The Use of Platelet-Rich Fibrin in Sinus Floor Augmentation Surgery: a Systematic Review

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ABSTRACT

Objectives: This systematic review aims to critically assess the impact of platelet-rich fibrin on maxillary sinus floor augmentation and outline the specific aspects of new bone formation, bone height, implant stability quotient, and Schneiderian membrane thickness.
Material and Methods: A systematic review and meta-analysis were conducted, analysing studies from MEDLINE (PubMed), the Cochrane Library, and ScienceDirect databases, published from January 29, 2018 until January 29, 2024 that compared maxillary sinus floor augmentation (MSFA) using bone graft material with and without platelet-rich fibrin (PRF). This review focused on patients 18 years and older who undergone MSFA before the dental implant placement. It systematically examined five studies, encompassing randomized controlled trials, and reported on 112 MSFA procedures conducted in 84 patients.
Results: The meta-analysis reveals a marginal significance in new bone formation with PRF, suggesting a trend towards beneficial outcomes that were not statistically significant. No significant impact on bone height was observed. However, a notable improvement in implant stability quotient (ISQ) was recorded, indicating enhanced implant stability with PRF. The Schneiderian membrane thickness did not show significant changes post-treatment with PRF.
Conclusions: While platelet-rich fibrin shows promise in enhancing implant stability, its effects on new bone formation and Schneiderian membrane thickness are inconclusive, highlighting the need for further research. Platelet-rich fibrin did not significantly affect bone height. The findings support platelet-rich fibrin's potential as a beneficial adjunct in maxillary sinus floor augmentation, particularly for implant stability.

Keywords: dental implantation; dental implants; maxillary sinus floor augmentation; platelet-rich fibrin; Schneiderian membrane.

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INTRODUCTION

Implant placement in the posterior maxilla has long posed a significant challenge due to factors such as poor bone quality, ridge atrophy, and sinus floor expansion following tooth extraction [1].

Tatum [2] in 1986 described in detail the maxillary sinus floor augmentation method, where an autogenous bone graft was inserted into the floor of the maxillary sinus using the lateral bone window approach prior to placement of dental implants. The use of autogenous bone grafts is widely accepted as the standard of bone augmentation procedures and essential to facilitate bone integration [2].

In response to promising outcomes reported in the literature, an increasing number of clinicians and patients are turning to implant-supported restorations in the posterior maxilla. Consequently, techniques for maxillary sinus augmentation and augmentation have gained popularity [3].

To address the need for improved maxillary bone height, several surgical techniques have been proposed, with a focus on integrating and placing dental implants. Maxillary sinus floor augmentation often involves the use of biologic or synthetic grafting materials, either independently or in combination with autogenous bone grafts [4].

Various kinds of biomaterials have been utilized for maxillary sinus floor augmentation, encompassing autografts, allografts, xenografts, alloplasts, and growth factors. Determining the optimal graft material has remained contentious. Autogenous bone graft stands as the benchmark in augmentation procedures owing to its osteoinductive, osteogenic, and osteoconductive properties [5,6]. However, utilizing autogenous bone grafts is linked to the risk of donor site morbidity and unpredictable graft resorption [7-9].

In 1970s, Ross et al. [10] made a pivotal discovery regarding the regenerative potential of platelets. They found that platelets contain a variety of growth factors responsible for cell mitosis, increased collagen production, blood vessel growth, and other essential elements for tissue healing and regeneration. One valuable tool that has emerged in implantology is platelet-rich fibrin (PRF). It offers diverse applications, such as enhancing grafts with slow-releasing osteoinductive properties (I-PRF), serving as a complete substitute for grafted bone (solid PRF), or acting as a membrane in various regenerative procedures, including maxillary sinus membrane grafting and connective tissue grafting. Additionally, PRF can be blended with bone graft materials to improve outcomes [11]. Studies have indicated that PRF exhibits a superior affinity for osteoblasts, suggesting that it exerts a more robust and enduring effect on the differentiation and proliferation of these cells compared to platelet-rich plasma (PRP) [12,13].

The combined application of PRF and autologous bone grafts has demonstrated promising outcomes, characterized by reduced bone resorption, and augmented bone volume and quality [5,14].

The purpose of this systematic literature review is to critically assess the impact of platelet-rich fibrin on maxillary sinus floor augmentation and outline the specific aspects of new bone formation, bone height, implant stability quotient, and Schneiderian membrane thickness.

MATERIAL AND METHODS

Protocol and registration

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement criteria were followed for guiding this systematic review [15]. According to the database search tool applied, research publications were found in databases such as MEDLINE (PubMed), the Cochrane Library, and ScienceDirect.

Focus question

The following focus question was framed according to the problem, intervention, comparison, and outcome (PICO) process (Table 1): What is the effect of PRF on maxillary sinus floor augmentation?

