Review Article

Application of Dentine Particles in Combination with Platelet-Rich Fibrin for Alveolar Ridge Preservation: A Systematic Review

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ABSTRACT

Alveolar ridge preservation (ARP) reduces post-extraction bone resorption and promotes bone regeneration. Dentine particles (DP), derived from extracted teeth, contain type I collagen and growth factors that support bone healing, while platelet-rich fibrin (PRF) enhances wound healing. This systematic review evaluates the clinical and radiographic outcomes from randomized controlled trials (RCTs) using DP and PRF for ARP. RCTs involving human subjects treated with DP and PRF for ARP were included, focusing on clinical and radiographic outcomes. Animal studies and non-randomized trials were excluded. Searches were conducted across five databases (PubMed, Scopus, Web of Science, Cochrane, Embase), and risk of bias was assessed based on randomization, allocation concealment, and blinding. Five RCTs with at least six participants met the inclusion criteria. DP and PRF showed significant improvements in bone density, with the test group showing 26.31 ± 0.55 compared to 24.98 ± 0.74 in controls. Ridge width and height resorption were also reduced in the DP and PRF groups. Regardless of preparation method, DP demonstrated positive clinical and radiographic outcomes. However, variability in study design led to moderate risks of bias, particularly in randomization and blinding. DP and PRF show promising results for ARP, especially in bone regeneration. However, further studies with larger sample sizes, standardized outcome measures, and longer follow-up periods are needed to address gaps in soft tissue outcomes and long-term implant stability.

Keywords: Alveolar ridge preservation (ARP), dentine particles (DP), platelet-rich fibrin (PRF), platelet concentrate, bone regeneration

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1.0 Introduction

Physiological bone resorption is a typical sequela after dental extraction. The dimensional changes of the alveolar ridge after extraction are relatively foreseeable over time (1); physiological bone resorption caused around 11-22% of changes in the vertical dimension and 32% in the horizontal dimension during the three months following extraction (2,3). This may affect the placement of implants, which may potentially develop into bone defects in the future. As a result, long-term implant stability and aesthetics may be affected, and additional reconstructive surgery may be required (2).

Alveolar ridge preservation (ARP) successfully suppresses physiological bone resorption and preserves the socket (4–7). Various methods of bone grafting are involved in ARP treatment (8,9). These methods include bone grafts of autografts, alloplasts, allografts, and xenografts in the presence of bioresorbable or non-resorbable membranes (5,6,10–16). These graft placements have been shown to enhance the stimulation of osteoblastic activity, followed by bone formation (17). However, bone grafting may increase the risk of infection, and the grafting material will disintegrate slowly, affecting the healing of soft and hard tissues in the extraction socket (6). On the other hand, allografts may increase the risk of rejection and the transmission of viral infections (18).

Human dentine has been discovered as a relatively suitable replacement for bone graft material (19). Human dentine soluble proteins are bioactive proteins required for bone development, which incorporate a variety of growth factors. This bioactive protein is an acid-insoluble collagen-binding bone morphogenetic protein that belongs to the transforming growth factor-β (TGF-β) superfamily (20). Furthermore, because of its non-immunogenicity, good mechanical characteristics and potentially abundant dentinogenetic components, an acellular dentine matrix is likely suited as a scaffold for tooth tissue engineering (21). Moreover, extracted teeth are readily obtained from patients themselves. Thus, this method provides a non-invasive, safe treatment with a low risk of infection, while rejection or hypersensitivity is unlikely to occur (21).

In addition, autologous platelet-rich fibrin (PRF) has been investigated for use in ARP. PRF is a fibrin-based biomaterial adjunct for micro-vascularisation and wound healing (22). It was developed by Choukroun and co-workers in 2001 and is the second generation of platelet concentrates (6). PRF is a source of growth factors and cytokines, consisting of a polymerised fibrin matrix that combines the platelets, cytokines, and leukocytes in a trimolecular structure. These characteristics are necessary for wound healing, in which angiogenesis, immunological control, stem cell regulation, and epithelialisation are required (23).

Apart from that, previous studies have indicated that soft tissue thickness tends to increase following tooth extraction in the esthetic zone due to the resorption of the underlying bone. Three-dimensional analyses have shown that sites with a thin alveolar bone phenotype (defined as a thickness of 1 mm or less) are more prone to resorption compared to sites with a buccal bone plate thicker than 1 mm. Additionally, in cases with a thin bone biotype, the labial gingiva tends to increase in thickness. This phenomenon is partially attributed to the activity of fibroblasts and myofibroblasts. Fibroblasts migrating to wound areas experiencing vertical bone resorption tend to differentiate into myofibroblasts to stabilize the wound margins, ultimately leading to increased gingival thickness at the extraction sites (24).

Several studies have demonstrated the potential of leukocyte-platelet rich fibrin

(L-PRF) for promoting bone and soft tissue regeneration without eliciting inflammatory reactions, which can be utilized alone or in combination with graft materials, facilitating haemostasis, angiogenesis, and bone regeneration (25,26). The central hypothesis of this study is that combining dentine particles (DP) and PRF after tooth extraction could enhance graft particle stability and accelerate new bone formation. To the authors' knowledge, no previous research has explored the effects of combining DP and PRF in alveolar ridge preservation.

Thus, this study aims to provide an overview of the usage of DP and PRF in bone regeneration and to explore the potential of these two materials as an alternative option for improving ARP outcomes.

2.0 Materials and Methods

Five electronic databases—PubMed, Scopus, Web of Science, Google Scholar and Cochrane Library—were searched from January 2022 to August 2022. The MeSH terms used were "Alveolar ridge preservation (ARP)", "autologous dentine particles", "platelet-rich fibrin", "PRF", and "autogenous dentine*". Both MeSH and entry terms were correctly adapted according to the syntax rules for each database using Boolean operators (OR, AND) to combine terms. A manual search in the references of the listed papers was conducted to identify further citations. A search alert was activated in each database to get updates when new articles met our search criteria.

All the citations found on databases and by hand were entered into reference management software (EndNote 20). Duplicates were manually and automatically excluded. Titles, abstracts and full text were independently analysed for eligibility by two review authors (FK and EN). Any disagreements between the two reviewers were typically resolved through discussion to reach a consensus. If consensus could not be achieved after discussion, a third reviewer or adjudicator was involved to make an independent assessment and provide a final decision, ensuring the resolution of discrepancies.

The modified Cochrane Collaboration tool is used to assess the risk of bias in randomized controlled trials. Bias is evaluated for each trial element across five key domains: selection, performance, attrition, reporting, and other potential sources of bias. Each element within these domains is assigned a judgment of "high," "low," or "unclear" risk of bias, based on the trial's methodology and execution (27).

2.1 Protocol

This review employed the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) statement (Figure 1) (28). A detailed protocol following the population, intervention, comparison, and outcome (PICO) system was designed to answer the question: Can a socket with alveolar ridge deficiency be successfully treated with a bone graft consisting of a combination of PRF and autogenous teeth? Additionally, the study protocol was registered on PROSPERO, an international prospective register of systematic reviews, with the registration number CRD42022336547.

2.2 Selection criteria

An electronic search of English literature was carried out in January 2022 in Medline/PubMed, Cochrane, Scopus, Web of Science and Google Scholar databases. Restricting the search to English language studies in a systematic review can be justified for several reasons which includes the feasibility and resources as translating non-English studies requires significant time, expertise, and financial resources. Publications between 2017 and 2022 were included. Choosing a specific date range

can significantly impact the relevance and applicability of the findings, including technology advancement, avoiding historical bias and availability of data.

