),<sup>63</sup> which is more frequently performed than the full SP technique, reduces the risk of subsequent shape distortion.<sup>58,64,65</sup> Other complications including infection, rippling, nipple numbness, and reoperation were not significantly different among the groups.

This research included 19 studies reporting 25,744 cases undergoing primary breast augmentation. The main limitation of our research was the retrospective nature of the included studies ( $n = 13$ ). RCTs are usually the first choice for meta-analyses; however, few RCTs ( $n = 2$ ) were conducted on breast implant augmentation procedures. Relying on observational studies when conducting a meta-analysis is more challenging because of the risk of variation (such as the different properties of implants and breasts) and the inherent bias. Second, four studies received funds from breast implant manufacturers<sup>5,7,18,19</sup> and the authors of three studies were consultants for such companies.<sup>12,21,23</sup> However, the choice of implant placement was not generally affected by corporate interests. Third, our results favored SF placement as a better technique with lower complication rates. However, this result should be interpreted with caution, as there may be some level of publication bias based on the emerging technology preferences in a limited number of studies ( $n = 7$ ) on 779 cases. Despite these limitations, we believe that this research is a valuable addition to the current knowledge of breast augmentation surgery because it represents, to the best of our knowledge, the first overall comparison of the three commonly used placement techniques.

## Conclusions

Breast augmentation surgery shows high satisfaction rates among patients, as reported. However, for this high-volume procedure, an evidence-based approach is vital for reducing the incidence of complications, even by a small percentage. Sound evidence exists showing that SG placement increases the risk of CCs, hematomas, and seromas. Care should be taken when treating patients with risk factors, such as cigarette smoking, smooth-surface implants, prior radiation, prior hematoma, and secondary surgery. SP placement can be used across a broader range of breast types because of its lower complication rates and better implant coverage. The pectoralis muscle should be carefully and judiciously released from the lower sternum to minimize animation deformities in bodybuilders. The SF plane seems to be as safe as the SP plane for controlling complications, although

supporting evidence remains insufficient. Whether SF placement is sufficient to hide implant margins in the upper pole while achieving long-term benefits is a question that requires further research with a larger number of patients.

## Author contributions

All authors approved the final version of the manuscript. J.H.X. and Z.R.S. contributed to the design of the study. J.Q.S., X.C., and Y.J.Y. performed the database searches, screening process, and data extraction. C.Y.C., X.H.L., and Z.Z. performed the meta-analyses. Z.R.S. drafted the manuscript and J.H.X. revised it.

## Declaration of Competing Interest

The authors declare no competing interests. And the funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.09.010.

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