Information sources

The literature was sourced from MEDLINE (PubMed), the Cochrane Library, and ScienceDirect

Table 1. PICO framework

Component	Description
Population (P)	Patients who underwent posterior maxillary sinus floor augmentation for dental implants
Intervention (I)	Maxillary sinus floor augmentation with bone graft material and platelet-rich fibrin
Comparison (C)	Maxillary sinus floor augmentation with bone graft alone
Outcome (O)	New bone formation, bone height, implant stability quotient, bone density, Schneiderian membrane thickness

Table 2. Search and screening

First concept	((": platelet rich fibrin "[Mesh]) OR "Maxillary sinus floor augmentation "[Mesh]) OR "Dental Implants"[Mesh]
Second concept	(("Platelet Rich Fibrin "[Mesh]) OR " Maxillary Sinus Floor Augmentation" [Mesh]) OR "Dental Implants"[Mesh] OR "Bone Graft" (TW)
Third concept	(("Platelet-Rich Fibrin "[Mesh]) And "Sinus Floor Augmentation"[Mesh]) And "Dental Implants"[Mesh] And" Bone Graft" [Mesh] (TW)
Fourth concept	(("Platelet-Rich Fibrin "[Mesh]) And ("Maxillary Sinus Floor Augmentation "[Mesh])

TW = text word.

databases. Filters were used to ensure that the studies included were in English and were published between January 2018 and January 2024. The reference lists of the chosen papers were manually searched for additional related publications. Grey literature, letters, editorials, PhD thesis, abstract case series, case reports, cross-sectional studies, reviews, unpublished literature as well as other databases were not included in the search strategy of the present systematic review.

Search

Research publications were searched from January 29, 2018 until January 29, 2024 based on Preferred reporting items for systematic reviews and meta-analysis (PRISMA) [15] guidelines in MEDLINE (PubMed), the Cochrane Library, and ScienceDirect databases using the database's search tool. Articles were chosen according to the inclusion and exclusion criteria. Titles and abstracts were initially screened, and full-text papers were then separated for review. The use of different combinations of keywords was used: platelet-rich fibrin, maxillary sinus floor augmentation, bone graft, dental implants (Table 2).

Selection of studies

The titles of the identified reports were independently screened by two reviewers (O.B. and E.L.) based on the inclusion criteria. A third reviewer (G.J.) checked possible mistyping. After evaluation of summary the title indicated that the study was relevant to the search topic. A full-text analysis was performed for those articles that met the selection criteria. The reviewers checked the results separately and resolved disagreements by discussion with the senior investigator (G.J.). Reviewers were calibrated by calculating Cohen's kappa coefficient (κ) values to ensure inter-rater reliability for abstract and title, selecting 10% of the publications.

Types of publication

This systematic review covered human studies that were published in the English language.

Types of studies

The review included all human randomized clinical trials, from January 2018 until January 2024 on patients who had done maxillary sinus floor augmentation before dental implant placement which are 18 years and older. Articles with patients that underwent maxillary sinus floor augmentation with PRF only.

Type of population

Healthy adult patients without any systematic disease maxillary sinus floor augmentation in the posterior zone.

Inclusion and exclusion criteria for the study selection

Inclusion criteria

The following inclusion criteria were applied to retrieved bibliographic sources for inclusion in this systematic literature review:

- Articles written in English from January 2018 to January 2024.
- Adult patients 18 years and older.
- Patients who underwent posterior maxillary sinus floor augmentation for dental implants using bone graft material.
- Patients who underwent posterior maxillary sinus floor augmentation for dental implants using bone graft material and PRF.
- Clinical trials.
- Randomized controlled trials.
- Prospective and retrospective cohort studies and case-control studies.
- Full text articles.
- Studies with follow-up.

Exclusion criteria

The following exclusion criteria were applied:

- Systemic review or literature review.
- Clinical studies on patients with less than 10 patients.
- Studies other than human.
- Anterior maxillary sinus floor augmentation.

Sequential search strategy

The methodology for this systematic review was executed in a series of distinct stages. Initially, a search was conducted to identify articles using specific keywords previously mentioned. Following this, any duplicates found across various databases were removed. Title and abstract screenings were performed using an online screening tool Rayyan® (Qatar Computing Research Institute; HBKU, Doha, Qatar [www.rayyan.ai]). Next, each publication was subjected to a detailed assessment to evaluate its relevance and conformity with the established selection criteria, which was based on an analysis of the full text. Publications that successfully met these criteria were subsequently included in this systematic review.

Data extraction

According to the aim and tasks of the review in the form of variables, data extracted from the articles were. The data items extracted are listed below.