2.3 Search methods

A combination of the following keywords was used in the in all five databases Medline/PubMed, Cochrane, Scopus, Web of Science and Google Scholar: (autologous Dentine particles and Platelet rich-fibrin) OR (autogenous dentine* and PRF). As a result, six articles from Medline/PubMed, four from Cochrane, four from Scopus, four from Web of Science and 434 from Google Scholar were analysed.

2.4 Inclusion criteria

The literature search was limited to dental journals published in the English language. The inclusion criteria were human studies, including at least five patients per study, wherein the surgical sites were examined by clinical and radiographic evaluation. Randomised clinical studies were considered in this study if the interventions were carried out in the test group using autogenous DP and PRF to preserve sockets or implants, and the control group remained untreated or was treated with either DP or PRF, but not both, with modified Cochrane Collaboration tool is used to assess the risk of bias. Randomized controlled trials (RCTs) are chosen as it is considered as gold standard for evaluating the effectiveness of treatments. This is because RCTs minimize bias through randomization and control groups, providing stronger, more reliable evidence of cause-and-effect relationships. While a sample size of five patients is undeniably low, it is a reflection of the limited research available in this niche area. The inclusion of these studies ensures that the review has a sufficient number of studies to analyze, enabling a more comprehensive synthesis of existing data. Nonetheless, this highlights the urgent need for future research to prioritize larger sample sizes and standardized methodologies to strengthen the evidence base for DP and PRF in ARP. The authors chose to compare DP/PRF with untreated controls and individual treatments aiming to isolate the specific effects of the combined treatment. This design allows for a clearer understanding of how each component contributes to outcomes such as bone regeneration or healing. Including both treatments together could complicate the interpretation of results, making it difficult to determine the contribution of each component.

The primary focus may be to evaluate whether the combination of DP and PRF produces a synergistic effect that enhances clinical outcomes compared to each treatment alone. By excluding the combined treatment group from the comparison, researchers can assess whether the outcomes are significantly better than those achieved with either DP or PRF alone. The authors may have opted for a simpler design to reduce complexity and enhance the clarity of their findings. Including too many groups can lead to confounding factors that complicate the analysis.

The authors may have intended to specifically investigate the effects of DP/PRF in relation to conventional treatments, which allows them to concentrate their analysis on those specific interventions rather than introducing additional variables. This focus can make it easier to conclude relevant to practitioners who may be considering DP/PRF. By limiting the comparison to treatments more closely aligned in their biological behavior, the study can provide clearer insights. Including additional treatment groups, like xenografts or synthetic grafts, would expand the scope of the research significantly. The authors may have wanted to maintain a more focused investigation

within a specific context, thereby limiting the potential for confounding factors that could arise from including various graft materials.

2.5 Exclusion criteria

Longitudinal studies were excluded, including cohorts, case reports, case series, pilot studies and review papers. Studies on animals and in vitro studies were excluded, as well as studies with only histological evaluations. Longitudinal studies, while valuable, are often observational and may be prone to confounding variables and biases, limiting their ability to definitively establish causality. Apart from that, along with case reports, and case series do not typically include randomization or control groups, making it difficult to eliminate confounding factors that might influence outcomes.

Furthermore, standardization of results remains to be our priority and longitudinal studies often report on wide range of outcomes over different timeframes, which can make it difficult to synthesize the data in this systematic review. By excluding these study types, the authors aim to focus on higher-quality evidence from RCTs. Excluding studies with only histological evaluations or animal/in vitro studies ensures the review focuses on clinical outcomes relevant to human patients. Animal and in vitro studies provide important mechanistic insights but may not translate directly to clinical practice. Meanwhile for pilot studies are usually small and exploratory in nature, designed to test feasibility rather than provide conclusive evidence. Similarly, review papers summarize existing literature but do not provide original data. Including these types of studies might dilute the strength of evidence and make it harder to draw definitive conclusions. While histological studies provide valuable insights into tissue-level changes, the focus of many systematic reviews is on clinical outcomes (such as bone regeneration, implant success, or patient-reported outcomes) rather than purely biological or microscopic changes. By excluding studies focused only on histology, the review can concentrate on practical, patient-centred results.

2.6 Outcome variables

Four outcome variables were defined: 1) Clinical analysis of postoperative complications including infection post-operatively together with wound dehiscence occurrence, and radiographic evaluations either 2-dimensional or 3-dimensional radiographs including 2) alveolar ridge width resorption, 3) alveolar ridge height resorption, and 4) bone density. Time points for measuring outcomes in this study were disregarded due to significant limitations for several reasons including variability in healing and response time between the studies, as the outcome timeframe is not relatively comparable, and it may potentially report the outcome bias. The small number of studies included in this systematic review, with only four manuscripts meeting the inclusion criteria, raises concerns about the generalizability and robustness of its conclusions. While this limitation may reflect the relatively limited body of high-quality research on the use of DP and PRF for ARP, it is important to acknowledge the potential impact of this small sample size on the strength of the review's findings. A systematic review aims to synthesize the available evidence to offer more reliable and comprehensive conclusions than individual studies. However, when only a few studies are included, as in this case, it becomes more challenging to draw firm conclusions that can be generalized across broader populations. The small number of studies also limits the ability to identify consistent trends, assess variations in methodology, and detect any potential outliers or biases that may influence the outcomes. Furthermore, the limited sample

size makes it more difficult to assess the effects of heterogeneity between studies, such as differences in patient populations, intervention protocols, and outcome measures. This heterogeneity could significantly affect the pooled results and interpretations.

While the review highlights the promising clinical and radiographic outcomes of DP and PRF, the small number of studies makes it difficult to establish definitive conclusions about the effectiveness and broader applicability of these materials. To strengthen future reviews, it would be beneficial to encourage more high-quality research on ARP techniques, focusing on larger, multicenter trials that follow standardized protocols. Expanding the evidence base would enhance the reliability and generalizability of systematic reviews on this topic.

2.7 Data extraction

All study titles were initially screened to exclude research that did not focus on human subjects, including animal or in vitro studies. Subsequently, abstracts were reviewed based on key inclusion criteria, such as a minimum sample size of five patients and a randomized controlled trial (RCT) study design. This process aimed to identify studies that examined essential characteristics and relevant radiographic outcomes, such as alveolar ridge resorption and bone density. The publications that remained after abstract screening were analysed according to inclusion/exclusion criteria. Finally, four articles were included in the present review. Data extraction was carried out using standardized forms to collect specific data points using specific search terms, such as the number of patients and the clinical and radiographic outcomes.

Two reviewers (FK and EN) independently performed the extraction. In cases of disagreement, the reviewers discussed the issue to reach a consensus. If consensus could not be reached, a third reviewer or adjudicator (FA) was consulted to make an independent assessment and provide a final decision, ensuring that any discrepancies were resolved. A meta-analysis of the data reported in this systematic review could not be performed due to the heterogeneity of the data in the included manuscripts whereby the studies provide different intervention procedures, different timeframe of the outcome, and the outcome measures.