Data items

The data was extracted to previously defined templates according to the aims of the current review:

- First author and publication year - revealed the author and the publication year.
- Study design - indicated the study design.
- Total number of patients - indicated the number of the investigated subjects.
- Mean age - indicated mean age of investigated patients.
- Group of study - indicated test and control groups.
- Type of bone graft - type of bone graft material.
- Type of PRF - indicated PRF and L-PRF.
- Maxillary sinus floor augmentation in the posterior region - indicated sinus floor augmentation method and localization.
- Maxillary sinus floor augmentation with PRF only - indicated that sinus floor augmentation was performed using only PRF.
- Outcome measure - new bone formation, bone height, ISQ, bone density, Schneiderian membrane thickness.
- Follow-up examination - indicates the outcomes follow-up period in months.

The risk of bias assessment

The methodological quality of the studies that met the inclusion criteria was assessed by two researchers using The Joanna Briggs Institute (JBI) Critical Appraisal Checklist for randomized controlled trials (RCT) [16] (Table 3). The RCT checklist contains 13 assessment criteria. Every criterion was given a rating of 'yes', 'no', 'unclear' or 'not applicable. Methodological quality was categorized

Table 3. The Joanna Briggs Institute Critical Appraisal Checklist for randomized controlled trials (RCT)

Question number	Defined question
Q1	Was true randomization used for assignment of participants to treatment groups?
Q2	Was allocation to treatment groups concealed?
Q3	Were treatment groups similar at the baseline?
Q4	Were participants blind to treatment assignment?
Q5	Were those delivering treatment blind to treatment assignment?
Q6	Were outcomes assessors blind to treatment assignment?
Q7	Were treatment groups treated identically other than the intervention of interest?
Q8	Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed?
Q9	Were participants analysed in the groups to which they were randomized?
Q10	Were outcomes measured in the same way for treatment groups?
Q11	Were outcomes measured in a reliable way?
Q12	Was appropriate statistical analysis used?
Q13	Was the design of trial appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

as follows: "high risk of bias", when the study scored up to 49% of positive answers; "moderate risk of bias", when study scored between 50 and 69% of positive answers; "low risk of bias", when study reached more than 70% of favourable answers.

Synthesis of the results

Relevant data points from the aforementioned studies were systematically collected and tabulated into the following fields: year of publication, study design, patients, study group, bone graft, PRF type, area of augmentation, age, outcome of each study, new bone formation, bone height, implant stability quotient (ISQ) and Schneiderian membrane thickness.

Statistical analysis

The level of agreement between the two raters in selecting abstracts and studies to be read in full-text were measured using Cohen's kappa coefficient (κ). The meta-analysis utilized the Cohen's d measure within a random-effects model. This approach accounts for both the within-study variance and the between-study variance, offering a more nuanced view of the treatment's effectiveness across different research contexts. The effect size provides a numerical representation of the magnitude of the treatment's impact, with confidence intervals offering a range within which the true effect size is likely to fall.

RESULTS

Study selection

During the database exploration phase, the search across MEDLINE (PubMed), ScienceDirect, and the Cochrane Library identified 2630, 2322, and 2944 articles respectively, adding up to an initial tally of 7896 potentially relevant articles. Post elimination of 3769 duplicate entries, 4127 articles remained under consideration. The next phase of scrutiny led to the exclusion of 2430 articles due to reasons such as being published more than 6 years ago, written in languages other than English, on animal research, or being review articles. An additional 1688 articles were disregarded after evaluating their titles and abstracts for relevance, narrowing the selection down to 9 articles for full review based on inclusion and exclusion criteria. Ultimately, 5 records were meticulously reviewed and met the stringent criteria for inclusion in this systematic review and reported on 112 MSFA procedures conducted in 84 patients (Figure 1). The level of agreement between two authors (O.B. and E.L.) in the selection of abstracts was measured at $\kappa = 0.86$.

Exclusion of studies

Four articles were not included in this review because of the materials used by test groups [17-19], one article with 3 groups of study [20].

Quality assessment of the included studies

The quality of the included studies is summarized in the Table 4. Three studies [17-19] were characterized as moderate risk of bias and two studies [20,21] were characterized as low risk of bias.

Study characteristics

This review systematically examined five studies, encompassing RCT, and reported on 112 maxillary sinus floor augmentation procedures conducted in 84 patients. Four of the studies [17-20] utilized deproteinized bovine bone mineral (DBBM) in their MSFA procedures. Shiezadeh et al. [21] opted for an allograft material for MSFA. Three of these articles [17,18,20] incorporated L-PRF in the test groups, whereas two studies [19,21] used PRF for their test groups in MSFA scenarios. The MSFA procedures across all five articles were performed in the posterior region of the maxilla. The characteristics of the studies included are detailed in Table 5.

Outcome characteristics

All the 5 studies are compared the effect of PRF combine with bone graft to bone graft only on the MSFA. Table 6 describes the effect of the test and control groups on: new bone formation, bone height, ISQ, and Schneiderian membrane thickness.

New bone formation

de Almeida Malzoni et al. [20] showed that the experimental group using L-PRF + DBBM had significantly higher new bone formation 18.35 (SD 5.62)% compared to the control group using DBBM alone 12.95 (SD 5.33)% and the P-value was 0.0135. Shiezadeh et al. [21] employing PRF showed a new bone formation percentage of 43.25% in Group A compared to 38.25% in Group B (without PRF), indicating a non-significant trend towards improved outcomes with PRF (P = 0.087).

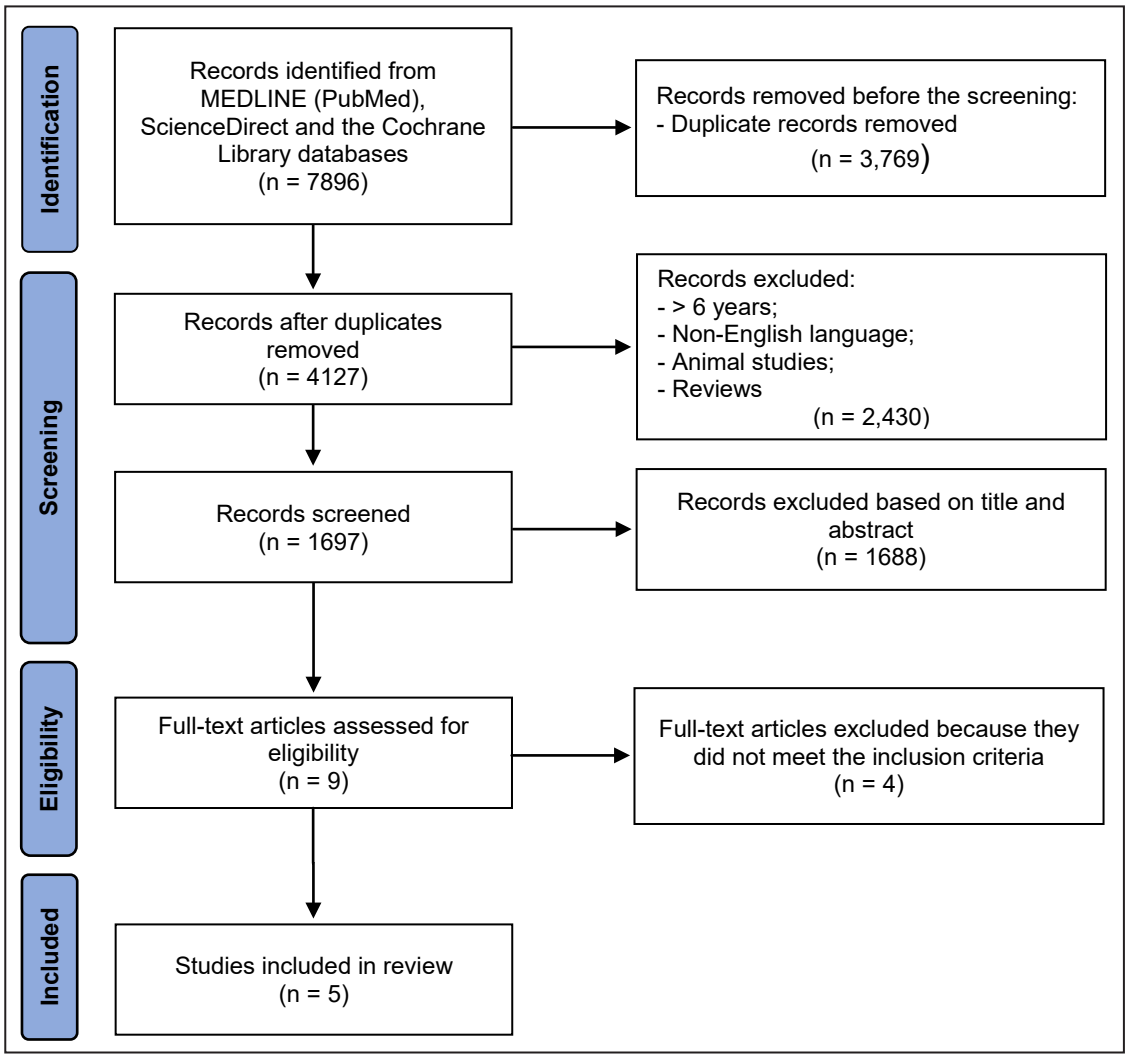

Figure 1. PRISMA flow diagram summarizing the search strategy and study selection.