3.0 Results

3.1 Search methodology

A total of 452 titles were obtained from the electronic search, ranging from 2017 to 2022. After the elimination of duplicated articles, a total of 439 articles remained. The first screening of headlines and abstracts led to the inclusion of 42 manuscripts. Of these 42 papers, 38 articles were excluded according to the inclusion and exclusion criteria. Finally, after complete text analysis, four manuscripts remained to be reviewed (Figure 1). The full-text papers that were excluded, together with their justifications, are listed in Table 1. The most common reasons for exclusion were the absence of the variables dentine or PRF, languages other than English, and a study design other than randomised controlled trial (RCT) with clinical and radiographic evaluation, such as animal studies, case reports, cohorts, pilot studies, reviews, in vitro studies, and histological evaluation only.

3.2 Characteristics of the study

In the four included RCT conducted in humans, the outcome of the ARP was clinically assessed by the presence of complications, such as dehiscence and infections during follow-up, and radiographic assessment by either 2-dimensional (29) or 3-dimensional (30–32) imaging to observe the bone width, bone height and bone density differences with the baseline during follow-up.

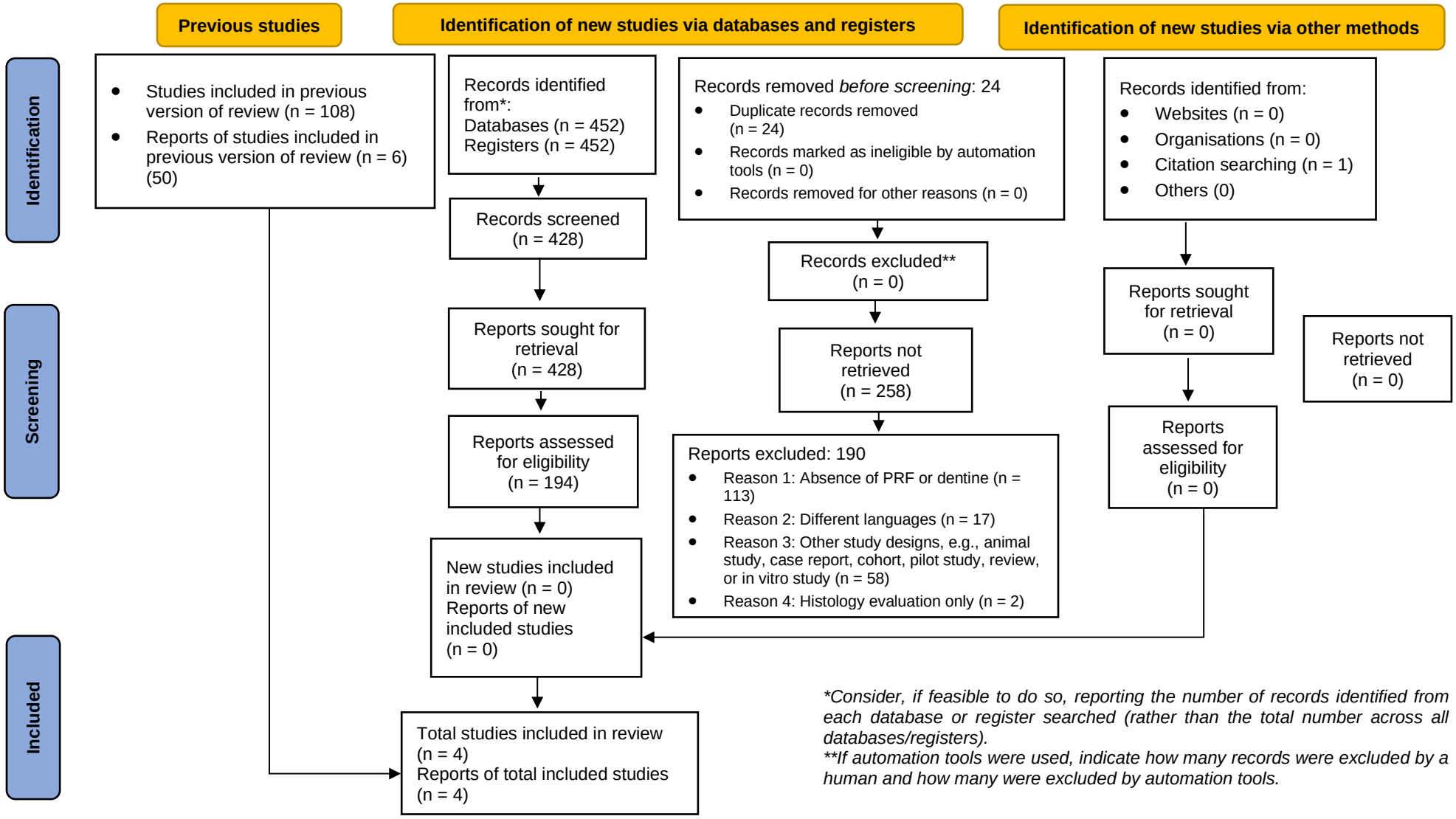

Figure 1: PRISMA author's checklist guidelines

Table 1: List of excluded full-text papers and reasons for exclusion

First author, year and journal	Title	Exclusion category	Reasons for exclusion
Yüceer-Çetiner E (2021), J Craniofac Surg (33)	Effect of Autogenous Dentine Graft on New Bone Formation	Study design exclusion	Histology as an outcome parameter
van Orten A (2022), Dent J (Basel) (34)	Tooth-Derived Granules in Combination with platelet-rich fibrin ("Sticky Tooth") in Socket Preservation: A Histological Evaluation		Case series
Andrade C (2019), Clinical Oral Investigations (35)	Combining autologous particulate dentine, L-PRF, and fibrinogen to create a matrix for predictable ridge preservation: A pilot clinical study		Pilot study
Andrade, Oral presentation (2018) (36)	"Dentine block" in alveolar ridge preservation: a histological descriptive pilot study as proof of principle		Pilot study, no full text
De Biase A, Case Reports in Dentistry (2020) (37)	Prevention of periodontal pocket formation after mandibular third molar extraction using dentine autologous graft: A split mouth case report		Case report
Pohl S, International Journal of Oral & Maxillofacial Implants (2021) (38)	Effectiveness of Autologous Tissue Grafts on Soft Tissue Ingrowth in Patients Following Partial Root Extraction with Socket Shield: A Retrospective Analysis of a Case Series.		Retrospective case series
Melek L.N., The Saudi Journal for Dental Research (2017) (39)	Evaluation of "autogenous bioengineered injectable PRF–tooth graft" combination (ABIT) in reconstruction of maxillary alveolar ridge defects: CBCT volumetric analysis		Clinical case series
Kubaszek, B, coatings (2022) (40)	Radiological and Microbiological Evaluation of the Efficacy of Alveolar Bone Repair Using Autogenous Dentine Matrix—Preliminary Study		Pilot study, no PRF component
Mazzucchi G., Materials (Basel) (2022) (41)	Autologous Dentine Graft after Impacted Mandibular Third Molar Extraction to Prevent Periodontal Pocket Formation—A Split-Mouth Pilot Study	Outcomes not relevant	No PRF component
Joshi CP, Contemporary clinical dentistry (2017) (42)	Comparative alveolar ridge preservation using allogenous tooth graft versus free-dried bone allograft: A randomised, controlled, prospective, clinical pilot study		No PRF component

Table 2: Summary of the characteristics of the study. PD particulate dentine, PRF platelet-rich fibrin, DTM demineralised tooth matrix, ATBG autogenous tooth bone