Table 4. Results of randomized controlled trials from the Joanna Briggs Institute Critical Appraisal Checklist

Study	Year of publication	Study design	Checklist												
			Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Nizam et al. [17]	2018	Randomized controlled trial	+	-	+	-	-	+	-	+	+	+	-	+	-
Pichotano et al. [18]	2019	Randomized controlled trial	+	-	+	-	-	+	-	-	+	+	+	+	?
Salimzade et al. [19]	2022	Randomized controlled trial	+	-	+	-	-	+	-	+	+	+	-	+	+
de Almeida Malzoni et al. [20]	2023	Split-mouth randomized controlled trial	+	-	+	-	-	+	-	+	+	+	+	+	+
Shiezadeh et al. [21]	2023	Randomized controlled trial	+	-	+	-	-	+	-	+	+	+	+	+	+

? = unclear; + = yes; - = no.

Nizam et al. [17] compared the study group (with PRF) and the control group (without PRF), where the percentages of new bone formation were almost identical 21.38% and 21.25%, respectively, indicating a significant difference at a P value of 0.96. Pichotano et al. [18] demonstrated a significant difference in new bone formation with the test group (with PRF) showing a higher percentage 44.58% compared to the control group 30.02% with a P-value of 0.0087 (Table 6).

Table 5. Characteristics of included study

Study	Number of patients	Age (years)	Group of study		Bone graft	PRF type
			Test group	Control group		
Nizam et al. [17]	13	49.92 (SD 10.37)	MSFA DBBM + L-PRF (n = 13)	MSFA DBBM alone (n = 13)	DBBM	L-PRF
Pichotano et al. [18]	12	54.17 (SD 6.95)	MSFA DBBM + L-PRF (n = 13)	MSFA DBBM alone (n = 13)	DBBM	L-PRF
Salimzade et al. [19]	15 (30 MSFA)	53.6 (SD 0.18)	MSFA PRF with bone graft (n = 15)	MSFA bone graft with membrane (n = 15)	DBBM	L-PRF
de Almeida Malzoni et al. [20]	24	54.08 (SD 10.07)	MSFA L-PRF with bone graft (n = 24)	MSFA only bone graft (n = 12)	DBBM	L-PRF
Shiezadeh et al. [21]	20	Group with PRF: 42.7 (SD 5.79); Group without PRF: 40.3 (SD 4.83)	MSFA PRF with bone graft (n = 10)	MSFA-only bone graft (n = 10)	Allograft	PRF

MSFA = maxillary sinus floor augmentation; DBBM = deproteinized bovine bone mineral; PRF = platelet rich fibrin; L-PRF = leukocytes platelet rich fibrin; n = number of maxillary sinus floor augmentation procedures; SD = standard deviation.

Table 6. Outcome variables of included studies

Study	New bone formation	Bone height (mm)	ISQ	Schneiderian membrane thickness (mm)	Follow-up
Nizam et al. [17]	Test group (with PRF) 21.38 (SD 8.78)% vs. Control group (without PRF) 21.25 (SD 5.59)% (P = 0.96)	Test group (with PRF) 13.6 (SD 1.09) vs. Control group (without PRF) 13.53 (SD 1.2); (P = 0.88)	NR	NR	6 months follow-up
Pichotano et al. [18]	Test group (with PRF) 44.58 (SD 13.9)% vs. Control group (without PRF) 30.02 (SD 8.42)% (P = 0.0087)	Residual graft in the control group 13.75 (SD 9.99)% vs. Test group 3.59 (SD 4.22) (P = 0.0111)	Test group 60.9 (SD 9.35) vs. Control group 75.13 (SD 5.69) (P = 0.0003)	NR	Immediately after implant placement, 4 and 8 months after sinus augmentation
Salimzade et al. [19]	NR	NR	NR	Test group: baseline 2.17, after 2 months 1.77 vs. Control group: baseline 1.85, after 2 months 2.54; (P = 0.2)	2 months follow-up
de Almeida Malzoni et al. [20]	Test group (L-PRF + DBBM) 18.35 (SD 5.62)% vs. Control group (DBBM) 12.95 (SD 5.33)% (P = 0.0135)	Test group: DBBM4 0.58 cm^3 - DBBM8 0.72 cm^3 vs. Control group: mean t1 - t2 0.48 cm^3	Test group L-PRF + DBBM4 to L-PRF + DBBM8 72.19 (SD 5.43) vs. Control group 75.56 (SD 4.6) (P ≤ 0.0001)	NR	1-year follow-up
Shiezadeh et al. [21]	Group A (with PRF) 43.25% vs. Group B (without PRF) 38.25% (P = 0.087)	Group A (with PRF) 2.74 mm vs. Group B (without PRF) 2.72 mm	NR	NR	Average of 33 months follow-up

ISQ = implant stability quotient; NR = not reported; PRF = platelet rich fibrin; L-PRF = platelet rich fibrin; DBBM = deproteinized bovine bone mineral; SD = standard deviation.