Author/ Year	Types of study/ OCEBM level of evidence	Parallel arms or split-mouth	No. of patients (Smoker/non-smoker)	Age of patients (year old)	Gender of patients	Intervention vs control group	Types of surgery
Mohammed, Abdullah Mahmud (2021) (30)	Randomised clinical trial = 3	2 parallel arms	16 patients. Smoking status was not reported				Partially impacted mandibular 3rd molar
			Test group = 8 patients	Minimum = 20 age	Male = 7	Test group = Particulate dentine (PD)/PRF mix	
			Control group = 8 patients	Maximum age = 37	Female = 9	Control group = Empty socket	
Ouyyamwongs, Warisara; (2019) (29)	Randomised clinical trial = 3	Split-mouth, 2 parallel arms	40 sockets (24 maxillary, 16 mandibular premolars) in 12 patients. Smoking status was not reported				Orthodontic treatment
			Test group = 20 sockets	Minimum = 20 age	Male = 2	Test group = DTM and PRF	
			Control group = 20 sockets	Maximum = 22 age (Mean age 20.5 ± 0.80 years)	Female = 10	Control group = PRF only	
ElAmrousy, Walid; Issa, Dalia Rasheed; (2022) (31)	Randomised clinical trial = 3	2 parallel arms	26 patients, all non-smokers				Immediate implant placement
			Test group = 20 patients	Minimum = 18 age	Male = 12	Test group = ATBG and L-PRF	
			Control group = 20 patients	Maximum age = 50 (Mean age 35.8 ± 8.6 years)	Female = 14	Control group = ATBG only	
Gabr A., Aboelhasan M. (2019) (32)	Randomised clinical trial = 3	2 parallel arms	12 implants in 6 patients, all non-smoker or smoked less than 10 cigarette/day				Immediate implant placement
			Test group = 6 implants	Minimum age = 20	Male =3	Test group = Tooth graft and PRF	
			Control group = 6 implants	Maximum age = 35 (Mean age 31.17 ± 6.05)	Female = 3	Control group = Tooth graft only	

The sample sizes across the four studies varied (see Table 2), with the smallest cohort comprising 6 patients, evenly split between three males and three females in one study (32). This was followed by 12 patients, consisting of 2 males and 10 females in another study (29), then 16 patients, comprising 7 males and 9 females in one study (30), and the largest group of 26 patients, which included 12 males and 14 females in another study (31).

Age distributions varied among the studies, with one study reporting ages from 20 to 37 years (30), another from 20 to 22 years (29), one ranging from 18 to 50 years (31), and another from 20 to 35 years (32). Regarding smoking status, two studies specified participants as non-smokers (31) or as non-smokers who smoked fewer than 10 cigarettes (32). Conversely, two studies did not provide any information on smoking status (29,30). Notably, out of the four studies, only one employed blinding of the operator (31).

The extraction sites also varied across studies, including premolars prior to orthodontic treatment (29), third molars (30), and sites for implant placement (31,32).

The follow-up periods for clinical and radiographic measurements also differed among the studies. For clinical assessments, follow-up schedules included 8 weeks post-extraction of partially impacted mandibular third molars (30), follow-ups every 2, 4, 6, and 8 weeks after orthodontic extractions (29), assessments on the third and seventh days post-extraction for immediate implant placement (31), and daily visits for one week, followed by weekly check-ups for one month post-extraction for immediate implant placement (32). In terms of radiographic evaluations, follow-up periods ranged from 6 months in three studies (30–32) to 6 to 8 weeks in one study (29).

Differences in the type of extraction sites, such as premolars versus third molars, can significantly influence the outcomes of studies on bone regeneration and healing and subsequent measurements, with the third molars often being more impacted and associated with denser bone, healing dynamics and tissue response as well as the microenvironment. This may affect the ease of extraction and the subsequent healing process, as third molars are often located in areas with more complex bone morphology. Variability in outcomes attributed to differences in extraction sites could obscure the effectiveness of treatments being evaluated. Thus, acknowledging and controlling for the extraction site type is essential in drawing accurate conclusions regarding the efficacy of various interventions in bone regeneration and healing.

3.3 Characteristics of the intervention

The use of different grafting materials and preparation methods in ARP plays a crucial role in the outcomes of bone regeneration and healing following tooth extraction. In particular, two distinct approaches were employed in the reviewed studies: DP combined with PRF (30) and freeze-dried auto-demineralized tooth matrix (auto-DTM) (29). Each of these methods brings unique benefits and challenges to the table, influencing clinical outcomes in different ways.

The first approach involved preparing DP using a Smart Dentine Grinder (SDG) (Kometa Bio®, Holon), followed by mixing it with PRF in a 1:1 ratio to form a homogenous paste (30). This method offers the advantage of quick preparation, allowing for the immediate use of DP from the extracted tooth. PRF, a bioactive material rich in growth factors, enhances the regenerative potential of the graft, accelerating wound healing and promoting faster bone regeneration. The DP provides a scaffold for new bone formation, while PRF delivers the necessary bioactive molecules to stimulate tissue repair and

angiogenesis. This combination is particularly effective in improving graft handling, offering a pasty consistency that ensures better stabilization of the graft material within the extraction site. In contrast to other approaches, this immediate preparation method maximizes the bioavailability of growth factors, making it a promising solution for achieving early bone regeneration and reducing complications, such as delayed healing or infection.

On the other hand, the second approach employed in one study utilized freeze-dried auto-DTM (29). This process involves an extensive preparation technique, starting with cryogenically pulverizing the extracted tooth, followed by defatting, demineralization, and sterilization. The particles are stored for future use, making this method more suitable for long-term preservation. While this approach ensures that bioactive components like bone morphogenetic proteins (BMPs) are retained, the complexity of the process may impact the immediate availability of these bioactive molecules during grafting. Unlike the DP-PRF mixture, auto-DTM is stored and prepared over time, which might slow down the early release of growth factors critical for rapid healing.

When comparing the two methods, it becomes clear that each serves a distinct purpose. The DP-PRF method provides an immediate solution for enhancing bone regeneration, particularly in cases where early healing and graft stabilization are critical. PRF's ability to deliver growth factors rapidly to the graft site leads to quicker angiogenesis, cellular migration, and wound healing. In contrast, freeze-dried auto-DTM is designed for long-term graft preservation, with bioactive molecules preserved for use at a later time. However, the prolonged preparation and the absence of PRF's immediate bioactivity may result in slower bone formation during the early stages of healing.

Interestingly, one of the studies also briefly mentioned the use of a VacuaSonic® Tooth (Cosmobiomedicare, Seoul, South Korea), an ultrasonic autoclaved bone preparation device, to process graft material (27). However, the description of this technique was extremely brief and lacked a detailed explanation of how it differs from the other preparation methods. This raises the question of why the VacuaSonic® method was not explored in greater depth, especially in terms of how it might compare to both the DP-PRF and auto-DTM methods. The lack of information limits the ability to evaluate its effectiveness or justify its use relative to the other methods.

In choosing these specific grafting techniques for ARP, the studies aimed to explore the benefits of autologous materials in those derived from the patient's own tissues and to minimize the risk of immune rejection and optimize bone regeneration. Both the DP-PRF mixture and auto-DTM reflect a contemporary approach to ARP, each offering unique advantages depending on the clinical scenario. The DP-PRF method, with its ease of preparation and rapid regenerative potential, is suited for immediate interventions, while auto-DTM serves as a more controlled and storage-friendly option, albeit with a slower regenerative onset.

The comparative analysis of these two methods reveals that each technique has distinct applications in ARP. The DP-PRF combination is highly effective for early-stage bone regeneration and wound stabilization, benefiting from the bioactivity of PRF and the structural integrity of DP. Conversely, auto-DTM offers a longer-term preservation method, though it may lack the immediate regenerative potential of PRF. The choice of method ultimately depends on the clinical objectives, whether rapid bone regeneration is prioritized or long-term stability is the main goal. Future research could provide more insight by directly comparing these methods and exploring alternative techniques like the VacuaSonic® machine in greater detail.

Table 3: Risk of bias summary. Y yes, N no, ANOVA Analysis of variance

Author/ Year	1) Randomised 2) Adequate sequence generation 3) Allocation concealment 4) Concealment adequate	1) Ethics approval 2) Informed consent	Masking (Therapist/ Patient/ Examiner/ Statistician)	Calibration (Intra-examiner / inter-examiner)	Source of funding	Statistical analysis	Estimated risk of bias (High/ moderate/ low)
Mohammed, Abdullah Mahmud (2021) (30)	Y N N N	N N	N	N	N	p-values, mean and SD	High
Ouyyamwongs, Warisara; (2019) (29)	N N N N	Y Y	N	N	N	1. ANOVA & post hoc 2. Paired t-test 3. P-values < 0.05 for statistically significant value	High
ElAmrousy, Walid; Issa, Dalia Rasheed; (2022) (31)	Y Y Y Y	Y Y	Y (Masked operator)	Y Intra-examiner calibration	N	1. Paired t-test (compare changes) 2. Student's t-test and chi-square tests (intergroup) 3. P-values < 0.001 for statistically significant value	Low
Gabr A., Aboelhasan M. (2019) (32)	Y N N N	Y Y	N	N	N	1. ANOVA test 2. Wilcoxon signed rank test 3. P-values < 0.05 for statistically significant value	High

Assessing the risk of bias in clinical studies involves a systematic evaluation across several key domains, including randomization, blinding, attrition, reporting, and other potential sources of bias (Table 3). Each domain plays a critical role in determining the integrity of the study findings. Randomization is the first domain to consider. This process involves the allocation of participants to different intervention groups in a manner that is random and unbiased. Studies that clearly describe their random allocation methods and demonstrate appropriate implementation should be rated as having a low risk of bias. Conversely, if the randomization process is inadequately described or if significant issues are identified in its execution, the study should be rated as having a high risk of bias. In cases where information is insufficient to make a clear judgment, the rating should be classified as unclear. The second domain, blinding, refers to whether participants, study personnel, and outcome assessors were unaware of the specific interventions received by participants. Effective blinding minimizes bias in the reporting and assessment of outcomes. Studies that implement and describe blinding clearly should receive a low risk of bias rating. However, a lack of blinding or inadequate description of the blinding methods leads to a high-risk rating, while insufficient information results in an unclear rating. Next, the domain of attrition examines the completeness of outcome data, specifically focusing on participant dropout rates. Studies that experience minimal loss to follow-up and employ strategies like intention-to-treat analysis should be rated as having a low risk of bias. In contrast, if there is a significant dropout rate without proper justification or handling, the study should be assigned a high risk of bias. A rating of unclear is appropriate when information regarding attrition is inadequate. The reporting domain assesses whether the study reports all pre-specified outcomes. A study that comprehensively reports outcomes as originally planned should be rated as having a low risk of bias. However, if certain outcomes are omitted or discrepancies are present, the study will warrant a high rating. An unclear rating applies when the reporting status cannot be determined due to lack of information. Lastly, the evaluation of other sources of bias considers factors such as funding sources and potential conflicts of interest. If no significant biases are identifiable, the study should be rated as low risk. Conversely, if substantial biases are evident, the study should receive a high-risk rating. An unclear rating is appropriate in cases where information regarding these potential biases is lacking. After assessing each domain, researchers can summarize the overall risk of bias for the study based on the ratings assigned across these domains. A predominance of low ratings across the domains indicates that the study has a low risk of bias, while a majority of high ratings suggests a high risk of bias. Mixed ratings will lead to a more nuanced conclusion, often resulting in an overall assessment of unclear risk. This comprehensive evaluation of bias is crucial for interpreting the validity and reliability of study findings in the context of clinical research.

Assessing the risk of bias in clinical trials is essential for evaluating the reliability of study findings. In this analysis, we examine the risk of bias for four studies based on various methodological criteria, including randomization, allocation concealment, ethics approval, informed consent, masking, calibration, source of funding, and statistical analysis.

One of the studies reported randomization but failed to provide adequate sequence generation and allocation concealment (30). Additionally, it did not obtain ethics approval or informed consent from participants. The absence of masking for therapists, patients, examiners, and statisticians raises further concerns

about potential bias. The lack of calibration among examiners and transparency regarding the source of funding also contributes to the risk. Statistical analysis included p-values, means, and standard deviations. Given these deficiencies across multiple domains, this study is assessed as having a high risk of bias.

In another study, randomization was not reported, nor were adequate sequence generation and allocation concealment measures implemented (29). While the study obtained ethics approval and informed consent, the lack of masking (for therapists, patients, examiners, and statisticians) introduces significant bias risks. Calibration was not mentioned, and no information regarding the funding source was provided. Statistical analyses employed ANOVA, paired t-tests, and p-values to identify statistically significant results. Due to the numerous methodological shortcomings, this study is also assessed as having a high risk of bias. Apart from that, another study (31) demonstrated a stronger methodological framework compared to the previous studies. It reported randomization, adequate sequence generation, and allocation concealment, indicating a more rigorous approach to participant assignment. Ethics approval and informed consent were secured, and masking was implemented for the operator. The study also involved intra-examiner calibration, enhancing the reliability of outcome assessments. While the source of funding was not disclosed, statistical analyses included paired t-tests, Student's t-test, and chi-square tests, yielding statistically significant results with p-values less than 0.001. Based on these factors, this study is assessed as having a low risk of bias.

Similar to the first two studies (29,30), the other study (32) reported randomization but lacked adequate sequence generation and allocation concealment. It secured ethics approval and informed consent, which is a positive aspect. However, there was no mention of masking, calibration, or funding sources, which raises concerns about potential bias. The statistical analysis used ANOVA and Wilcoxon signed rank tests, reporting p-values to indicate statistically significant findings. Due to the significant methodological limitations, this study is rated as having a high risk of bias.

In summary, the assessment of risk of bias across the four studies reveals varying levels of methodological rigor. While one study (31) was rated as having a low risk of bias due to its comprehensive adherence to ethical and methodological standards, the remaining studies demonstrated substantial deficiencies, resulting in a high risk of bias assessment (29,30). These findings underscore the importance of robust study design in clinical research to ensure the validity and reliability of results.

3.4 Evaluation of clinical results

Clinical complications related to autogenous tooth bone regeneration are reported in Table 4. None of the cases reported the occurrence of complications like infection and dehiscence during the respective follow-ups.