Bone height

de Almeida Malzoni et al. [20] in their study revealed that bone height increase in the control group was 0.48 cm³. In the test group, DBBM4 resulted in a bone height of 0.58 cm³ and DBBM8 in 0.72 cm³. The article does not specify a P-value directly related to bone height differences between these groups. In study of Shiezadeh et al. [21] the bone height in Group A (with PRF) was 2.74 mm compared to 2.72 mm in Group B (without PRF). This comparison indicates a minimal difference, with the P-value not explicitly stated for bone height. Nizam et al. [17] reported that the bone height was 13.6 mm in the study group (with PRF) compared to 13.53 mm in the control group (without PRF). The P-value for this comparison was 0.88, indicating no statistically significant difference in bone height between the groups. Pichotano et al. [18] study does not provide direct measurements of bone height increase but focuses on the residual graft material, with the test group showing significantly less residual graft 3.59 (SD 4.22)% compared to the control group 13.75 (SD 9.99)%, with a P-value of 0.0111 for this comparison (Table 6).

ISQ

de Almeida Malzoni et al. [20] reported a comparison of ISQ between the experimental group (L-PRF + DBBM) and the control group (DBBM), where ISQ values were recorded as 72.19 and 75.56, respectively. The P-value for this comparison was less than 0.0001, indicating a statistically significant difference favouring the test group. Pichotano et al. [18] indicate a comparison between the control group and the test group, with the control group having an ISQ of 75.13 (SD 5.69) and the test group an ISQ of 60.9 (SD 9.35). P-value for this comparison is 0.0003, suggesting a statistically significant difference between the two groups (Table 6).

Schneiderian membrane thickness

Schneiderian membrane thickness estimated by Salimzade et al. [19] in the control group, the baseline value was 1.85 mm and after 2 months it increased to 2.54 mm. In the test group, the baseline value was 2.17 mm, and after 2 months, it decreased to 1.77 mm. The P-value was relatively high 0.2, indicating the results may not be statistically significant, and any observed differences might be due to random variation rather than a real effect (Table 6).

Meta-analysis

A meta-analysis was only performed when there were similar comparison studies with identical outcome parameters. However, the included studies revealed significant differences between the various assessment criteria. Thus, given the heterogeneity of the data, a meta-analysis could only be performed on new bone formation and bone height.

The forest plot (Figure 2) combines the results from three studies, with the overall effect size slightly favouring a positive outcome but not definitively significant. For the new bone formation evaluation the Cohran's Q was 6.14 and P-value 0.05, 95% CI, that mean that there were not significant changes between the groups in new bone formation (Figure 2).

Figure 3 shows the meta-analysis for bone height, where the overall effect size was -0.005 and the overall Cohen's d was -0.00, with a very high P value of 0.984, indicating that there was no statistically significant difference in bone height because of the treatment.

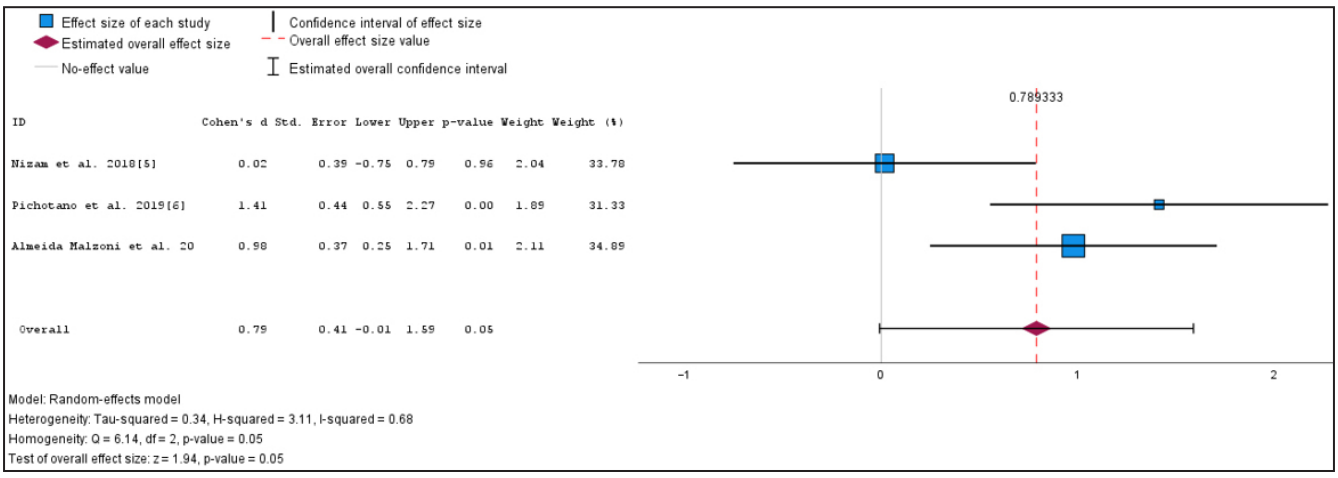

Figure 2. Forest plot of new bone formation.