One of the primary clinical outcomes in such studies is the process of bone healing, specifically focusing on ARP. Following tooth extraction, maintaining the height and volume of the alveolar ridge is essential for future dental procedures, such as implant placement. Successful ARP ensures that the ridge remains stable, preventing significant bone loss. Additionally, the extent of new bone formation in the socket or grafted area is crucial. Radiographic or histological assessments are commonly used to measure how well the graft material integrates into the surrounding bone and whether it is effectively replaced by new, healthy bone. An equally important outcome is bone density. The quality and density of the regenerated bone have a direct impact on the stability and longevity of dental implants. Denser bone typically leads to

Table 4: Post-surgical clinical evaluation. Y yes, N no

Author/ Year	Reason for extraction	Socket anatomy (Single-/multi-rooted)	Flap elevation in ARP groups	Primary closure in ARP groups	Clinical evaluation				
					No. of dropouts	Follow-up schedule	Infection	Dehiscence	Others
Mohammed, Abdullah Mahmud (2021) (30)	Partially impacted mandibular 3rd molar	Multi-rooted	None	N	0	8 weeks	0	0	0
Ouyyamwongs, Warisara; (2019) (29)	Orthodontic treatment	Single (first or second premolar)	None	Yes, using PRF membrane and figure of 8 sutures	0	2, 4, 6, 8 weeks (soft tissue healing completed 6 weeks). 2 & 4 weeks = control > test group	0	0	3 = incomplete buccal plate fractures (2 sites in test group, 1 in control group)
ElAmrousy, Walid; Issa, Dalia Rasheed; (2022) (31)	Immediate implant placement	Multi-rooted	Full-thickness crestal with distal vertically released incisions. Buccal and lingual flaps were reflected to reveal the extraction socket and bone deficiency labially.	Y	0	3rd and 7th day	0	0	Final titanium abutment and zirconia prosthesis after 6 months
Gabr A., Aboelhasan M. (2019) (32)	Immediate implant placement		None	Y	0	Daily for a week, once/week for a month	0	0	Visual analogue scale

Table 5: Post-surgical radiographic evaluation. STO suture to open, Nil no value measured, NS non-significant value, g gram, mg milligram BD twice a day, TDS three times a day, 5/7 five days, 1/52 one week

Author/ Year	Medication prescribed	Suture to open (STO)	Radiographic evaluation			
			Follow-up schedule	Alveolar ridge width resorption	Alveolar ridge height resorption	Bone density
Mohammed, Abdullah Mahmud (2021) (30)	Nil		6 months	Nil	6 months: Marginal bone loss **Test** 26.31 ± 0.55 **Control** 24.98 ± 0.74 p-value = 0.012	6 months: Bone density **Test** 224.14 ± 47.69 **Control** 178.43 ± 37.26 p-value = 0.008
Ouyyamwongs,Warisara; (2019) (29)	Antibiotics and anti-inflammatories	2 weeks	6^{th}-8^{th} weeks	8 weeks = test > control group 1. Mesial marginal bone **Test** -0.67 ± 0.47 **Control** -0.86 ± 0.31 p-value = 0.202 2. Distal marginal bone **Test** -0.93 ± 0.47 **Control** -0.81 ±0.42 p-value = 0.378	8 weeks = test > control group **Test** -0.79 ± 0.47 **Control** -0.70 ±0.28 p-value = 0.451	8 weeks = test > control group **Test** 44.84 ± 9.12 **Control** 35.85 ±15.15 p-value = 0.253
ElAmrousy, Walid; Issa, Dalia Rasheed; (2022) ((31)	Amoxicillin clavulanic acid 1g BD + analgesics		6 and 9 months	Ridge width loss **Test** 0.03 ± 0.09 **Control** -0.005 ±0.006 p-value > 0.001 NS	Marginal bone loss **Test** 0.02 ± 0.007 **Control** -0.05 ±0.013 p-value < 0.001	Mesiodistal bone gain **Test** -0.003 ± 0.005 **Control** -0.16 ±0.37 p-value < 0.001
Gabr A., Aboelhasan M. (2019) (32)	Amoxicillin 875 mg/ clavulanic acid 125mg (Augmentin 1gm) BD x 5/7 Diclofenac sodium 50mg TDS x 5/7 Chymotrypsin tablet TDS x 1/52	1 week	6 months	Horizontal bone loss **Test** 0.077 (0.065-0.130) **Control** -0.595 (0.450-0.690) p-value: 0.026 p-value: 0.028	Vertical bone loss **Test** 0.510 (0.480-0.530) **Control** 1.490 (1.400-1.640) p-value: 0.028 p-value: 0.027	Nil

better integration and support for the implant. Another aspect of bone healing to consider is the overall socket healing process after tooth extraction or implant placement. Ensuring that the socket heals without complications, such as infection or graft failure, is critical to the overall success of the procedure.

Moreover, the level of post-operative pain and discomfort experienced by the patient plays a crucial role in evaluating the success of the procedure. Techniques or materials that promote faster healing with minimal pain are generally more favorable to patients. Additionally, the ability to restore normal functionality, such as chewing comfort and overall oral function, is critical for long-term satisfaction. Patients who can quickly return to normal function after the procedure are likely to view the outcome more positively. Lastly, the absence of surgical complications, such as infection or wound dehisence, contributes to a smoother recovery process and greater satisfaction

3.5 Evaluation of radiographic results

The clinical relevance of the results from these studies provides critical insights into the effects of grafting materials and interventions on ARP following tooth extraction. Though some differences in alveolar ridge width resorption between test and control groups appear minor, particularly in terms of millimeters, it is important to interpret these findings in the context of their potential impact on long-term clinical outcomes, such as implant stability and overall bone regeneration success. A key aspect of these studies is the measurement of alveolar ridge resorption, particularly in terms of width and height (Table 5). In the study by Mohammed *et al*. (2021) (30), resorption was minimal in both the test and control groups. The alveolar ridge width showed a difference of 0.03 mm (test) versus -0.005 mm (control) after six months, with the p-value indicating this difference was not statistically significant. While this may seem clinically insignificant, even small differences in ridge width can have meaningful implications in cases where space is critical for implant placement. If ridge width is not preserved adequately, additional bone augmentation procedures may be required, potentially complicating or delaying implant surgery.

Similarly, the study by ElAmrousy *et al*. (2022) (31) found that ridge width loss was also minimal and statistically insignificant (0.03 mm in the test group vs. -0.005 mm in the control group). However, the test group in this study demonstrated significantly better results in mesiodistal bone gain and marginal bone loss, suggesting that although width resorption might be minor, other aspects of bone preservation, such as vertical bone gain or loss, may hold more clinical relevance. In particular, reduced mesiodistal bone loss could improve implant stability and reduce the need for future bone augmentation.

Conversely, in the study by Gabr and Aboelhasan (2019) (32), both horizontal and vertical bone loss showed statistically significant differences between the test and control groups, with the test group exhibiting significantly less resorption. Horizontal bone loss in the test group was measured at 0.077 mm, compared to -0.595 mm in the control group, and vertical bone loss was 0.510 mm in the test group versus 1.490 mm in the control group. These findings indicate that the interventions used in the test group (likely a combination of graft materials) were highly effective in mitigating alveolar ridge resorption. Reduced ridge resorption enhances the chances of successful implant placement, as sufficient bone volume is essential for implant osseointegration and long-term success.

Another critical clinical outcome is bone density, which plays a major role in the overall quality of the regenerated bone and the potential success of dental implants.

Higher bone density generally indicates better bone quality, which enhances the likelihood of stable and durable implant placement. In the study by Mohammed *et al*. (2021) (30), bone density in the test group was significantly higher than in the control group after six months (224.14 ± 47.69 vs. 178.43 ± 37.26, respectively, with a p-value of 0.008). This suggests that the test group, which likely used a combination of dentine particulate and PRF, provided a more favorable environment for bone regeneration compared to the control group, which had no grafting intervention.
The study by Ouyyamwongs *et al*. (2019) (29) also measured bone density but found no statistically significant differences between the test and control groups at the eight-week follow-up. Although the test group had slightly higher values (44.84 ± 9.12 vs. 35.85 ± 15.15), the p-value of 0.253 indicates that the differences were not significant. This suggests that, at least in the short term, bone density did not differ substantially between the two groups, which could imply that the benefits of the interventions in terms of bone density may take longer to manifest. This highlights the importance of long-term follow-ups to fully assess the benefits of grafting materials.

In terms of marginal bone loss, the study by ElAmrousy *et al*. (2022) (31) showed that the test group experienced significantly less marginal bone loss compared to the control group (0.02 ± 0.007 mm vs. -0.05 ± 0.013 mm, respectively, with a p-value < 0.001). Reduced marginal bone loss is critical in maintaining the structural integrity of the alveolar ridge, particularly in cases where future implant placement is planned. This finding underscores the potential clinical value of the interventions used in the test group, as less marginal bone loss translates into a more favorable environment for implant success.

While the differences in alveolar ridge width and height resorption may seem minor, even small improvements in these metrics can translate into significant clinical benefits. Maintaining sufficient bone volume is crucial for achieving implant stability, as inadequate bone height or width can compromise the primary stability of the implant, increasing the risk of implant failure. Furthermore, the preservation of marginal bone is a critical factor in long-term implant success, as bone loss around the implant can lead to complications such as peri-implantitis or implant mobility.

In addition, the improvement in bone density observed in the studies, particularly in Mohammed *et al*. (2021) (30), suggests that the use of interventions like dentine particulate and PRF may enhance the quality of regenerated bone, providing a more stable and durable foundation for implants. A denser bone structure improves the implant's osseointegration process, contributing to its long-term stability and reducing the likelihood of complications.

Although some of the differences in alveolar ridge width resorption, bone density, and marginal bone loss across the studies may appear small, these outcomes have significant clinical implications for implant stability and bone regeneration success. The findings suggest that the grafting materials and interventions used in the test groups, such as dentine particulate and PRF, may offer important benefits in preserving alveolar ridge dimensions and improving bone quality. These benefits are particularly relevant in implant dentistry, where adequate bone volume and density are essential for long-term success. Therefore, even small improvements in these clinical outcomes can contribute to better overall patient outcomes, especially in cases where implant placement is planned.

3.6 Evaluation of implant stability, implant survival and failure rates

A significant limitation of this review lies in the lack of consistent and comprehensive

data on key outcomes on implant survival, stability, and failure rates. While the importance of these outcomes is acknowledged in the discussion, the absence of standardized reporting across the reviewed studies hinders the ability to draw meaningful conclusions. Implant survival and failure rates are critical indicators of the long-term success of ARP techniques, particularly for clinical applications involving dental implants. Without reliable data on these outcomes, the full effectiveness of grafting interventions, such as DP and PRF, cannot be accurately assessed.

Good stability, known as the absence of clinical mobility, has long been considered an essential factor for implant success (5). Implant survival and failure rate were evaluated six months after placing the prosthesis. None of the reviewed studies adopted a consistent guideline for reporting implant-related data. Therefore, the assessment of implant survival rate was limited.

In the absence of reliable or consistent data on implant survival and failure rates, it becomes imperative to recommend that future studies adopt standardized reporting guidelines. By following established frameworks for reporting clinical outcomes, such as the Consolidated Standards of Reporting Trials (CONSORT) guidelines for randomized controlled trials or the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies, researchers can ensure that critical data points are consistently reported across studies. These guidelines would encourage the inclusion of specific data on implant survival rates, reasons for implant failure (e.g., infection, poor osseointegration, or mechanical failure), and factors related to implant stability (e.g., primary and secondary stability measurements).

Additionally, future studies should aim to include longer follow-up periods, allowing for a more comprehensive evaluation of implant success over time. Short follow-up periods, typically seen in some of the reviewed studies, may not capture late-stage implant failures or complications, such as peri-implantitis, which often develops months or years after implant placement. Without these improvements, the full clinical potential of grafting materials such as DP and PRF remains unclear, and the impact of these interventions on implant success cannot be accurately determined.

4.0 Discussion

The literature analysis revealed few studies concerning autogenous tooth bone graft material in combination with PRF. No systematic reviews or meta-analyses were found. Thus, the purpose of this systematic review was to assemble the data reported in the literature evaluating two aspects: a) clinical evaluation and b) radiographic evaluation.

The topic focused on autogenous tooth bone graft material and PRF as a bone graft for ridge augmentation in both complete and partial edentulism, without taking into account the surgical protocol, surgical site or the type of surgery (tooth extraction and immediate implants).

An autogenous tooth bone graft can be used in a particulate form or as a block graft. According to the literature, some studies showed no significant difference in volumetric reduction between particulate bone and block bone grafts (43,44). Autogenous tooth bone graft material is an osteoconductive material with excellent biocompatibility, which shows high bone formation activity. Dentine contains proteins such as osteopontin, which promotes bone formation (45). On immunohistochemical staining with anti-DSP antibodies, the positive reaction was localised to the dentine of the extracted tooth fragments incorporated into the new bone at six weeks, suggesting that dentine has a high affinity for and marked

osteoconductive effect on jawbone (45). This is aligned with the articles results reviewed in this study.

Dentine particulates showed gradual resorption during the first three months. At six months, new bone was replaced with trabecular bone, with resorption of most graft material (44). Osteoinduction and osteoconduction were observed, similar to the histological analysis in other papers (46–48).

This systematic review has limits because the number of articles reviewed, and the average sample size are small. Moreover, in the current literature, no studies compare the efficacy of dentine particles and PRF with other typical bone graft materials. Another critical point is the lack of uniformity in the variables across the included studies, such as different teeth, anatomy considerations, periods and assessment methods and other types of surgeries within the same survey. It is reasonable to assume that only some of these variables can be standardised. Long-term observational research studies with more extensive sampling for histological evaluation are required in future studies. In spite of these limitations, the combination of dentine particles and PRF is useful as a bone graft material for alveolar ridge preservation.

This review concludes that test groups showed reduced height resorption and increased bone density in three out of four papers. However, there was more width loss in the test groups compared to control groups in two trials. This is due to the degradation properties of DP, while particulate dentine improves the capacity for bone remodelling, providing a physical matrix for the deposition of new bone and thereby preserving the height of bone crests (49). Although the use of autogenous teeth for bone grafting is still insufficient to support definitive conclusions, it has demonstrated clinical safety, good bone-forming capacity, and positive results in terms of implant stability (50). The slow release of growth factors from PRF and the fibrin mesh provide an excellent scaffold for migrating stem cells and osteogenic cells, possibly improving angiogenesis and new bone formation (23).

None of the studies reported on hard and soft tissue morphology, for example, gingival biotype, keratinised gingival width, buccal plate thickness, or alveolar ridge volume, which may modify the outcome of ARP. Therefore, the possible impact of these factors on ARP cannot be determined.

Only four studies were included (29-32); they had limited sample size (30,32) and short follow-up periods (29-32), and the majority were at a high risk of bias (29,30,32). However, it has been shown that the combination of autogenous tooth bone graft and PRF is clinically safe and has excellent bone-forming capacity, with positive results on implant stability (29-32).