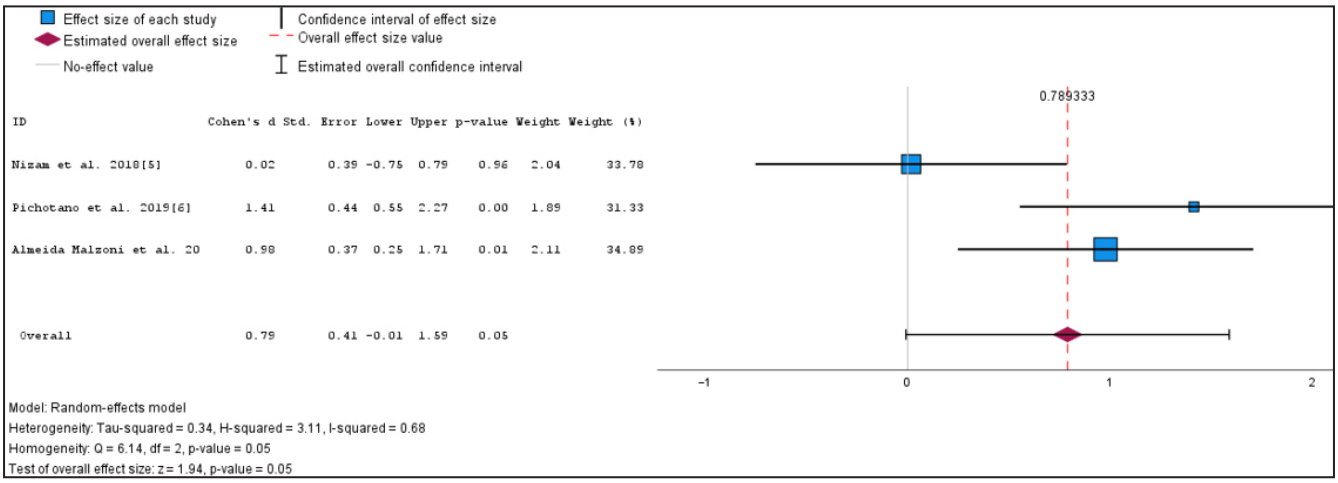

Figure 3. Forest plot of bone height.

DISCUSSION

This systematic review examines the effect of PRF on MSFA before dental implantation. The following parameters were examined: new bone formation, bone height, ISQ, bone density, and Schneiderian membrane thickness during MSFA with or without PRF. Studies within this review underscore the presence of crucial components in PRF, including fibrin matrix, platelets, growth factors, leukocytes, and stem cells [22]. These elements collectively contribute to the efficacy of PRF in various regenerative processes. The prevailing focus of clinical research on PRF in implantology centres is around enhancing clinical outcomes in sinus floor augmentations. PRF is particularly investigated as a standalone grafting material, often employed simultaneously with implant placement [23].

The five articles encompassed in this study collectively demonstrate the effectiveness of PRF in MSFA.

The varied results across these studies underscore the complexity of bone regeneration and the potential role of PRF. While de Almeida Malzoni et al. [20] and Pichotano et al. [18] provide strong evidence supporting the beneficial effects of PRF in enhancing new bone formation, Shiezadeh et al. [21] and Nizam et al. [17] present more nuanced outcomes, suggesting that the effectiveness of PRF might be influenced by specific conditions or variables not fully explored in these studies. According to meta-analysis of new bone formation indicated a marginal significance level with a P-value of 0.052. Since this value is slightly above the conventional threshold, it suggests that the difference in new bone formation observed due to the treatment with PRF might not be considered statistically significant.

The collective findings from these studies suggest a nuanced understanding of factors influencing bone height increase. The use of DBBM appears to enhance bone height more effectively than the control treatments, as indicated by the results from de Almeida Malzoni et al. [20]. This could imply that the osteoconductive properties of DBBM provide a scaffold that promotes bone growth more effectively than other materials or the absence of such materials. In the meta-analysis concerning bone height, the overall effect size was -0.005, Cohen's d overall -0.00 with a very high P-value of 0.984, which indicates there was no statistically significant difference in bone height as a result of the treatment.

In contrast, the use of PRF, as explored by Shiezadeh et al. [21] and Nizam et al. [17] does not show a significant impact on bone height increase. This could be due to the role of PRF primarily in enhancing healing and not necessarily in providing a structural basis for bone growth. The minimal differences observed, and the lack of statistical significance suggest that while PRF may have benefits in wound healing or reducing inflammation, its direct contribution to bone height may be limited.