One of the most significant shortcomings focusing on the osteoconductive properties of DP and PRF, while not adequately linking these properties to clinically relevant outcomes such as implant success, patient recovery, and long-term stability. Osteoconductivity, the ability of a material to support bone cell growth and guide new bone formation, is undoubtedly critical in the context of bone regeneration. However, its ultimate value must be evaluated in terms of its impact on patient-centered outcomes, such as implant stability and patient satisfaction. The fact that DP and PRF are biocompatible and osteoconductive is important, but their practical utility should be measured by how well they contribute to long-term functional success, including the prevention of complications like peri-implantitis and the maintenance of ridge volume over time. Therefore, a stronger connection between these material properties and clinical outcomes should be explored to provide a clearer understanding of their significance in real-world applications. Moreover, the studies do not sufficiently address the

importance of soft tissue health, which plays a crucial role in the success of dental implants and ARP procedures. While hard tissue outcomes, like bone regeneration and ridge preservation, are essential, soft tissue outcomes, including gingival thickness, health, and stability, are equally critical in ensuring implant survival and optimal aesthetics. The lack of data regarding soft tissue morphology is acknowledged in the manuscript, but this could be elaborated upon further. Future studies should aim to include parameters related to soft tissue healing, such as the quality of the gingiva and mucosal attachment around implants, which are known to influence long-term implant stability and the prevention of peri-implant diseases.

The review also notes some heterogeneity among the included studies, but the potential impact of this variability on the overall results and conclusions is not discussed in depth. Differences in study design, follow-up periods, patient populations, and techniques for preparing DP and PRF could all introduce variability that affects the comparability of outcomes across studies. For instance, differences in ridge width loss between the test and control groups were noted, but the long-term clinical implications of this ridge width loss, particularly for implant placement, are not thoroughly examined. Ridge width loss could influence implant stability, especially in cases where the buccal bone is compromised, potentially leading to implant failure or aesthetic complications. A more detailed exploration of these factors, including whether greater ridge width loss might necessitate additional interventions like bone grafting prior to implant placement, would provide a more nuanced understanding of the clinical relevance of these outcomes.

Another unmeasured factors that may influence the clinical success of ARP when using DP and PRF need to be further discussed too. For example, the discussion could address how factors like patient age, smoking status, systemic health conditions (e.g., diabetes), and oral hygiene habits might affect the outcomes of these interventions. These factors, which are often unmeasured in clinical studies, can significantly impact both soft and hard tissue healing, and their inclusion in future research would allow for a more comprehensive assessment of the effectiveness of DP and PRF in diverse patient populations. Understanding the role of these variables is essential for clinicians to make informed decisions about whether DP and PRF are appropriate for their patients, particularly those with complex medical histories or higher risks of implant complications.

While the osteoconductive and biocompatible nature of DP and PRF is well-supported by the current literature, a more in-depth discussion of their long-term clinical relevance is needed. Future studies should aim to provide standardized data on both hard and soft tissue outcomes, as well as patient-centered metrics like implant survival rates, patient satisfaction, and overall quality of life following ARP procedures. By addressing these gaps, future research can provide a more comprehensive understanding of the clinical value of DP and PRF in ARP, ensuring that these materials not only regenerate bone but also contribute to the long-term success of dental implants and patient outcomes.

5.0 Conclusion

The need for further research, offering clear and targeted recommendations for future research include longer follow-up periods, larger sample sizes, and the adoption of standardized outcome measures. Additionally, a broader exploration of soft tissue outcomes, healthcare costs, and patient experience would further enhance the clinical relevance of the findings.

Firstly, future studies should aim to include longer follow-up periods. The

current review includes studies with relatively short follow-up durations, ranging from six weeks to nine months. While these timeframes may be sufficient for observing early bone healing and ridge preservation, they do not capture long-term outcomes such as implant survival, bone stability, and overall tissue health. Studies with follow-up periods extending to one year or longer would provide more robust data on the durability of the results, particularly in terms of bone density and ridge width maintenance, which are crucial for the success of implants placed after ARP. Longer-term studies could also provide valuable insights into how the grafting materials (DP and PRF) perform under functional loading, which is essential for ensuring the long-term stability and success of dental implants.

In addition to longer follow-up periods, future research should involve larger sample sizes to increase the statistical power and generalizability of the findings. The current review includes studies with relatively small sample sizes, which may limit the ability to detect clinically meaningful differences between groups. Larger trials would enable a more accurate assessment of the effectiveness of DP and PRF in different patient populations, including those with varying risk factors such as smoking, systemic diseases, and poor oral hygiene. This would also allow for subgroup analyses, which could provide a more nuanced understanding of which patients are most likely to benefit from these interventions.

Another crucial recommendation for future research is the adoption of standardized outcome measures. The current studies use a variety of clinical and radiographic parameters to assess the effectiveness of DP and PRF, making it difficult to compare results across studies. Standardized measures of alveolar ridge resorption, bone density, soft tissue healing, and implant survival rates would improve the consistency and reliability of future studies. This would also facilitate meta-analyses, enabling researchers to draw more definitive conclusions about the clinical efficacy of DP and PRF. Importantly, future studies should also evaluate soft tissue outcomes in addition to hard tissue regeneration. Soft tissue health is critical for implant success, as it affects not only aesthetics but also the long-term stability of the implant by preventing complications such as peri-implantitis.

Moreover, an exploration of how DP and PRF might affect healthcare costs and improve patient experiences would add significant value to future research. While the current review focuses primarily on the biological and clinical outcomes of DP and PRF, understanding the economic implications of these materials is equally important. If DP and PRF can reduce the need for more expensive graft materials (such as xenografts or synthetic grafts), they could potentially lower the overall cost of ARP procedures. Additionally, if these materials lead to faster healing and fewer complications, this could reduce the need for follow-up treatments and improve the efficiency of dental care. Evaluating healthcare costs in future studies would provide a more comprehensive picture of the value of DP and PRF in clinical practice.

In terms of patient experience, future research should investigate how the use of DP and PRF impacts patient satisfaction and recovery. A key factor in patient satisfaction is the speed and comfort of recovery after dental procedures. If DP and PRF are associated with faster healing times, less postoperative pain, and fewer complications, this could lead to higher levels of patient satisfaction. Additionally, if these materials improve the aesthetic outcomes of ARP by preserving ridge volume and maintaining soft tissue contours, patients may be more satisfied with the final appearance of their dental restorations. Understanding how these factors influence patient experience would

provide valuable insights for clinicians when selecting materials for ARP procedures.

Finally, future studies should explore how DP and PRF contribute to better patient satisfaction and recovery experiences. If these materials can improve both hard and soft tissue outcomes, they may lead to more predictable and successful implant placements, which are key factors in patient satisfaction. Additionally, a quicker recovery with fewer complications can improve the overall patient experience, leading to better adherence to follow-up care and higher levels of trust in dental providers. This could ultimately enhance the patient-provider relationship, making patients more likely to return for future dental care and recommend their clinicians to others.

In conclusion, while the current review highlights the favorable clinical outcomes of DP and PRF, future research should focus on longer follow-up periods, larger sample sizes, standardized outcome measures, and the inclusion of soft tissue assessments. Additionally, investigating the impact of these materials on healthcare costs and patient satisfaction would provide a more comprehensive understanding of their value in clinical practice. By addressing these gaps, future studies can ensure that DP and PRF not only offer biological benefits but also contribute to improved patient care and overall treatment success.

Authorship contribution statement

FK: Literature search, screening, data extraction, formal analysis, writing – original draft. **FAA**: Risk of bias assessment, data synthesis, validation, visualization, writing – review & editing. **ER**: Conceptualization, methodology, protocol development, data curation, validation, writing – review & editing.

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Conflict of interest

The authors declare no conflict of interest related to this article.

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