The significance of residual graft material reduction in the test group, as reported by Pichotano et al. [18] suggests an interesting angle for future research. The correlation between lower residual graft material and possibly more effective bone regeneration or remodelling highlights the complexity of bone healing processes and the potential for certain treatments to facilitate more natural bone structure restoration.

The findings from these studies highlight the importance of material choice and treatment method in achieving optimal implant stability. The significant improvement in ISQ values with the use of L-PRF in combination with DBBM suggests that

this combination not only promotes bone growth but also enhances the stability of the implant in the newly formed bone. The mechanism behind this could involve the synergistic effect of L-PRF's growth factors and DBBM's osteoconductive properties, facilitating faster and stronger bone integration with the implant.

On the other hand, the reduced ISQ values in the test group reported by Pichotano et al. [18] raise questions about the materials or methods used in this group. Without specific details on the treatment differences, it's challenging to pinpoint the cause of reduced stability. However, it suggests that not all treatment combinations or materials yield the same positive effect on implant stability, emphasizing the need for careful selection based on evidence of effectiveness.

The increase in membrane thickness in the control group could be interpreted in several ways. It may reflect a natural variability in membrane thickness over time, or it could indicate a response to physiological factors or interventions that were not controlled for in the study. Without statistical significance, it is challenging to draw concrete conclusions about the clinical relevance of this increase.

The decrease in thickness in the test group is intriguing, as it suggests that the intervention might have had a potential effect on reducing membrane thickness. However, the lack of statistical significance (P-value of 0.2) cautions against over interpreting this result. It's possible that the intervention could influence membrane thickness in a beneficial way, but the evidence from this study alone is insufficient to confirm such an effect.

Recent investigations have unveiled encouraging results concerning the use of PRF in facilitating bone regeneration. Mazor et al. [24] and Diss et al. [25] has shown that in the context of direct sinus lifts using the lateral window approach, initial postoperative panoramic X-rays conducted 8 to 10 days following the procedure displayed implants positioned within the sinus cavity without dense tissue envelopment, with the PRF filler appearing radiolucent. However, at the six-month mark post-sinus lift, the area around the implants in the sinus cavity was characterized by dense, bone-like tissue. Radiological evaluations consistently demonstrated significant bone augmentation, with gains ranging from 7 to 13 mm using longer implants. In this methodology, implants acted as stabilizers to demarcate the required bone volume, with the shape of the implant not affecting the new sinus floor's location. Furthermore, in the study by Diss et al. [25] that applied the bone added osteotome sinus floor augmentation (BAOSFE) technique, PRF was employed as a grafting substance. Their results showed a bone increase of 5.8 mm and 5.2 mm on the mesial and distal sides of the implant, respectively. Although the findings from both studies were akin, the significance of the research outcomes was notably profound.

Limitations

This systematic review possesses certain limitations that merit consideration. Primarily, variations exist in the maxillary sinus floor augmentation technique, diverse dental implant types employed, and various conditions that could impact the outcomes. The acknowledgment of limitations in the studies includes factors such as sample size. Additional research is warranted to conclusively establish and substantiate the efficacy of PRF in maxillary sinus floor augmentation.

Looking ahead, it is imperative to recognize the evolving landscape of regenerative dentistry and the continuous refinement of techniques and materials used in maxillary sinus floor augmentation. While the studies reviewed here contribute valuable insights, they also underscore the need for more comprehensive investigations. Future research endeavours could delve into exploring the optimal combination of PRF with other biomaterials or growth factors, aiming to enhance its efficacy in bone regeneration. Additionally, a deeper understanding of the specific conditions that may influence the outcomes of PRF in MSFA is essential. Investigations into the long-term effects, such as the stability of newly formed bone and the durability of implant integration, could shed light on the sustained benefits of PRF in clinical practice. Furthermore, considering the dynamic nature of dental implant technology, future studies may also explore the potential synergies between PRF and emerging implant designs or surfaces, potentially unlocking novel approaches for achieving superior clinical outcomes. As the field progresses, embracing a multidisciplinary approach that integrates insights from biomaterial science, molecular biology, and clinical practice will be crucial in advancing our understanding and harnessing the full regenerative potential of PRF in the context of maxillary sinus floor augmentation.

CONCLUSIONS

1. New bone formation with the use of platelet-rich fibrin is not statistically significant by conventional standards.

2. There is no demonstration of a statistically significant impact on increasing bone height.
3. The implant stability quotient demonstrates a significant positive impact of platelet-rich fibrin when used in conjunction with maxillary sinus floor augmentation.
4. The impact of platelet-rich fibrin on Schneiderian membrane thickness does not demonstrate significant changes.

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